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Voelcker, Je

Agricultural pamphlets.

Analysis of the Anthracite of the Calton Hill, Edinburgh.

By Dr A. VOELCKER, Professor of Chemistry in the Agricultural College, Cirencester.*

(*From the Edinburgh New Philosophical Journal for April* 1850.)

We are in possession of analyses of anthracite from several localities, and we have learned by them, that the composition of this mineral, like that of coal, varies very much according to the locality where it is found; so that there are scarcely two localities which furnish anthracite of exactly the same composition.

All samples of anthracite which have been analysed, have been found to contain carbon, hydrogen, oxygen, nitrogen, and more or less inorganic matter, as well as sulphur (at least where it has been looked for), in a proportion which differs but slightly from that in which it occurs in common coal. Generally speaking, the per-centage of carbon is larger in anthracite than in common coal, whilst hydrogen predominates in the latter; and we find, likewise, that the more the anthracitic character of a sample is pronounced, the greater is the deviation from the composition of common coal. On the other hand, the more an anthracite resembles common coal in its physical character, the closer is the approximation to the latter in chemical composition. The sulphur which has been found in every specimen of anthracite in which it has been sought for, is generally considered as existing in it as well as in coal, in combination with iron, as iron pyrites, but the subjoined results shew that the sulphur found in anthracite does not always occur in the form of iron pyrites, but is, in part at least, in combination with the organic elements of the mineral. In the following analyses the greatest care was taken to deprive the anthracite

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* Read before the Royal Society of Edinburgh, 4th March 1850.

of any hygroscopic water, by keeping it finely powdered in a glass tube, at a temperature of about 230° F., and passing over it a current of dry air for several hours.

The per-centage of carbon was ascertained by burning from three to four grains with a mixture of oxide of copper and oxide of lead, and the simultaneous application of oxygen gas, in order to secure complete combustion of the carbon. The oxygen, for that purpose, was disengaged from chlorate of potash, mixed with pure oxide of copper, and placed at the closed end of the combustion-tube. A mixture of the oxides of copper and lead possesses the advantage over pure oxide of copper, of being much less hygroscopic ; for that reason it is peculiarly adapted for combustions in which the exact amount of hydrogen is to be ascertained. The nitrogen was determined according to Will and Varrentrapp's method, by heating the finely-powdered anthracite with soda-lime in the usual way.

For the determination of ash about 10 grains were burned in a platina capsule. The ash was coloured red by oxide of iron.

The proportion of sulphur was ascertained by introducing, into a red-hot crucible, a mixture of anthracite with carbonate of soda and nitre, in small quantities at a time, and heating the whole afterwards a little more strongly. The resulting fused and perfectly white mass was dissolved in water, supersaturated with hydrochloric acid, and the sulphuric acid then precipitated with chloride of barium.

According to the different results obtained, the composition of the anthracite of the Calton Hill is :—

Carbon = 91·23
Hydrogen = 2·91
Nitrogen = 0·59
Oxygen = 1·26
Sulphur = 2·96
Ash = 1·05

100·00

For comparison with this analysis, I subjoin a few analyses of anthracite from different localities.

	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.
From Lamure, Isère Department, according to Jacquelin (Annal. de Chimie et de Phys. lxxiv., 200),	89·77	1·67	3·63	0·36	4·57
From Sablé, Sarthe Department, . . .	87·22	2·49	1·08	2·31	6·90
From Vizille, Isère Department, . . .	94·09	1·85	...	2·85	1·90
From another locality in Isère Department, . .	94·00	1·49	...	0·58	4·00
Anthracite from Pembrokeshire, according to Schafhäutl, Lond. & Edin. Phil. Mag. xvii., 215, .	94·100	2·390	1·336	0·874	1·300
From Coalbrook in Carmarthenshire, . . .	90·58	3·60	3·81	0·29	1·72
Anthracite from Wales, .	91·44	3·46	2·58	0·21	1·52
				Sulphur. 0·79	

The last analysis is taken from Sir Henry de la Beche and Dr L. Playfair's Coal Report, the others from Hausmann's Mineralogy.

The most remarkable peculiarity of the anthracite of the Calton Hill is the comparatively large quantity of sulphur which it contains. By far the greater portion of this sulphur must have been in combination with the organic elements of anthracite; for, even supposing the whole of the ash to consist of oxide of iron, the quantity of iron would still be too small to combine with all the sulphur. I am not aware that attention has been drawn to the fact of sulphur occurring in anthracite in organic combination; but a little consideration, I think, will shew that such a compound may exist in nature, as we can prepare artificially, similar combinations. It is well known that, in preparing sulphide of carbon, by passing sulphur in vapour over red-hot charcoal, the charcoal which remains in the vessel in which the experiment has been made, contains sulphur in such a state of combination that it cannot be expelled by heat, provided the air be excluded. According to Prout, a similar combination of sulphur with carbon is easily obtained by washing on a filter common gunpowder with water till all the nitre is removed, and heating the insoluble part of the gunpowder in a retort; some of the sulphur will distil off, and part of it remain in combination with the charcoal in the retort. This sulphur, and the nitrogen, which is always found in anthracite, testify in favour of the vegetable origin of this mineral, and appear to support the opinion of those who regard it as the carbon-remains of organized bodies of the oldest formation, in which the process of carbonification has proceeded still farther than in coals.

At all events, the above analysis furnishes an additional proof of the erroneous notion of former naturalists, who regarded anthracite as primitive carbon. This notion, probably, has arisen from the fact, that anthracite, exposed to a red heat, produces no hydrocarbons like coals, and that it resembles carbon likewise, inasmuch as it is consumed by fire almost entirely, leaving but a small proportion of mineral matter in the form of ash behind. The loss incurred by incineration of anthracite was generally calculated as carbon by chemists, before the present methods of analysing organic substances were known. Some observers, however, inferred that water existed in a state of chemical combination in anthracite, as appears from a statement of Lampadius, in an able paper on the Anthracite of Schönfeld in Saxony, which appeared in Erdmann's Journal der Chemie, 1835, 4th Bd., p. 393. By a careful observer like Lampadius, the presence of sulphur and nitrogen in anthracite was not overlooked. He likewise examined all the products of its dry distillation, and obtained, besides water, a mixture of gases, which consisted of carbonic acid, carburetted hydrogen, carbonic oxide, and nitrogen.

Similar results were obtained on analysis of two varieties of anthracite from North America, which Professor Breithaupt of Freiberg procured for him. These samples, from Manchchunk in North America, and from Rhode Island, are described by Professor Breithaupt as remarkably fine anthracite. The imperfections of the analytical methods at that time, however, led Lampadius to draw false conclusions from his analytical results, and induced him to consider all anthracites as hydrates; but we know at present that the hydrogen and oxygen in anthracite are not united as water. Though mistaken in his quantitative analyses, Lampadius, nevertheless, has the credit of having pointed out the qualitative composition of several varieties of anthracite more accurately than any chemist who examined this mineral before him. In all samples he detected carbon, oxygen, hydrogen, nitrogen, and sulphur, besides the ash, or the same substances which were found to enter into the composition of the anthracite of the Calton Hill.

[*From the* Annals and Magazine of Natural History *for Mar.* 1850.]

XVII.—*On the Watery Secretion of the Leaves and Stems of the Ice-plant* (Mesembryanthemum crystallinum, *L.*). By Dr. Augustus Voelcker, Prof. of Chemistry Royal Agricult. College, Cirencester*.

A few months ago I had the pleasure of communicating to the Botanical Society of Edinburgh the results of an examination of the watery liquid in the ascidia of *Nepenthes destillatoria*. Those present at the meeting, as well as the readers of the 'Annals of Natural History,' will remember that, in opposition to the statements of most botanists who have directed their attention to the subject of the watery secretions of the leaves of plants, I found the liquid in the ascidia of *Nepenthes* to differ materially from pure water, inasmuch as it contained from 0·30 to nearly 1 per cent. of solid substances, partly organic partly inorganic. I stated at that time my doubts as to the watery secretion of plants being nothing but pure water, and gave some reasons for this opinion; Prof. Balfour, with whom I discussed the subject, kindly furnished me with the means of investigating this point still further by favouring me with fresh specimens of the curious Ice-plant (*Mesembryanthemum crystallinum*), a plant which is remarkable on account of the gland-like vesicular eminences with which its leaves and stems are covered. The result of the examination of the fluid secreted by the leaves of this plant has fully confirmed the opinion expressed in regard to the watery secretions of plants; at all events it has shown me that the secretion of the leaves of the Ice-plant is not merely pure water, but water containing several substances in solution. Though I was unable to determine quantitatively the composition of this secretion on account of the small quantity of liquid at my command—a quantity insufficient even for a minute qualitative analysis—yet I had no difficulty in detecting the chief constituent parts of the fluid. The secretion I procured by lacerating the gland-like eminences with

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* Read before the Botanical Society of Edinburgh, Jan. 10, 1850.

which the leaves are covered, with a needle, and collecting the fluid in a glass bottle. The fluid thus obtained was colourless and nearly clear, without smell, and possessing no distinctly pronounced taste. Litmus-paper dipped in it was very slightly turned red, showing the presence of merely traces of a free acid or an acid salt. In order to free it entirely from any particles of epidermis which might accidentally have mingled with the liquid, I filtered it through white filtering-paper. The fluid passing through the filter slowly was now perfectly clear. On heating to 212° F. white flakes were separated, which proved to be identical with vegetable albumen. They were collected in a filter, and the filtrate evaporated to dryness on a water-bath. During the evaporation the liquid turned yellow, particularly when evaporated to a small bulk, and left a brownish-coloured, very hygroscopic residue, which redissolved in a small quantity of distilled water, leaving but a trace of a humus-like, dark-coloured organic substance undissolved.

The chemical nature of the fluid from which the albumen had been separated, was ascertained as far as possible by the following tests:—

Ammonia produced no change.

Carbonate of ammonia gave no precipitate.

Carbonate of soda on boiling gave a white precipitate.

Oxalate of ammonia produced no change.

Phosphate of soda and ammonia, added to the concentrated liquid, gave a crystalline white precipitate of phosphate of magnesia and ammonia.

Chloride of platinum, added to the concentrated liquid after the removal of the magnesia, produced a crystalline yellow precipitate.

The presence of soda was indicated by the yellow colour given to the alcohol flame.

Lime-water produced a white precipitate.

Sulphate of lime likewise produced a white precipitate.

Chloride of barium gave a heavy white precipitate.

Nitrate of silver gave a white flaky precipitate, soluble in ammonia, but insoluble in nitric acid.

Acetate of lead produced a white precipitate.

Basic acetate of lead gave a voluminous white precipitate.

A portion of the water evaporated to dryness and heated to redness left a white ash which effervesced with acids, indicating the presence of carbonates, originated from organic acids present in the fluid.

The nature of the organic acids, which in all likelihood accompanied the oxalic acid, I could not determine from want of material. The presence of oxalic acid however is distinctly indicated by the above reactions. They likewise show the presence of chloride of sodium, potash, sulphuric acid and magnesia.

In comparing this secretion of the leaves of the Ice-plant with the fluid in the ascidia of *Nepenthes,* we find a material difference in their respective compositions, as will be seen by the annexed table, which exhibits the composition of both fluids :—

Composition of the fluid in the ascidia of Nepenthes.	*Composition of the watery secretion of the leaves of* Mesembryanthemum crystallinum.
Organic matter, chiefly malic and a little citric acid.	Organic matter (albumen, oxalic acid, &c.).
Chloride of potassium.	Chloride of sodium.
Soda.	Potash.
Lime.	Magnesia.
Magnesia.	Sulphuric acid.

which the leaves are covered, with a needle, and collecting the fluid in a glass bottle. The fluid thus obtained was colourless and nearly clear, without smell, and possessing no distinctly pronounced taste. Litmus-paper dipped in it was very slightly turned red, showing the presence of merely traces of a free acid or an acid salt. In order to free it entirely from any particles of epidermis which might accidentally have mingled with the liquid, I filtered it through white filtering-paper. The fluid passing through the filter slowly was now perfectly clear. On heating to 212° F. white flakes were separated, which proved to be identical with vegetable albumen. They were collected in a filter, and the filtrate evaporated to dryness on a water-bath. During the evaporation the liquid turned yellow, particularly when evaporated to a small bulk, and left a brownish-coloured, very hygroscopic residue, which redissolved in a small quantity of distilled water, leaving but a trace of a humus-like, dark-coloured organic substance undissolved.

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Chloride of potassium.	Chloride of sodium.
Soda.	Potash.
Lime.	Magnesia.
Magnesia.	Sulphuric acid.

From the Journal of Agriculture, and Transactions of the Highland and Agricultural Society of Scotland, March 1851.

The Effects of Burnt Clay as a Manure. By Dr Voelcker, Professor of Chemistry in the Royal Agricultural College, Cirencester.—One of the best means of improving stiff clay land, next to thorough drainage, is the practice of soil-burning—an operation which must not be confounded with paring and burning. The latter affects merely the surface soil, whilst in the former, the soil under the vegetable mould is also burned with faggots, brushwood, grass-sods, all kind of vegetable refuse matter and coal, where it can be obtained at a cheap rate. The advantages resulting from burning clay land are so manifest, that in districts where such land abounds, as in the counties of Suffolk, Essex, Gloucestershire, and in localities situated on the Oxford clay, the system of soil-burning has been long since introduced with the best effects. Properly burnt clay is, therefore, justly considered by many farmers as one of the most valuable fertilising materials, which not only improves the first crop, but likewise decidedly benefits several succeeding crops. We have the testimony of several good farmers, that the effects of burnt clay are shown in some instances, even after a lapse of eight years, by the more luxuriant growth of crops and land dressed with burnt clay, when compared with those growing in soils which had not received such a dressing. It would be easy to cite many experiments made both on a small and on an extensive scale in Britain and on the Continent, together with the opinions of high agricultural authorities, all tending to prove the advantages resulting from the application of burnt clay, were such arguments necessary to convince the sceptical on the subject. To produce such conviction is not, however, the object of the following observations. I shall, therefore, merely refer to one or two experiments conducted under peculiar advantages, and affording much instruction. Those who desire further information on the subject, may find it in the valuable papers published in the *Journal of the Royal Agricultural Society of England*, by Mr Pym, vol. iii. p. 323; Mr Randell, vol. v. p. 113; Mr Pusey, vol. vi. p. 477; Mr Mechi, vol. vii. p. 297; Mr Poppy, vol. vii. p. 142; and Mr Long, vol. vii. p. 245.

Mr Pusey testifies to the good effects of burnt clay, chiefly, as he says, on account of the very bad quality of the land on which the burning succeeded. The soil was like bird-lime in wet weather, and in a dry summer like stone, and was purchased for £14 per acre. It was drained with 34 inch drains, at first at 10 feet apart, and then at 30 feet apart. After burning the clay with Essex labourers, a field of 8 acres yielded the following returns of wheat, the natural soil yielding only 16 bushels per acre:—

One acre.	Wheat.
With no manure, ...	37¾ bushels.
.. 80 yards of burnt clay, ...	45½ ...
... ... and sheep folded, .	47½ ...

The draining cost £3, 1s., and burning the clay £2, 5s. per acre. The produce was worth £17 per acre.

Mr Pusey justly observes, that burnt clay does not act merely mechanically, but also as a manure, (that is, chemically.) The reason, however, why it does so, and sometimes fails to do so, he does not attempt to explain. To elicit from the nature of the chemical changes, produced by the process of burning, and from a consideration of the various circumstances under which it may be performed, some solution of those questions has been the object of my investigation.

Practical men agree that clay-burning is rather a nice operation, and requires much attention and judgment on the part of the operator. It is well known that, if the heat in burning clay is allowed to become too intense, the result will be that, instead of a friable mass, large hard lumps, resembling brick-bats, will be produced, which rather injure than improve the soil. It is fair to infer, therefore, that ignorance or carelessness, in this respect, accounts for the failure of some cases. All failures, however, cannot be attributed to this cause; for many men, well acquainted with the subject, affirm that some kinds of clay are unfit for burning, because the increase of the crops is not adequate to the expense and trouble of burning and spreading this kind of manure. Now, it is clear that, unless we know the true cause of the effect produced by the application of burnt clay, we are not likely easily to settle, without incurring much expense, which kind of clay is well adapted for burning, and which not. At the same time, the discovery of the cause of the efficacy of burnt clay might lead us to supply the same substances or materials, on which the effects in burnt clay depend, in another form at a cheaper rate. An additional advantage may be derived from this consideration, by which improvements are likely to be effected in the existing methods of burning clay, which shall render them easier, cheaper, and more certain.

These and similar considerations, I think, will at once show the practical importance of a thoroughly fundamental investigation of this subject.

The analyses of different samples of agricultural clays, taken from several geological formations, and even those of the same geological epoch, afford great differences in their chemical constituents. Such clays are generally composed of alumina, silica, oxide of iron, manganese, lime, magnesia, potash, soda, traces of sulphuric and phosphoric acid, and chlorine, in different proportions. It is perhaps just on account of the complexity of composition, and the various changes in the chemical relation of these different constituents, under so powerful an agent as heat, that the difficulty of settling the above questions arises. Room for much speculation is the necessary result of these circumstances; consequently many theories with regard to the effects of burnt clay have from time to time been advanced by agriculturists and chemists. Even though such a high authority on agricultural chemistry as that of Liebig had made us acquainted with a theory, in explanation of these effects, it must be confessed—and practical men as well as agricultural chemists acknowledge—that we have still much to learn on the subject, before we can, with any amount of probability, offer an explanation of these various effects.

With a view of contributing something to the solution of the problem, I made some experiments during last winter, which have furnished me some interesting analytical results. These, I trust, will throw some light on the rationale of clay-burning, and at the same time show the importance of a more extensive practical application of the process on heavy clay lands.

Before submitting to the reader my own results, I shall take a rapid survey of the history of the observations of others on the subject.

It has been mentioned already that burnt clay appears to have been used as a manure long ago. Amongst those who recommended it, Robert Sommerville, and particularly General Beatson, deserve notice. The General, in his book entitled *New System of Cultivation, without Manure, Lime, or Fallow*, of which a second edition appeared in 1821, mentions the names of Curwen, Boyd, Cartwright, Cray, and others, as observers of the beneficial effects of burnt clay on vegetation, and strongly recommends the practice of soil-burning, as one of the best means of improving land, especially stiff heavy clay soil. The appearance of this work created some sensation at the time amongst the agricultural community and the scientific public, both in this country and on the Continent. It excited, indeed, the curiosity of German agricultural chemists in a high degree, and occupied the attention of several eminent Continental philosophers, in a measure which was scarcely equalled by the attention bestowed on the subject by the scientific men of England. Sprengel, the celebrated German agricultural chemist, Professor Hermbstädt, Professor Kastner, Professor Zierl, Kersten, and, above all, Professor Lampadius, took up the subject with much warmth, and each speculated, after his own manner, on the causes of the alleged beneficial effects of burnt clay. A short review of the labours of these distinguished men, which by no means are so well known by the agricultural public of Great Britain as they deserve, I trust will not be unacceptable to the reader, if it were only for the purpose of demonstrating how fallible the judgments of even great men are, and of inculcating the moral lesson so frequently forgotten by theoretical writers, that theories should be put forward with the utmost caution and modesty. How often do we find a favourite theory offered to the public in a manner in which only a mathematical truth, or a law of nature, confirmed by the experience and labours of many generations, can be advanced, and, after all, the same theory, stated with so much confidence, and often arrogance, appears very erroneous and even absurd, as the circle of our experience expands. Fortunately for such a theorist, this seldom takes place in his lifetime, but sometimes the decline of his life is embittered by seeing the dreams of his enthusiasm vanishing and exploded, and exposed to the ridicule and scorn of his contemporaries. We long to see the time when caution, modesty, a generous regard for the opinions of others, and, above all, a love of truth for its own sake, shall characterise the mind of natural philosophers, and feel convinced that men whose spirit is so constituted, will not only enjoy themselves a greater amount of happiness and satisfaction, but that the cause in which they are engaged will be decidedly a gainer, and advance more rapidly, and prosper better than it now does.

It must be regarded as a matter of deep regret, that the want of caution and modesty on the part of many scientific men has contributed more than perhaps anything else to bring science into discredit with the agricultural public. Many a practical man, not otherwise entertaining prejudices against science, has been led thereby to undervalue the labours of his best friends, and to regard science—a term of which he often entertains very vague ideas—as antagonistic to practice. In my conversations with farmers, it has often struck me how generally the words *practice* with *science*, which several agricultural societies have accepted as their motto, are misdunerstood. Mere theory and science are synonymous terms, I fear, with most farmers; and many, I am convinced, regard science as the very antagonist principle to practice; and if they adopt the motto Science with Practice, I think it is only because, in their opinion, a little opposition—that is, a little science or theory—keeps a good practice alive. Now nothing can be more incorrect. True science and practice are never opposed to each other. The source from which both are upheld is observation. Well-regulated observation constitutes experience: experience is the mother of sound practice, but it is also the parent of sound science; for science itself is nothing else than the systematic arrangement or generalisation of a number of isolated facts. Where, then, is the antagonistic principle between science and practice?

The labours of Lampadius demand our special notice. With much interest and zeal he took up the investigation into the causes of the beneficial effects resulting from the application of burnt clay, brick-dust, and burnt soil in general; and during the years of 1829-36, he continued his experiments, which are full of instruction, with a perseverance which cannot be too highly commended. The results of his experiments are recorded in a series of papers which appeared in Erdmann's *Journal für Technische und Œconomische Chemie*, during the years of 1826-36; and as they are valuable contributions to our agricultural literature, we will point out the more important of them, and briefly state the theoretical conclusions to which they lead the praiseworthy investigator. Happily he did not confine his experiments to the laboratory, nor to the practical tests of a few flower-pots or a slip of garden land, but conducted them on a large scale in a truly philosophical manner in the field. Although, we believe, he mistook the causes of the advantages of burnt clay, his labours have advanced scientific agriculture in no small degree, and contributed much to the more general application of this valuable manure. They also afford some data to succeeding investigators, who are happier in their conclusions. The result at which Lampadius arrived, by numerous well premeditated and carefully executed experiments, may be briefly thus stated: Properly burnt clay acts on a variety of crops—as on wheat, barley, oats, green crops, and particularly on potatoes—as a most valuable manure. One of his experiments will serve sufficiently for illustration; and without entering into further details, it may be observed that few experiments have recently been recorded which possess more intrinsic value, and that few men were better fitted to submit the alleged effects of burnt clay to a severer test than Lampadius. Not only his extensive theoretical chemical knowledge and practical acquaintance with analysis, but also his acquaintance with practical farm operations, his physiological and meteorological knowledge, his acute talent of observation, adaptation, circumspection, and general skill in devising plans and carrying them out in a truly philosophical spirit, peculiarly fitted him for the task he had undertaken. We thus find him testing the results of the laboratory by experiments on a small scale, and these by others in the field. The physical characters of the soil on which the experiments were made were carefully described, its geological formation on which it rests specified, and its chemical composition ascertained by analysis; the preceding crops, further, grown on it for several years back were noted down. Besides this, the quantity of rain fallen during the season, the temperature, height of the barometer, and general state of the weather, the condition of the crop, from the beginning of the germination of the seed to the period of its maturity, were carefully recorded. The produce, in every case, was ascertained in exact numbers—obtained by means of balance and measure; and lastly, the composition of the produce was determined by analysis, in order to decide the inferiority or superiority of the same crop grown with different manuring substances. In addition to all this, minutes were kept of all the incidents which might have affected the ultimate results; and thus data are supplied which render his experiments valuable for all ages.

The experiment which we shall choose for an example was made on exhausted land, from which, in 1829, a crop of winter rye, and in 1830 and 1831 oats, were grown. The nature and composition of the land was previously ascertained, as well as that of the seed-potatoes, for it was on potatoes he experimented. The potatoes were planted on the 3d of May 1832.

1. On the first plot of the experimental field, 28 lb. of white potatoes were planted in two rows, and the ground manured with farm-yard manure.
2. On the second, 28 lb. of the same potatoes were planted, and the ground manured with 130 lb. of burnt clay, and the same quantity of manure as that applied on the first plot.
3. The third received 130 lb. of burnt clay only, and the same quantity of potatoes, (28 lb.)
4. On the fourth plot, 28 lb. of the same potatoes were grown without any manure whatever.

The produce was collected on the 27th of September, and gave—

1. 278 lb. of full-grown potatoes, with but few small ones. Some of the larger weighed from 5½ to 6½ ounces; the weight of most was 2 to 3 ounces.
2. 280 lb. of equally good potatoes. Some of the larger weighed 6 to 8 ounces. There were few under 1 ounce.
3. 276 lb. of perfectly matured, very good potatoes. Most were middle-sized, of 3 to 4 ounces weight, with but few small ones.
4. 127 lb. only of potatoes, of a scarcely mediocre quality, mixed with many small ones which had not come to perfection. The plants produced only a few seeds, whereas the potato plants in No. 3. furnished even a greater abundance of seed-apples than those planted in No. 1.

In comparison with the seed-potatoes, the produce of the four plots was therefore—

1. In the field manured with farm-yard manure, ten-fold.
2. In the field manured with farm-yard manure and burnt clay, nearly eleven-fold.
3. In the field manured with burnt clay only, nearly ten-fold.
4. In the field without manure, only a little more than four-fold.

In these experiments, the highly profitable effects of burnt clay on the potato crop, grown on perfectly exhausted land, are exhibited in a most convincing manner.

Passing over the details of the subsequent chemical analyses, to which not only the tuber, but likewise the roots, stem, leaves, and seeds of the potato plants were subjected by Lampadius, the following are the ultimate results at which he arrived:—

a. Burnt clay benefits the growth of potatoes on the poor loam of the neighbourhood of Freiberg nearly as much as mixed animal and vegetable manure, (common farm-yard manure.)

b. The tubers of the potato plants furnish the same quantity of starch, fibre, and water, whether they be grown with farm-yard manure or with burnt clay.

c. The seed-apples, roots, stems, tubers, and leaves of the potato plants, contain the same inorganic constituents, and in the same relative proportions, when grown with burnt clay or with farm-yard manure.

d. The amount of inorganic matters in the different parts of the potato plants differ very considerably.

In order to give an idea of the spirited manner in which Lampadius carried out similar experiments, I would draw the attention of the reader to the fact that, in the same year, this indefatigable philosopher tested the effects of burnt clay on no less than twenty different crops, in a manner which proved forcibly the economic value of this kind of manure. He further caused many farmers to try experiments with burnt clay on a large scale, and had the satisfaction to see his own experiments confirmed by the experience of many practical farmers. So successful, indeed, were nearly all his experiments, and so much the interest of the agricultural community of Germany excited by Lampadius's labours, that, by command of the Government, public establishments were erected in various parts of the country for the purpose of supplying farmers, at a cheap rate, with properly burnt and finely powdered clay.

The crops which were benefited most by the application of burnt clay, next to potatoes, were ascertained by Lampadius to be peas, kohl-rabi, carrots, beetroot, clover, oats, rye, and wheat. Less favourable he found its use as a top-dressing for pasture land. It is worthy of remark that the good effects of burnt clay were observed on beans, kohl-rabi, and carrots, after the third year, without receiving any additional manure.

Having thus shown on what grounds Lampadius recommended the more general use of burnt clay, we shall now endeavour to collect from his extensive papers the theories he advanced to account for these extraordinary and interesting effects.

At first he appears to be inclined to ascribe to humate of alumina, which according to him is formed in the soil, a highly beneficial action on vegetation, and hints that burnt clay would fail in its effects when the soil was exhausted of humus; but having soon after found that burnt clay in soil destitute of humus produced, nevertheless, unmistakeable effects, he soon gave up this theory, and next explained the effect, by saying that clay in burning undergoes some peculiar unexplained changes, by which changes the manuring substances in clay are rendered available to plants. It will be observed that this explanation amounts to little more than stating the fact in other terms. Indeed, the modified and varied opinions Lampadius entertained afterwards on this subject clearly show how little satisfied he was with this theory. As the probable causes of the effects of burnt clay, he mentions in 1833:—

a. The changes in the state of aggregation clay undergoes in burning.
b. The decomposition of the hydrates occurring in clay.
c. The changes which the earthy substances of the clay undergo in burning, which changes render them more soluble in the humic acids of the soil.
d. The higher state of oxidation of the oxides of iron and manganese produced in burning clay.
e. The production of a larger quantity of soluble sulphates, phosphates, and hydrochlorates, which, previous to burning, occur in a more fixed state in clay.
f. The absorption of light and heat by burnt clay.
g. According to Dr Sprengel, the formation of ammonia in burnt clay.

Several of these opinions were abandoned by Lampadius, who, in 1834, ascribes the effects of burnt clay to the following causes:—

(1.) To the inorganic constituent parts of unburnt and burnt clay, which are essential to the growth of cultivated plants.
(2.) These constituents are rendered more soluble, in various ways, in moderately burnt clay. Unburnt clay gave 0.20 soluble matters; moderately burnt clay, 0.30 soluble salts. Humic acid dissolves likewise silicate of alumina, and the other constituents of clay, more readily when clay has been previously burnt.
(3.) The protoxide of iron in the clay takes up more oxygen in burning, and becomes converted into peroxide, which, according to Sprengel, acts beneficially

on vegetation, whilst protoxide of iron is rather injurious to many vegetables.

(4.) In burnt clay, ammonia is formed when exposed to the atmosphere in a moist state.

In his last concluding paper on this subject, Lampadius advanced finally the following theories :—

a. Plants are supplied by burnt clay with humates of alumina and silica.

b. In burnt clay, exposed to moist atmospheric air, ammonia, which is beneficial to vegetation, is formed according to his own, Sprengel's, and Kersten's observations.

c. According to Zierl, accessory constituents of clay, as phosphoric acid and potash, contribute to the fertilising effects of burnt clay.

These, then, are the theoretical opinions advanced by Lampadius, and we shall see presently how far they are consistent with the present state of science; but, in order to avoid repetition, we shall first briefly state the opinions of others who have written on the subject, and shall then submit the various theories, which all more or less agree with Lampadius, to a short review.

Karl Kersten, who analysed a sample of clay, both in its natural state and burnt, could detect no material difference in the composition of the burnt and the natural clay. The only difference which he points out consists in a slightly greater amount of soluble matter—the amount of soluble substances in the natural clay being 0.20; in the burnt, 0.30. On so small a difference no theoretical speculation can be built, inasmuch as the unavoidable errors in good analyses fall between these limits. Kersten likewise observed the formation of ammonia in burnt clay which had been exposed to the atmosphere for some time, and inclines to ascribe to the latter the chief fertilising effects of burnt clay. No mention is made of the presence of ammonia in the natural clay.

Professor Kastner thinks clay, when burnt, absorbs light, which being given off again in the soil, exercises a beneficial effect on vegetation; but as his theory is founded on no experimental proof, we can dismiss it without any further inquiry into the probability of the explanation he has given.

Dr Sprengel's extensive researches on a multitude of chemico-agricultural subjects—amongst others, on the causes of the beneficial effects of burnt clay—are valuable contributions to scientific agriculture. The theory which he first advanced enjoyed the approbation of many of his contemporaries, and is partly still entertained by no less an authority than Liebig, and other eminent chemists of the present day. This theory is generally called the ammonia-theory. According to it, the chief fertilising agent in burnt clay is ammonia, which Sprengel supposes to be formed in burnt clay under the influence of protoxide of iron, from the elements of water and atmospheric air, and which, according to Liebig and others, exists ready formed in the atmosphere, whence it is simply absorbed by the clay. The clay being more porous after burning, they suppose absorbs more ammonia, and acts, consequently, more beneficial on vegetation than unburnt.

At first Sprengel attributed the effects of burnt clay to the circumstance that, in burning, the protoxide of iron, existing in many natural clays, is changed into peroxide, which he considers to be more beneficial to vegetation than the protoxide. Sprengel's second explanation entirely contradicts this statement, inasmuch as, according to it, during the burning process the peroxide of iron in clays is changed into protoxide—to which now he ascribes the greatest importance, as being the chief agent in the formation of ammonia in burnt clay; for, in slightly burnt clay, protoxide of iron is always present; and, as it has been ascertained by Hausmann and others, ammonia is formed when protoxide of iron, moistened with water, is kept in contact with nitrogen. Sprengel explains the beneficial action of burnt clay by the formation of ammonia, which is generated in it in the following manner:—The protoxide of iron, of which burnt clay usually contains more than unburnt clay, when exposed to the atmosphere in a moist state, is converted into peroxide by the oxygen of the water; the hydrogen of the decomposed water, in the moment of its liberation, unites with the free nitrogen of the atmosphere to ammonia, which is retained by the humic acids present in all cultivated plants. According to Sprengel's views, the more protoxide of iron clay after burning contains, the more certain it will appear in its effects, because more ammonia will be formed: burnt clay will cease to exhibit the same fertilising effects when all the protoxide of iron has become changed by oxidation into peroxide, because then no more ammonia can be formed. This is the case in overburnt clay, which contains peroxide of iron only, and no protoxide: overburnt clay thus exercises no beneficial effects on vegetation, because no ammonia is formed in it on exposure to the air.

So much for Sprengel's theory. The ammonia, then, which in burnt clay is formed during the oxidation of the protoxide of iron, Sprengel considers as the chief cause of action of burnt clay; at the same time he ascribes to the necessary constituents of clay, as potash, soda, lime, magnesia, &c., some influence in promoting the growth of plants; and agrees likewise with Lampadius's opinion, that humate of alumina, which he considers an important substance in the vegetable processes, is more readily produced in burnt clay than in unburnt.

The recent analyses of the ashes of most cultivated plants have shown the entire absence of alumina in plants; Lampadius and Sprengel's theory concerning the action of humate of alumina, therefore, falls to the ground. That ammonia exists in burnt clay Sprengel has demonstrated, by heating clay, free from organic matters; exposing the same, in a moist state, for three days to the atmosphere; and after that time heating the clay in a retort, to which a receiver was attached, containing water acidulated with hydrochloric acid. On evaporation of the liquid in the receiver, distinct crystals of sal-ammoniac were left behind in the basin in which the liquid was evaporated. The repetition of this experiment gave me the same result. However, Sprengel erred in thinking that ammonia is formed only in those clays which contain protoxide of iron, for I have found that in clay which contains not a trace of protoxide of iron, ammonia is found after exposure to the atmosphere for some time. It cannot be denied that protoxide of iron, in contact with moisture and atmospheric air, gives rise to the formation of ammonia; but the proof that in burnt clay a greater quantity of ammonia is found, because it contains, as Sprengel supposes, more protoxide of iron, he has not furnished; and his theory loses much in probability, by the consideration that ammonia is found in clay containing only peroxide of iron; and further, that certain blue clays, in their natural state, contain protoxide of iron in preference, with but little peroxide. If it was true that the ammonia is the chief cause of the effects of burnt clay, and that it is formed in clay under the influence of protoxide of iron, from water and atmospheric air, these blue clays ought to possess the same effects as burnt clay, or exhibit even greater fertilising effects than most burnt clays. The contrary, however, is the case. Sprengel appears to have felt the difficulty which presents itself in explaining why certain blue clays, which contain a large quantity of protoxide of iron, do not act so beneficially as burnt clays, containing much less protoxide; and he endeavours to meet it, by a reference to the changes which protoxide of iron undergoes during heating. He says, in unburnt clay, protoxide of iron occurs in a state of hydrate; on burning, it is changed into anhydrous protoxide, in which state it possesses the greatest galvanic energy, in consequence of which a larger decomposition of water, and also more considerable formation of ammonia, results. This explanation, probable as it may appear at first sight, nevertheless wants the only proof on which any explanation can be founded—namely, direct experiment—and amounts, therefore, to nothing more than explaining one difficulty by assuming another. For my own part, I cannot see why anhydrous protoxide of iron should be in a state of greater galvanic energy, and consequently produce more ammonia than the hydrated protoxide; and as Sprengel has not shown, by direct experiment, that this is really the case, the difficulty which presents itself to his ammonia-theory in certain blue clays cannot be said to be removed. We shall see hereafter that ammonia, which is found in burnt clay, indeed contributes to the general effect of the same; but we shall likewise see that it is not the chief cause. The part ammonia plays in producing these effects will be discussed afterwards.

It is now time to allude to the opinions which Professor Zierl entertained respecting the causes of the influence of burnt clay. Unlike Lampadius, Kersten, and Sprengel, he considers the accidental constituents of agricultural clays as the chief causes of the fertilising effects of burnt clay. Without giving any experimental support to his theory, he reasons, with much probability, by analogy, that some of these accessory constituents of clay, particularly potash, soda, lime, and magnesia, are rendered more soluble in the process of burning. To this circumstance he ascribes the chief causes of the effects of burnt clay. It is curious that his theory, set forth with much perspicuity and ingenuity, was by no means generally well received at the time of its publication. Nevertheless, Zierl's theory seems to me the most rational of all the theories which have been advanced. Without a previous knowledge of Zierl's paper, or the causes of the effects of burnt clay, I have formed a theory which, in many respects, agrees with his; and when I shall bring forward the facts by which I hope to support my theory, I shall point out the importance of Professor Zierl's speculations, which, unfortunately for him, were not borne out by any testimony or experiment.

It now remains for me only to say a few words about the opinion which Professor Hermbstädt advanced in a paper, which appeared in *Erdmann's Journal* for 1833, vol. i. p. 45, concerning the effects of burnt clay. His views on the use of inorganic constituents of the soil to plants are so entirely at variance with the generally accepted opinions of chemists and physiologists, that the endeavour to refute them might appear as a waste of words and of time. The same remark applies to his views concerning the effects of burnt clay; and we shall, therefore, only mention, that Professor Hermbstädt refers the active principle of burnt clay entirely to the organic matters which have not been destroyed by the fire. For obvious reasons, he is no advocate of the use of burnt clay; and, although Lampadius's, and many other practical experiments, were published in 1833, he prophesies a total failure to General Beatson's recommendations. Inconsistent as his own views were with the state of science in 1833, he charges General Beatson with ignorance of the first principles of the theory of manures, and this in terms which cannot be too highly deprecated. Ought not his example to make us more charitably inclined towards the opinions of others—more guarded and milder in our expressions, and less confident and dogmatic in propounding our own views?

From these remarks the reader will perceive that none of the above-mentioned theories explains satisfactorily the cause of the decidedly beneficial effects of burnt clay; that Sprengel's, Lampadius's, and Kersten's theory, concerning the use of ammonia, and the modified ammonia-theory of Liebig, are open to serious objections. Furthermore, none explains in the least why certain clays, when properly burnt, act more beneficially than others, and what the reasons are which explain the failures attending the application of over-burnt clay.

Most living agriculturists and agricultural chemists have adopted Liebig's views respecting the nature of the action of burnt clay, or consider the action to be entirely dependant on the altered physical state which clay after burning presents. Of recent writers on the subject, Professor Johnston, however, entertains much more rational and wider views than any of his predecessors. Giving all due importance to the mechanical effects of burning upon clay, Professor Johnston, in an excellent paper in his *Experimental Agriculture*, p. 254, shows that the mechanical effects of burning upon a clay are insufficient to explain the beneficial action of burnt clay, and demonstrates experimentally that the chemical changes produced in burning are of even a greater importance than the mechanical. "These chemical changes," the learned Professor says, "are of such a kind as to render the constituents of the clay more soluble—that is, soluble to a greater extent than before the burning—both in water and in acids." He further found by analysis, that by over-burning, new changes among the constituents of the clay take place, by which they are again rendered less soluble than when slightly burnt. The soluble matter consisted of potash, soda, lime, magnesia, chlorine, sulphuric acid, silica. The relative proportion of these substances, however, is not stated in the above-mentioned work, from which I infer that the nature of the soluble matters has been examined by Professor Johnston only qualitatively.

By my own experiments, I am enabled to confirm Kersten's and Johnston's observations of the greater solubility of burnt clay, and the observation of Johnston, that clay again becomes less soluble on over-burning. In addition to this, the quantitative analyses of a clay, burnt in three different modes, has given me results which will throw considerable light on the causes of the action of burnt clay. The mere fact that clay becomes more soluble in water and acids, appears to me insufficient to explain the beneficial effects of burnt clay; for it is quite possible that alumina, oxide of iron, or any other unimportant element of clay, of which most soils contain already sufficient quantities, is rendered soluble. It is evident that the greater solubility of any of such substances would increase the quantity of soluble matter, without adding anything to the aggregate fertilising effects of burnt clay. Pure pipe-clay, slightly burnt, is indeed more soluble in acids than the unburnt clay. Sulphuric acid decomposes moderately burnt clay, and dissolves, on boiling, *all* alumina, leaving the silica, with which the latter was combined, behind, whereas concentrated sulphuric acid has but little action on clay in the unburnt state. The greater solubility of burnt clay in itself, then, is insufficient to account for the effects of burnt clay. But this objection stands no longer in our way, since we are in a position to show that, in burning, one of the most important fertilising substances which is found in clay, if not the *most important* of all, is rendered more soluble.*

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* Want of space obliges us to postpone the remainder of this interesting paper to the next number.—Editor.

From the Journal of Agriculture, and Transactions of the Highland and Agricultural Society of Scotland, October 1851.

Effects of Burnt Clay as a Manure. By Dr VOELCKER, Professor of Chemistry in the Royal Agricultural College, Cirencester.—(*Concluded from p.* 79.)—In burning clay properly, I have found that a much larger amount of *potash* is rendered soluble, in a way which I shall explain, after having given the details of my analyses. But every physiologist knows that potash is one of the most valuable and essential food of plants. I am inclined, therefore, to consider the fact, that potash being rendered more soluble on burning clay, is the chief cause of the beneficial effects of burnt clay.

I am indebted to Sir Thomas Tancred for the material with which my experiments were made.

Having procured for me some clay of the new red sandstone formation from the farm of Huntstile, near Bridgewater, tenanted by Mr Thomas Danger, I proposed to myself the following questions:—

1. Is this clay more soluble after burning than in its natural state?

2. What are the relative proportions of insoluble and soluble matters in this clay, when burnt in different manners?

3. What is the relative composition of the soluble portion in each case?

4. Is it essential or desirable that clays fit for burning should contain lime?

5. What are the characteristics of clays, of which it can be said that they are totally unfit for burning?

6. Can it be determined by chemical analysis whether burning will be efficacious in rendering clay a fertiliser?

7. What are the reasons of the failure attending over-burning?

8. Does moderately burnt clay absorb more ammonia from the atmosphere than unburnt clay?

9. Does over-burnt clay absorb any or no ammonia from the atmosphere?

10. Is ammonia found in burnt clay, containing protoxide of iron, when exposed in a moist state to the atmosphere in much larger quantities than in the same clay exposed in a dry state to the atmosphere?

11. What is the reason that burnt clays improve, especially root and other green crops, as Mr Woodward states?

The nature of the *chemical* changes, which may be supposed to affect the action of burnt clay on the land to which it is applied, was examined by four distinct analyses.

No. I. Clay-soil in its natural state.

No. II. A quantity of the same clay-soil was exposed to a *dull* red heat in a *closed* platinum crucible, and kept at that temperature for half an hour. The clay, after burning, had a *dark-grey* colour.

No. III. Another portion of the same clay-soil was exposed to a *red* heat for half an hour in an open crucible. The contents of the crucible were frequently stirred with a platinum wire, in order to effect the complete combustion of all organic matters, and to secure the perfect oxidation of any protoxide of iron which was present in the clay. After burning, the colour of this portion of the clay was red; rather brighter than the natural colour of the soil.

No. IV. A fourth portion of the same clay-soil was exposed for about three hours to a full red heat in an open crucible.

Though water, containing carbonic acid, acts more slowly, yet it produces the same effects on the constituents of clay as dilute mineral acids. I preferred to apply dilute muriatic acid instead of water charged with carbonic acid, in order to test the solubility of the above four samples of clay. Accordingly, separate quantities of Nos. I., II., III., and IV., were taken for analysis, and each boiled for half an hour in four ounces of water, containing one-tenth of its bulk of hydrochloric acid; the insoluble part of the clay was collected on a filter, and washed with distilled water until nothing more was dissolved.

In the soluble part of Nos. I., II., III., and IV., the following substances were determined quantitatively:—Soluble silica, oxide of iron, and alumina; carbonate of lime, potash, soda, and phosphoric acid.

In No. IV. phosphoric acid was not determined.

The following table exhibits the results of these several analyses:—

	No. I.	No. II.	No. III.	No. IV.
Water, driven off at 212° F.,	5.539	9.160		
Organic matter and water of combination, .	3.621		9.200	9.300
Insoluble matter, (in dilute hydrochloric acid,) .	84.100	80.260	81.845	85.309
Soluble matter, consisting of—				
Soluble silica, . .	1.450	1.380	1.580	1.150
Oxides of iron and alumina, .	3.070	8.245	6.092	2.970
Carbonate of lime, . .	.740	.420	.550	.188
Potash, . . .	.269	.941	.512	.544
Soda, ...	.220	.336	.314	.104
Phosphoric acid, . .	.380	.165	.128	Not determined
Chlorine and sulphuric acid, .	traces	traces	traces	traces
Magnesia, (not determined,) .	...	...	...	...
	99.389	100.907	100.221	99.565

The suggestions to which these analytical results give rise will be more intelligible after we shall have briefly considered the origin and composition of agricultural clays in general, and pointed out on what substances chiefly the fertilising powers of clay depend.

Clays generally result from the disintegration and degradation of granitic and felspatic rocks. Felspar, a mineral composed of silicate of potash or soda, and silicate of alumina, exposed for a long time to the united action of the atmosphere and water, suffers a gradual decomposition, and falls altogether to powder. Silicate of potash, a soluble salt, is washed out by the rain falling on the decomposed rock, and converted, in its turn, by the carbonic acid of the atmosphere into carbonate of potash and silica. Part of the silica remains behind with the insoluble silicate of alumina, the chief constituent of clays. Agricultural clays, however, are never pure silicate of alumina, but mixtures of pure clay (silicate of alumina) with more or less of sand, undecomposed fragments of felspar and other minerals, lime, magnesia, free alumina, oxide of iron, soluble silicate of potash and soda, and traces of phosphoric acid, chlorine, and sulphuric acid. The state of combination in which these different constituents occur, varies in different clays. The complex nature of agricultural clays will become apparent by the subjoined analyses of three samples of clays from Dumbelton, in Gloucestershire, made in my laboratory.

	No. 1.	No. 2.	No. 3.
Water of combination and organic matter,	7.69	6.62	6.68
Oxides of iron,	8.24	7.33	8.63
Alumina, soluble in acids,	8.04	10.62	9.25
Alumina, in a state of silicate,	10.04	7.06	9.66
Lime, carbonate of,	1.12	0.70	0.19
Lime, in a state of insoluble silicate,	0.44	0.54	0.24
Magnesia, soluble in acids,	0.62	0.12	0.56
Magnesia, in a state of insoluble silicate,	0.34	0.39	0.34
Potash and soda, soluble in acids,	0.73	1.04	1.13
Potash and soda, in a state of insoluble silicate,	0.94	2.70	1.82
Silica, (soluble in acids,)	0.09	0.06	0.08
Silica, (insoluble in acids,)	61.71	62.82	61.42
	100.00	100.00	100.00

As alumina or silicate of alumina is not found in the ashes of cultivated plants, the chief component part of clay cannot be said to contribute in itself to the direct nutrition of plants, and we have, therefore, to look amongst the accessary ingredients of clay for the fertilising agents or substances which are used as direct articles of food by plants. Lime, magnesia, sulphuric and phosphoric acid, and chlorine—substances which, in larger or smaller quantities, occur in clays—are, indeed, essential to the growth of plants; but the value of an agricultural clay chiefly depends on the proportion of potash and soda which it contains. Potash is an essential element in all ashes of plants, and acts as a most powerful manure. The high price of salts of potash unfortunately prevents their more extensive application in agriculture, and plants are, therefore, dependent in a great measure on the natural sources from which they derive their potash. The chief source of potash in ordinary soils is the clay, which forms part of almost all soils, and which itself usually contains some undecomposed silicate of potash or a duple silicate of potash or soda and an earthy base, from which, in gradual decomposition, potash is set free and made available to plants. Clay, we have seen, is in many cases derived from felspar: the more undecomposed felspar-fragments a clay contains, the more it is likely to prove useful to plants. Hence we are enabled to explain the advantages of fallowing. By that process a fresh portion of the soil, not hitherto exposed to the action of the atmosphere, is brought up, and the undecomposed fragments of felspar are forced by the combined action of air and water, to yield their potash and soda, which are the indispensable requisites of a healthy vegetation.

Without doubt, then, potash is the most valuable substance in clays, and, if I am not mistaken, the substance on which their manuring qualities mainly depends.

In an age of railway and steamboat enterprise and telegraphic despatch, agriculture is forced to progress, and, in consequence of this, fallowing must necessarily yield to some more extensive and expeditious means of gaining the same advantages. Now, I am prepared to show, that, in burning clay, precisely the same changes are effected in a few days which in bare-fallowing are produced in so many months: in other words, the natural fertility of the soil, which in fallowing is restored after a long interval of rest, can be restored in many instances in a few days, by burning land.

Let us, however, examine the proposed questions separately.

1. Is the clay from Huntstile, near Bridgewater, more soluble in dilute hydrochloric acid, after than before burning?

A reference to the above tabulated analytical results will show that, after burning, this clay has become much more soluble than the clay in its natural state.

2. What are the relative proportions of soluble and insoluble matters in this clay when burnt in different manners?

The above-mentioned results not only teach, generally, that clay becomes more soluble in burning, but that the temperature to which it is exposed mainly regulates the solubility of the clay. A proper temperature for burning clay is, indeed, a condition in the process, on which the success of the operation chiefly depends.

We see, from the preceding tabulated results, that clay, in 100 parts in its natural state, furnishes only 6.74 grs. of soluble inorganic matter, leaving 84.100 insoluble mineral matters behind; whilst the same clay, burnt at a temperature, and under circumstances under which the organic matter was not altogether destroyed, left 80.260 grs. of insoluble inorganic substances, and furnished 10.580 grs. of soluble inorganic matters. An increase of the temperature, sufficiently high to burn off the small amount of organic matter which enters into the composition of this clay, had the effect of producing the solubility of its constituents to about 1½ per cent; and a more protracted exposure to a still higher temperature had the effect of a further reduction of its solubility, to such an extent that this over-burnt clay became less soluble than the same clay in its natural state.

	PROPORTION OF	
	Soluble inorganic matter.	Insoluble mineral matter.
Clay, No. 1, (unburnt,)	6.740	84.100
Clay, No. 2, (slightly burnt,) . .	10.580	80.260
Clay, No. 3, (burnt stronger than 2,) .	8.955	81.845
Clay, No. 4, (over-burnt,) . . .	5,391	85.309

It is difficult to determine at what exact temperature clay should be burnt for agricultural purposes, and I am inclined to believe that this point cannot be settled by small experiments in the laboratory. Besides, if it could be done, the mere indication of the degree of heat would not be a sufficient guide to the practical man, and therefore possesses little more than a theoretical value. Valuable results, however, might be obtained by recording the exact circumstances under which different clays have been burnt, by observing the practical effects of clay burnt in different ways, and reserving a portion of each sample of clay for chemical analysis. The analysis of a series of different clays, aud clays burnt in different manners, I have no doubt, besides throwing additional light on the rationale of the process of soil burning, is likely to be attended with important practical results.

3. What is the relative composition of the soluble matter in clay burnt in different manners?

Referring to the above analytical results, we find much difference in the composition of the soluble portion of each of the four samples of clay; but I would invite particular attention to the important fact, which is distinctly proved by these analyses, that the proportion of alkalies, more particularly that of potash, is much larger in the burnt than in the unburnt clay. Finding the quantity of so valuable a fertilising substance as potash very much increased in the soluble portion of burnt clay, and considering that this is precisely the effect produced in fallowing, as demonstrated above, I have no hesitation to assign the chief cause of the beneficial effects of burnt clay to a larger quantity of potash which is liberated by burning and rendered available for immediate use by plants.

The temperature to which the clay has been exposed, here regulates the proportion of potash rendered soluble in dilute muriatic acid in a remarkable manner. In the natural clay only 0.269 of a per cent of potash were soluble; whereas in clay burnt at a moderate heat, and under circumstances resembling those under which clay is burnt in the field, the quantity of soluble potash amounted to more than three times the former quantity, the exact proportion of potash being 0.941 of a per cent. In clay No. 3, the higher temperature to which it was exposed caused a diminution of the last-mentioned proportion of potash, the actual number obtained, on analysis of No. 3, being 0.512 of potash, and in No. 4 nearly the same quantity of potash—namely, .544 grs. were obtained.

The actual quantities of soda rendered more soluble in burning are trifling, but still sufficiently large to confirm the fact that soda is rendered more soluble in burning. The higher temperature applied in burning No. 3 and No. 4 likewise was attended with a slight diminution of soluble soda, when compared with No. 2.

	No. 1.	No. 2.	No. 3.	No. 4.
Soda, . .	0.220	0.336	0.314	0.104

Another important difference in the composition of these four samples of clays—which, however, is more interesting in a theoretical than in a practical point of view—is presented in the relative quantities of lime which were found in the soluble portion of each. In clay in its natural state, the quantity of carbonate of lime amounted to 0.740 per cent; in moderately burnt clay (No. 2) to 0.420; in clay burnt at a higher temperature (No. 3) to 0.550; and in over-burnt clay (No. 4) to 0.188. The three latter quantities are marked down in the analyses as carbonate of lime, for the sake of comparison with No. 1, in which the lime really existed as carbonate of lime; but as not the slightest effervescence took place on dissolving the burnt clay in dilute muriatic acid, it is clear that the lime did not exist in it in a state of carbonate. The lime must have existed in No. 2, No. 3, and No. 4, as caustic lime, or in a state of silicate; it would have been, therefore, more correct to indicate the quantity of pure lime in the above table.

The excess in analyses No. 1, No. 2, and No. 3, is partly due to this inaccuracy of stating the results, partly to the fact that silicate of protoxide of iron, in burning, becomes decomposed. The protoxide of iron is rendered soluble in dilute muriatic acid, but in the analyses it is determined and calculated as peroxide of iron; hence we find the largest excess in No. 2, in which most iron has become soluble in dilute muriatic acid.

The following considerations induce me to think that the lime in Nos. 1, 2, 3, and 4 existed in a state of silicate. Chemists are well acquainted with the methods of determining the quantity of potash and soda in insoluble silicates, to which class of silicates felspar belongs.

The usual method consists in fusing the finely powdered substance with an excess of carbonate of baryta. In this process potash and soda are rendered soluble in the following manner:—The baryta combines with the silica, originally present in combination with potash and soda: silicate of baryta is formed, and the alkalies, potash and soda, uniting with the carbonic acid of the carbonate of baryta, are rendered soluble.

Lime, which in its chemical relation is closely allied to baryta, acts precisely in the same manner on insoluble silicates of potash and soda. Now, if clay originally contains carbonate of lime, it will act at an elevated temperature on the insoluble silicate of potash, which is present in many clays in the shape of fragments of felspar; and by duple decomposition it will give rise to the production of silicate of lime and carbonate of potash. Silica enters into combination with lime in different proportions: some of these combinations are soluble in dilute acids; most of them are insoluble. Instead of carbonate of lime and insoluble silicate of potash, we thus find in burnt clay a larger proportion of soluble potash and silicate of lime, which is partly insoluble in acid. The diminution of the quantity of lime, and the increase of potash in the soluble portion of burnt clay, thus find a ready explanation. Much, however, as indicated by the practical observations, and the above analytical results, depends on a proper temperature. If the heat is allowed to become too intense, new changes in the constituents of clay are produced, which have the effect of rendering the potash again less soluble.

The fact that felspar is more readily decomposed after having been moderately calcined is not a new one, Professor Fuchs of Munich having shown clearly that this is the case, not only with felspar, but also with other minerals, into the composition of which silicate of potash enters. Fully in accordance with this fact is the practical observation of Professor Lampadius, who found, by a series of field experiments, that moderately calcined gneiss, granite, certain kinds of porphyry and trap rocks, all of which contain silicate of potash, in a similar manner as burnt clay, promote the luxuriant growth of many plants in a remarkable manner. It would be doing injustice to Professor Zierl of Munich to leave unnoticed that, in speaking of the causes of the effects of burnt clay, he suggested whether the accessary constituents of clay, particularly the alkalies, might not be rendered more soluble in the process of burning. Had Professor Zierl submitted unburnt and burnt clay to chemical analysis, he would, no doubt, have found that this was really the case; but as he brought forward no experimental proof in support of his theory, it had the fate of being disregarded by many at the time of its publication, and of being soon after forgotten by most.

As far as I am aware, the above analytical results, in support of my theory respecting the liberation of potash in clay, are the first direct proofs which have been furnished by any chemist. Though unacquainted with Professor Zierl's theory, and Professor Fuchs' experiments, when I undertook the investigation, I am bound to acknowledge that the theory I have embraced, respecting the liberation of potash in clay, is not a new one. Disclaiming the merit of being its discoverer, I shall feel amply rewarded by seeing these direct experimental proofs in support of this theory confirmed by the experience of other chemists.

4. Is it essential, or desirable, that clays fit for burning should contain lime?

My own experiments have been confined to clay which contained originally lime; I am, therefore, not prepared to answer the first part of the question—namely, is it essential that clays fit for burning should contain lime? The observations already made respecting the action of lime on insoluble silicates of potash and soda, however, enable me to answer the second part of the question—namely, is it desirable that such clays should contain lime?—in the affirmative. If the above explanation of the action of lime on silicate of potash is true, we can easily conceive how the addition of lime to clay, originally poor in this element, will increase the amount of soluble potash and soda. In this view of the matter I am much confirmed by an observation of Professor Fuchs of Munich, to which particular interest attaches. This eminent man, distinguished both as a good chemist and mineralogist, found that when felspar is moderately calcined, and in a powdered state is boiled with quick-lime and water for a short time—or even digested in the cold with quick-lime and water for a longer period—so large a proportion of potash is liberated from the constituents of felspar that, on these grounds, he recommended a process of extracting and manufacturing potash on a large scale from felspar. Professor Fuchs has shown that, under these circumstances, insoluble silicate of lime and soluble carbonate of potash are formed. I would, therefore, suggest the application of quick-lime to newly burnt clay land, or the mixing of clay with lime before burning, as likely to be attended with most beneficial effects.

5. What are the characteristics of clays, of which it can be said that they are totally unfit for burning?

The chief mass of all clays, silicate of alumina, does not in itself serve as direct food to plants. Pure clays, such as pipe and porcelain clay, which almost entirely consist of silica and alumina, for this reason will be found as sterile after burning as they are in their natural state. We have seen that the accessary constituents of agricultural clays furnish the materials from which plants derive inorganic food. Of these the most important and valuable are phosphoric acid and the alkalies. As phosphoric acid is not rendered more soluble in burning clay, but rather the contrary, as shown by the above table, we are bound to look to the alkalies as the chief fertilising substances in clays. The analyses of three different kinds of clays, from Gloucestershire, given above, as well as a great many others published by Professor Johnston, exhibit a great difference in the relative proportion of potash and soda which they contain. Whilst some of them contain considerable quantities of potash and soda, others contain but mere traces. Now, if it be true what has been advanced with regard to the fertilising substances in clays, and the effects produced in burning, we cannot hesitate to pronounce all clays which contain no potash or soda in an undecomposed form, or mere traces, as entirely unfit for burning. Experience, I think, will prove that such clays, naturally unfertile, will not be improved in the least by burning. On the other hand, those clays which contain undecomposed insoluble silicate of potash and soda, in the shape of fragments of felspar or any other mineral, will be found the more useful after burning, I think, the more of these alkalined silicates they originally contain.

6. Can it be determined by chemical analysis whether a clay will be efficacious when burnt or not?

From the preceding remarks it follows that the fertilising effects of clay mainly depend on the proportion of alkalies which it contains; and as any good analytical chemist may determine the exact quantity of potash and soda which may be extracted from a clay, we possess the means of deciding at once whether a clay is likely to be efficacious when burnt or not. The advantages which result from a previous analytical examination become most conspicuous when we consider that the trifling expense for analysis will guard the farmers against failure and loss attending the investment of much money and labour in burning soils, which cannot be rendered more fertile by this operation. Chemistry, in this manner, I have no doubt, will be found to confer material practical benefits to those who avail themselves of its aid. It cannot be expected that every farmer should himself be a good chemist, were it desirable or necessary; but we may justly demand of him that he should properly appreciate the labours of those engaged in chemico-agricultural researches. Without a knowledge of the first principles of the science, however, the practical man will never be able to appreciate properly the aid which chemistry is capable of conferring on him, nor will he fully understand the direct bearing which chemistry exercises on many practical operations. We would therefore recommend the study of the principles of the science as the foundation of true agricultural progress.

7. What are the causes of the failure attending over-burning?

When clay is burnt too strong it becomes hard like stone, loses much in porosity, and does not crumble to powder on exposure to the air. To these mechanical changes, no doubt, the failure of over-burnt clay partly must be ascribed. I say only partly, because Professor Johnston has already shown that, in over-burning, the constituents of clay are rendered less soluble than they are in the natural clay. My experiments fully confirm the Professor's observations. I have further found, that over-burnt clay does not absorb so much ammonia from the atmosphere as properly burnt clay, which is easily explained by the diminished porosity, and consequently diminished absorptive power, of such clays. The cause of the failure attending over-burning, then, must be sought—1st, In the mechanical changes clay undergoes in over-burning; 2d, In the chemical changes which render such clays less soluble; and 3d, In the diminished power of absorbing gases from the atmosphere.

8. Does moderately burnt clay absorb more ammonia from the atmosphere than clay in its natural state?

It will be remembered that many chemists and agricultural writers ascribe the advantages of burnt clay to ammonia, which, according to their views, is absorbed from the atmosphere by it in that state more extensively than when it is unburnt. In order to put this theory to the test, I made the following experiments with—

1. Clay from Huntstile, near Bridgewater, in its natural state, (the same as that used in the above analyses, marked No. I.)

2. Clay from the same locality moderately burnt (the same as that used in the above analyses, marked No. II.)

Both portions were moistened with water, and exposed in glass beakers to the atmosphere for a period of two months and twelve days, without, however, renewing the evaporated water. After that period the quantity of ammonia in each sample was determined by combustion with soda—lime in the usual manner. The following are the results:—

(1.) Clay from Huntstile, in its natural state. 239·15 grains, on combustion, furnished 4·94 grs. of bichloride of platinum and ammonium, or

100 parts of air-dry clay contained 0·240 per cent of ammonia (NH_4O).

(2.) Clay from Huntstile, moderately burnt. 210·15 grs., on combustion, gave 0·36 of bichloride of platin. and ammonium, or

100 parts of air-dry clay contained 0·019 of ammonia (NH_4O).

The clay, when unburnt, it will be observed, furnished a much larger quantity of ammonia—the same after moderate calcination. We must, however, not conclude that unburnt clay possesses a greater power of absorbing ammonia from the atmosphere; for the ammonia contained in the analysis is partly the result of the decomposition of nitrogenised organic matters which existed in the clay, and which were destroyed on burning.

At all events, the above analyses show that unburnt clay contains ammonia, or the elements from which ammonia is formed, in larger quantities than burnt clay. For that reason I cannot attach much value to the ammonia theory.

9. Does over-burnt clay absorb any or no ammonia from the atmosphere?

Sprengel, as has been mentioned before, thinks that in over-burnt clay no ammonia can be produced. The following experiment will show with what amount of confidence this doctrine is to be accepted.

A portion of over-burnt clay from Huntstile, the solubility of which, as proved by the above analysis, was considerably smaller than that of properly burnt clay, was exposed to the atmosphere, moistened with water, for two months and thirteen days. The amount of ammonia was then determined in the same manner as in the preceding experiment.

219 grs. of air-dry gave 0·155 grs. of bichloride of platinum and ammonium, or

100 parts furnished only 0·008 per cent of ammonium.

We thus find that Sprengel's theory is not borne out by direct experiment; but, at the same time, we see here that the power of absorbing ammonia in over-burnt clay is considerably reduced.

Moderately burnt clay will absorb double the quantity of ammonia from the atmosphere which will be absorbed by over-burnt clay under precisely the same circumstances.

10. Is ammonia found in burnt clay containing protoxide of iron, when exposed in a moist state to the atmosphere, in much larger quantities than in the same clay exposed in a dry state to the atmosphere?

In answer to this question, the following experiments were instituted:—

A portion of the same clay used throughout in all the experiments was moderately burnt in a closed crucible, after having been previously mixed with 1 per cent of charcoal powder. The charcoal powder was mixed with the clay for the purpose of reducing the peroxide of iron in the clay to protoxide.

(1.) One-half of the clay thus treated was exposed for two months and fourteen days to a dry atmosphere, in a dry state.

(2.) The other half was thoroughly moistened with water, and exposed for the same length of time to the same atmosphere.

The quantity of ammonia in each sample was then determined separately.

(1.) Clay exposed to the atmosphere in a dry state: 182·81 grs. gave 0·28 grs. of bichloride of platin. and ammonium, or

100 grs. gave 0·17 per cent of ammonium.

(2.) Clay exposed to the atmosphere in a wet state: 212·11 grs. of clay gave 0·33 grs. of bichloride of platin. and ammonium, or

100 grs. gave 0.018 per cent of ammonium.

These quantities of ammonia are nearly identical. Ammonia, accordingly, is not formed, as Sprengel supposes, by the decomposition of water under the influence of protoxide of iron and the atmosphere, in a larger quantity, in which ammonia is absorbed by dry clay from the atmosphere.

Thus, under no circumstance do we find ammonia in burnt clay in larger quantities than in unburnt clay. The effects of burnt clay, therefore, cannot be explained by the absorption of ammonia only.

11. What is the reason that burnt clay improves especially root and other green crops as Mr Woodward states?

Mr Woodward's observation that root-crops are particularly benefited by burnt clay also receives an easy explanation from the mode of its action, which we have explained; for we must recollect that turnips, swedes, mangold-wurzel, potatoes, &c., require much potash to mature their growth.

It may be mentioned, in conclusion, that I have determined the whole amount of alkalies which the clay from Huntstile farm is capable of furnishing, when fused with carbonate of baryta. The quantity of potash and soda present in the clay, for the greater part in a state of insoluble silicates, I find to be: Potash=4·726 per cent, and Soda=·88 per cent. As one of the characteristics of a clay fit for burning, we have pointed out the undecomposed alkaline silicates which good clays should contain. Thus, finding the proportion of potash and soda so considerable, as in this clay, we are justified in suggesting that this clay is most likely to prove very efficacious after burning. With this theoretical speculation agrees well the fact mentioned by Mr Danger, the tenant of Huntstile farm, that by burning this clay the land is very much improved. Mr Danger says: "Of course I can only speak to the fact. A soil which I have found *quite sterile*, on which this process has been used, became *totally changed*."

Having thus considered each of our propositions separately, and deduced from them what appeared to us the most prominent and legitimate conclusions, we shall conclude by merely recapitulating the principal and most practical facts which depend on them, leaving the discriminating reader to form his own opinion of the whole subject.

Summary.

1. The mechanical changes produced on clay upon burning, which by no means are *unimportant*, nevertheless do not sufficiently explain the fertilising effects of burnt clay.

2. These are dependent on the chemical, as well as on the mechanical changes, both produced upon burning clay.

3. Clay after burning becomes more soluble in dilute acids.

4. The temperature used in burning clay regulates the solubility of clay; too intense a heat renders clay, again, less soluble.

5. A temperature whereby the organic matter in clay soils is merely changed, but not destroyed altogether, should be employed in burning clay in the field.

6. On overburning, clay becomes less soluble than it is in its natural state.

7. Burnt clay contains more soluble potash and soda than unburnt.

8. Properly burnt clay furnishes a larger proportion of soluble potash and soda than clay burnt at too high a temperature.

9. In burning clay the same effects are produced as in bare-fallow.

10. The fertilising effects of burnt clay are mainly dependent on the larger amount of potash and soda, particularly of potash, which is liberated from the insoluble silicates in the process of burning.

11. Clays originally containing much undecomposed silicates of potash and soda are best suited for burning.

12. On the contrary, those resembling in composition pure pipe and porcelain clays, and all those which contain mere traces of undecomposed alkaline silicates, are unfit for burning.

13. It is desirable that clay which is intended to be burnt should contain lime.

14. The application of quicklime to newly burnt clay land, or the mixing of clay with lime before burning, is likely to be attended with much benefit.

15. Burnt clay absorbs ammonia from the atmosphere.

16. Clay in its natural state furnishes more ammonia than properly burned clay.

17. Overburnt clay does not absorb so much ammonia as properly burnt clay.

18. The causes of the failures attending over-burning, are due:

1. To the mechanical changes which clay experiences in overburning, whereby it is rendered hard like stone.

2. To the chemical changes whereby the constituents of clay are rendered less soluble.

3. To the diminished porosity, and consequently reduced absorptive power of such clays.

19. Burnt clay improves especially turnips, carrots, potatoes, and other green crops, because it furnishes potash, which these crops largely require, more abundantly and more readily than unburnt clay.

ON THE COMPARATIVE VALUE OF
WHITE SCOTTISH AND BLACK ENGLISH OATS;
AND
ON THE COMPOSITION OF RICE-MEAL.

From the Journal of Agriculture, and Transactions of the Highland and Agricultural Society of Scotland, for January 1853.

The comparative Value of White Scottish Oats and Black English Oats. By Dr AUGUSTUS VOELCKER, Professor of Chemistry in the Royal Agricultural College, Cirencester.—White oats are generally considered more valuable than black, and Scottish, in particular, are usually preferred to those grown in England, it being the opinion of practical men that the former possess greater nutritive properties than the latter. The direct proof, however, that this is really the case, as far as I am aware, has not been furnished; at all events, it has not been shown to what extent the feeding properties of the two varieties differ.

With a view to supply this deficiency, I examined, some time ago, specimens of white Scottish and black English oats, and am enabled by the results of this examination to furnish a direct and positive proof of the correctness of the opinion above stated.

Black oats can frequently be obtained in the market at a much cheaper rate than the white Scottish; but as the first are inferior to the latter in feeding value, as will be shown presently, the question naturally suggests itself, Is it more economical to buy white Scottish oats at a higher, or black English at a lower price? An answer to this question has a direct practical bearing, and I shall therefore endeavour to point out how far the difference in the cost price of both is compensated by the greater nutritive properties of the Scottish sample.

The commercial value of different kinds of wheat, barley, or other grains of the usually cultivated cereals, is influenced in a great measure by the relative proportions of bran and flour, which different samples of the same grain furnish to the miller. The various kinds of oats, especially, furnish greater differences in the proportions of husk and meal than probably any other grain. Whilst some yield as much as three-fourths of their weight of oatmeal, others yield only 10 parts of meal from 16 of grain; and some samples of inferior quality produce but one-half their weight of oatmeal.

My attention was therefore naturally first directed to the determination of the relative proportions of husk and meal, which the two specimens of white Scottish and black English oats yielded.

1. In the white Scottish I have found in 100 lb.—

Oatmeal, ...	71½ lb.
Husk, ...	28½ ...
	100 ...

2. In black English oats the proportion of husk and meal in 100 lb. was as follows:—

Oatmeal, ...	66¼ lb.
Husk, ...	33¾ ...
	100 ...

100 lb. of Scottish oats thus yielded 5½ lb. more meal than the black English. The former is thus decidedly more valuable than the latter.

Oats, however, are generally sold by measure, and not by weight. The weight of a bushel of oats, it is well known, is subject to great variations, some kinds being considerably heavier than others. In order to draw a fair comparison between the relative value of the two varieties of oats, it was necessary to determine the weight of a bushel of each, and to calculate from their relative weights the yield of meal which each variety furnished per bushel. One bushel of white Scottish oats was found to weigh 42 lb.; the bushel of black English oats weighed only 37½ lb. The price of the former at Cirencester was 20s. per quarter. English black oats were offered at Cirencester for 15s. 6d. per quarter.

Let us now calculate from these data how much oatmeal these two varieties furnished respectively.

1. *White Scottish Oats.*—100 lb. yielded 71½ lb. of oatmeal: 1 quarter accordingly produces 240¼ lb. of oatmeal, for—

Oats.		Meal.		The weight of 1 quarter oats.		Meal.		
100 lb.	:	71½ lb.	=	8 × 42	:	x	.	x = 240¼ lb.

240¼ lb. of Scottish oatmeal are thus obtained at an expense of £1.

2. *Black English Oats.*—100 lb. yielded 66¼ lb. of oatmeal. 1 quarter will thus furnish 198¾ lb., for—

Oats.		Meal.		The weight of 1 quarter oats.		Meal.		
100 lb.	:	66¼ lb.	=	8 × 37½	:	x	.	x = 198¾ lb.

198¾ lb. of English oatmeal, according to the above-mentioned price, will cost 15s. 6d.; or, for £1, 256½ lb. of oatmeal can be obtained.

Thus, by expending £1 for oatmeal, 16¼ lb. more meal can be got, if black English oats are bought at the price of 15s. 6d., the cost of white Scottish oats being £1 per quarter. Or for 1s. I can get 12 lb. of meal prepared from white Scottish oats; whilst for 1s. I can get 12 lb. 13 oz. of meal prepared from black English oats.

Supposing both kinds of oatmeal to possess equal nutritive and commercial value, according to these determinations, a saving of about 1s. 4d. for every quarter would be effected by preferring the black oats to the white. Such a supposition, however, is not admissible, since it is well known that the relative nutritive value of different samples of oatmeal is subject to considerable variations.

The nutritive value of different samples of grain, so far, at least, as it is dependent on their power of producing muscle, is usually estimated by the greater or smaller proportion of protein compounds which they yield on analysis. It appears to me, therefore, necessary to determine by analysis the percentage of these valuable compounds in the oatmeal prepared from the white and the black oats.

a. 18.31 grains of oatmeal, from white oats, dried at 212° F., gave 6.88 chloride of platinum and ammonium, or 2.59 per cent of nitrogen, which is equal to 14.743 per cent of flesh-forming substances.

b. 13.60 grains of oatmeal, from black English oats, dried at 212° F., gave 4.83 of chloride of platinum and ammonium, or 2.230 per cent of nitrogen, equal to 13.94 per cent of flesh-forming substances.

We thus see that Scottish meal possesses greater nutritive value than the meal prepared from black English oats. It is true, the difference in the proportion of flesh-forming principles in both kinds of oatmeal is not very great, but still the superiority of the Scottish sample in this respect appears to us more than sufficient to compensate for the greater price at which the white oats were bought. Apparently the difference in favour of the black English oats is 4s. 6d., but we have seen that it actually amounted merely to 1s. 4d. per quarter, supposing both kinds to possess equal nutritive value—which, however, is not the case.

Taking the greater nutritive value of the white oats into consideration, we are inclined to consider it more economical to pay £1 for white than 15s. 6d. for black oats.

It will hardly be necessary to mention that the above observations apply merely to the two samples of oats which have been examined, and not in general to all kinds of Scottish and English oats.

The Composition of Rice-Meal or Rice-Dust. By Dr AUGUSTUS VOELCKER.—Rice-meal, rice-dust, or rice-refuse, which is obtained in cleaning rice for our market, consists of the husk and external layers of rice, together with fragments of the grain itself, and some accidental foreign impurities. This refuse has been used by several practical feeders with advantage in the feeding of stock. Whenever it can, therefore, be obtained at a moderate price, rice-dust will be found a valuable article of food, provided it is given to cattle judiciously along with other more substantial food. We fear, however, that this refuse is sold often much above its real value, and it appeared to us necessary, for this reason, to determine its value by analysis. From the manner in which rice-dust is obtained, we cannot expect it to be of uniform composition, but the following analyses may be taken as representing the composition of a fair average sample of unadulterated rice-dust. The sample analysed was offered for sale at £3, 12s. 6d. in London, or, with expenses for carriage to Cirencester, would have cost £4, 5s. 6d. per ton.

a. Percentage of water.—Dried in the water-bath, it lost 12.019 per cent of water, or about the same quantity which common flour loses on drying.

b. Percentage of ash.—Burnt in a platinum capsule, a whitish ash was left behind, amounting to 13.49 per cent of the whole weight of the meal in its natural state. The greater portion of the ash, namely 9.83 per cent, consisted of insoluble matters, chiefly carbonate of lime and silicic acid, with some phosphates; the smaller portion, namely 3.66 per cent, was soluble in water, and consisted of soluble salts, chiefly alkaline chlorides.

c. Percentage of protein compounds.—The proportion of flesh-forming substances in rice-dust was calculated from the percentage of nitrogen, obtained by burning the substance with soda-lime, according to Will and Varrentrapp's methods. In two combustions, precisely the same quantity (6.687 per cent) of protein compounds was found.

d. The oil in rice-dust was determined by digesting the substance repeatedly with ether, in which the oil is readily soluble. On evaporation of the several ethereal extracts, a yellow sweet oil remained behind, which amounted to 5.610 in the natural substance.

e. Woody fibre, *starch*, and *sugar* were determined in the usual manner.

The following numbers represent the composition of this sample of rice-meal or rice-dust:—

Water,	12.019
Woody fibre, containing insoluble inorganic matters, 9.83,	46.500
Starch, gum, and sugar,	25.524
Protein compounds, or flesh-forming constituents,	6.687
Fatty matters,	5.610
Soluble saline substances,	3.660
	100.000

These analytical results suggest to us the following observations:—

1. That this refuse is very rich in oily or fatty matters. It contains, indeed, as much fatty substance as the best oats, but is inferior in this respect to Indian corn, which contains rather more oil. Rice-dust, for this reason, is well adapted for the laying on of fat upon animals.

2. In rice itself, according to Payen, only 0.8 per cent of fatty matters occur; and we find thus, that, as in most other kinds of grain, the fat is chiefly deposited in the exterior part of the seed.

3. Harsford found in the grain of rice 6.27 per cent of protein compounds in its ordinary, or 7.4 per cent in its dry state. In rice-dust I have found nearly the same quantity, namely, 6.687 per cent, in its natural state, or 7.600 per cent in its dry state. As far as the power of producing muscle is concerned, rice meal or dust appears to be fully as valuable as the grain of rice itself.

4. Rice-dust contains nearly half its weight of woody fibre, which possesses little or no value as a feeding substance. The

exact quantity amounted to 46.500, which, added to 12.019 of water, gives 58.519 per cent of useless matters.

It has already been mentioned that the price of this refuse per ton, delivered at Cirencester, was £4, 5s. The practical question, which chiefly interests the farmer, is, Will it pay to buy rice-dust at this price, in preference to barley, oats, Indian corn, or any other kind of corn? We should say decidedly that it would not pay at this price. Crushed oats of good quality, which can be had at about £6, 6s. to £7 per ton, contain the same quantity of fatty matters as rice-dust, but at least double the quantity of flesh-forming constituents, and also once as much starch, gum, and sugar, as rice-dust. Oats appear, therefore, at least twice as valuable as this refuse; and the price of the latter should, for this reason, not be more than about £3 to £3, 5s.

Barley-meal is not quite so nutritious as oatmeal, but, taking into consideration that barley-meal does not contain so much husk as oats, and comparing its composition with that of rice-dust, we think that barley-meal may be considered as possessing once as much value, as a feeding substance, as rice-dust, without committing any great practical error. Barley-meal, however, can be had at £7 per ton.

ON THE COMPOSITION

OF

GREEN RYE AND RAPE.

From the Transactions of the Highland and Agricultural Society of Scotland,
for July 1854.

* ON THE COMPOSITION OF GREEN RYE AND RAPE.

By Dr Augustus Voelcker,

Professor of Chemistry in the Royal Agricultural College, Cirencester.

In a paper of mine on the composition of green food, which appeared in the July number of this Journal for 1853, analyses of most articles of food which are used in a green state will be found. I have not stated, however, in that paper the composition of green rye, as I had not an opportunity of obtaining the material for analysis in a perfectly fresh condition at the time when the other analyses were made. In order to supply this deficiency, I have this spring submitted young rye to a detailed analysis, the results of which may not be without interest to the agricultural reader. The analysis of rye is followed by detailed analyses, both organic and inorganic, of rape. Since the publication of the general composition of green rape in the paper referred to above, my attention was directed by several good practical farmers and sheep-breeders in this neighbourhood, to the remarkable fattening properties of green rape, which, I am told, render it a most valuable food for sheep. This circumstance induced me again to examine green rape. As the chief object of my previous analyses was to ascertain its flesh-forming properties, direct determinations of the fatty matters, and other substances which are employed in the animal economy in the laying on of fat, were omitted. In the subjoined proximate analyses, on the contrary, particular care was bestowed on the direct and accurate determination of the fat-producing constituents of green rape. At the same time, the ultimate composition of green rape has been ascertained as well as that of its ash. It is much to be regretted that we possess so few detailed organic analyses of agricultural products, on the accuracy of which dependence can be placed. Most analyses of this sort were made at a time when organic chemistry was quite in its infancy. The analytical processes with which chemists were then acquainted necessarily were very imperfect, and consequently ill calculated to furnish accurate results. More correct proximate analyses of most kinds of agricultural produce are thus much required. With the publication of such analyses, a clear description of the method which has been followed in determining the different organic constituents should never be omitted, for the publication of analytical methods will often induce others to engage in similar researches. At the same time, it will tend much to the suppression of analyses made by improperly qualified persons; and it may likewise lead to more accurate or simple plans of operation. Before stating, therefore, the results of the analyses of green rye and rape, I shall briefly describe the method which I employed in the determination of the various constituents entering into the composition of these two crops.

1. *Determination of water and ash.*—For the determination of water 1000 grs. of the fresh substance were taken. The weighed substance was first dried in the air, subsequently at the top of a water-bath, and finally in a hot-air bath, at a temperature of 220° Fahr.

The loss in weight, by calculation, gave the per-centage of water.

Two separate portions of the dried substance were then reduced to ash, at a moderate heat, over a gas-burner, in a platinum capsule.

2. *Determination of cellular fibre, insoluble protein compounds, and insoluble inorganic salts attached to the fibre.*—The separation of all the soluble constituents from the insoluble was effected in the following manner:—

For analysis 1000 grs. of the fresh rye or rape were weighed out at the same time at which the respective portions for the water-determination were weighed. I am particular in stating this, because the amount of water in the leaves and other parts of green plants varies from day to day, for which reason the weighings for the different determinations ought to be made all at the same time. In order to secure a fair average sample, it is advisable to cut the fresh plant, or that part of the plant which is to be analysed, in one or two-inch pieces, and to mix together a quantity of such bits, sufficient for all the separate determinations. If this precaution is neglected, on adding up the results of the analyses there will be found almost always either an excess or a deficiency.

The 1000 grs. of the fresh substance were mashed in a porcelain mortar to a fine pulp, with the addition of a small quantity of distilled water. The preparation of a fine pulp, in the case of grass or leaves, is a tedious process, which succeeds best by using no more water than is necessary to prevent portions of the substance being thrown out of the mortar by agitation with the pestle. When sufficiently fine, about four or five ounces of distilled water were added, and the pulp digested with it for about half an hour. After that time the liquid, containing in solution gum, sugar, soluble albumen, and other soluble matters, was strained through a piece of fine linen, previously wetted with distilled water, and tied over a large glass beaker. The impure cellular fibre on the linen was squeezed in the cloth as tightly as possible, then transferred back in the mortar, and thoroughly agitated with the pestle, a small quantity of water being added at the same time. The insoluble portion was then again digested with four to five ounces of distilled water for half an hour, and the liquid strained through the linen cloth as before. The same operation was repeated a third time; the cellular fibre on the cloth by that time was nearly white, and, after a few washings with water, imparted nothing soluble to water. Thus washed clean, the impure fibre was dried in the water-bath, and its weight ascertained.

A portion of the dried impure fibre was subsequently reduced to ash in a platinum capsule, and by this means the proportion of insoluble inorganic matters attached to the fibre was determined. The ash of the fibre consisted principally of carbonate and phosphate of lime, and contained, likewise, some sulphate of lime, magnesia, and silica.

Another weighed portion of the finely-powdered and dried impure fibre was employed for a nitrogen determination. The amount of nitrogen was ascertained in the usual way, by combustion with soda-lime, and, by calculation from the amount of nitrogen, that of the insoluble protein compounds contained in young rye and rape were determined.

A third portion of the impure fibre was digested with alcohol and ether, in order to deprive it of any remains of fatty matter which may have been attached to it.

The amount of insoluble protein compounds and inorganic matters thus obtained, being deducted from the impure fibre, exhausted with alcohol and ether, furnished by calculation the percentage of pure cellular fibre.

3. *Determination of Soluble Albumen.*—The united liquids which passed through the linen cloth were raised to the boiling-point in a glass beaker, when a considerable quantity of greenish-coloured flakes of coagulated albumen was separated. These flakes were allowed to settle for twenty-four hours. After that time the supernatant liquid, now become clear, was passed through a weighed filter, on which the coagulated albumen was also collected. The albumen was washed on the filter with distilled water, dried at 212° Fahr., then digested with alcohol and ether, and finally dried in the water-bath until it ceased to lose weight. The greenish colour of the albumen is due to some chlorophyll, the greater part of which is removed by digestion in alcohol and ether.

A few drops of acetic acid added to a portion of the liquid from which the albumen had been separated by boiling and filtration, produced no change, and thus showed the absence of casein in the juice of the plants under consideration.

4. *Determination of gum, pectin, and salts, insoluble in alcohol.*—In the liquid from which soluble albumen was separated by boiling and filtration, gum, pectin, sugar, and soluble inorganic salts, besides traces of other less important compounds, the quantitative determination of which was omitted, were present.

The separation of the sugar and salts soluble in alcohol from gum, pectin, and salts insoluble in alcohol, was effected as follows:

—The liquid separated from the albumen was evaporated on the water-bath to a thickish syrup. On addition of alcohol to this syrup, pectin, and gum, with some inorganic salts, were thrown down. In order to remove any traces of adhering sugar, the precipitate was repeatedly boiled out with alcohol, until the solvent ceased to take up any perceptible quantity of soluble substance from the precipitate. The insoluble residue was then transferred to a weighed porcelain crucible, dried in the water-bath and weighed. The amount of inorganic salts contained in it was ascertained by reducing it to ash, which being deducted from the weight of the impure gum and pectin, gave the proportion of pure gum and pectin. The salts soluble in alcohol were found to consist principally of chlorides of sodium and potassium.

5. *Determination of Sugar.*—The alcoholic liquids obtained in determining the gum and pectin were introduced into a retort, and the alcohol distilled off in the water-bath. The residue in the retort was transferred to a porcelain crucible, and, after evaporation on the water-bath, dried at 230° F., until it ceased to lose weight. It being exceedingly difficult to expel the water completely from the sugar at 212° F., a somewhat higher temperature was employed for drying. In the sugar thus obtained, a considerable proportion of inorganic salts, soluble in alcohol, was present. On burning this impure sugar, the inorganic salts were left behind in the form of a white ash, the weight of which being deducted from that of the impure sugar, gave the proportion of pure sugar.

6. *Determination of Fatty Matters.*—Like all vegetable productions, green rye and rape contain appreciable quantities of oily and fatty matters. Their quantitative determination was effected by repeatedly digesting 100 grains of the dried and powdered substance in ether, a liquid which readily dissolves all fatty matters. The ethereal solutions were passed through a filter, upon which the powdered substance, boiled out several times with ether, was washed with this solvent, in order to remove all traces of adhering fat. The greater part of the ether employed in this determination was obtained back again by distillation of the mixed ethereal liquids at a moderate temperature; the ether which passed over first into the receiver was collected by itself, and in this way a much stronger ether than the commercial article was obtained. The residue in the retort, evaporated to dryness, was found to contain some sugar, which had been dissolved with the oil by the alcohol, usually contained in commercial ether. In order to obtain the oil and fatty matters free from sugar, a small quantity of the strong ether, prepared as described by fractional distillation, was added to the mixture of sugar and fatty matters. The sugar was left insoluble, and the oil and fat dissolved in the ether. On evaporation of the ether, the oil was left behind quite pure; and after

drying on the water-bath, its weight was determined on the balance. It is essential to examine carefully the residue which is left on evaporation of the first ethereal liquids, for commercial ether always contains some water and alcohol, which both dissolve a small proportion of sugar from the vegetable substance which is treated with such ether.

7. *Determination of the whole amount of protein compounds, or flesh-forming constituents.*—In order to ascertain how far the direct determination of albumen, and that of the insoluble protein compounds obtained by combustion, agreed with a total determination of the protein compounds, about 20 grains of the dried substance were burned with soda-lime in a combustion-tube; and the amount of nitrogen obtained, by following the method of Will and Varrentrapp, being multiplied by 6¼, gave the proportion of protein compounds in young rye and rape.

Having thus described briefly the method according to which the organic analyses were executed, I shall now proceed to state the results obtained in the analyses of both green foods.

I. COMPOSITION OF GREEN RYE.

Water.—(1.) Dried in the air-bath, at 220° F.; green rye lost 79.58 per cent of water.

(2.) In another determination, 79.23 per cent of water were obtained; on an average, green rye thus contained 79.405 per cent of water.

(3.) Another sample, taken from the field some days after the two preceding; 75.423 per cent were found.

Ash.—(1.) 250 grains of fresh rye, on burning, gave 4.44 grains of ash, or 1.778 per cent; or 8.633 per cent of ash in the dried substance.

(2.) In the sample of rye, which was analysed some days after the preceding, 1.57 per cent of ash were found. This ash was distributed amongst the different constituents of rye as follows:—

Ash in cellular fibre,	.418
„ gum and pectin,	.572
„ sugar,	.368
„ albumen,	.180
	1.538

These separate determinations of ash agree as closely as possible with the total determination of ash.

Protein compounds.—(1.) By separate determinations there were found—

Soluble albumen,	2.357	with	.3771	of nitrogen.
Insoluble protein compounds,	.736	„	.1178	„
	3.093	„	.4949	„

(2.) In the sample taken some days after the preceding, the total proportion of nitrogen was found, in two determinations, on an average, at .442 per cent, equal to 2.762 per cent of protein compounds.

By separate determinations there were found—

Soluble albumen,	1.810	with	.289	of nitrogen.
Insoluble protein compounds,	.894	„	.143	„
	2.704	„	.432	„

The two latter determinations agree well with the total amount of protein compounds, as ascertained by combustion.

According to these determinations, the general composition of both samples of green rye may be represented as follows:—

	No. I.	No. II.
Water,	79.230	75.423
Inorganic matters (ash),	1.778	1.538
Nitrogenised substances (flesh-forming constituents),	3.093	2.704
Non-nitrogenised substances (fat and heat-producing matters),	15.899	20.335
	100.000	100.000

And that of rye in a dry state—

	No. I.	No. II.
Nitrogenised substances, capable of producing flesh,	14.891	11.002
Substances free from nitrogen, and fitted to support respiration, and for the formation of fat,	76.476	82.739
Inorganic matters (ash),	8.633	6.259
	100.000	100.000

It will appear that the first sample, although containing more water, is richer in flesh-forming constituents than the second. In the more succulent condition, rye thus appears to contain especially more soluble albumen than at a more advanced state of maturity; we may therefore infer from this fact, that it is not a good plan to let the green rye remain too long on the ground before eating it off by sheep.

The following tables exhibit the results of the detailed proximate analyses of both samples of rye, in its natural state and in a perfectly dry state:—

PROXIMATE COMPOSITION OF GREEN RYE, NO. I.

	In natural state.	Calculated dry.
Water,	79.405	—
Solid substance, 20.595, consisting of—		
Cellular fibre,	8.579	41.454
Soluble albumen,	2.357	11.444
Insoluble protein compounds,	.736	3.775
Fatty matters,	.892	4.332
Gum and sugar,	6.253	30.362
Inorganic substances (ash),	1.778	8.633
	100.000	100.000

PROXIMATE COMPOSITION OF GREEN RYE, NO. II.

	In natural state.	Calculated dry.
Water,	75.423	—
Cellular fibre,	10.488	42.674
Ash united with fibre,	.418	1.701
Insoluble protein compounds,	.894	3.638
Soluble albumen,	1.811	7.369
Gum and pectin,	4.449	18.102
Salts, insoluble in alcohol,	.572	2.327
Sugar,	4.685	19.062
Salts, soluble in alcohol,	.368	1.499
Fatty matters,	.892	3.628
	100.000	100.000

A comparison of the composition of green rye with that of Italian rye-grass will show that both possess about equal nutritive value. Green rye, it thus appears, is inferior to the better sorts of clover as a feeding-stuff.

II.—COMPOSITION OF RAPE.

Water.—(*a.*) *In leaves.*—The proportion of water varies to some extent in rape, as will be seen by the following determinations, which indicate the amount of water in different samples of rape-leaves, taken from the field at different periods:—

1. Per-centage of water,	88.99
2. — —	86.90
3. — —	88.72
4. — —	87.20
5. — —	87.05
6. — —	85.25
7. — —	85.52
Average,	87.09

(*b.*) *In stalks.*—In two different portions of the stems of rape the amount of water was—

	I.	II.	Average.
Per cent,	94.77	90.08	92.42

The stems are thus more watery than the leaves.

(*c.*) *In roots.*—

	I.	II.	Average.
Per-centage of water,	78.54	86.37	82.45

The first determination was made with a sample of the more ligneous older roots, the second with the more tender young roots.

Ash.—(*a.*) *In leaves.*—The proportion of ash in different samples of fresh leaves was found as follows:—

1. Per-centage of ash,	1.27
2. — —	1.60
3. — —	1.63
4. — —	1.43
5. — —	1.60
6. — —	2.17
7. — —	1.91
Average,	1.66

(*b.*) *In stalks.*—

	I.	II.	Average.
Per-centage of ash, .	1.25	1.15	1.20

(*c.*) *In roots.*—

Per-centage of ash, .	1.84	1.66	1.75

Protein compounds.—(*a.*) *In leaves.*—The proportion of protein compounds was determined by multiplying the per-centage of nitrogen, as ascertained by combustion with soda-lime with 6¼. According to the periods of gathering, the per-centage of nitrogen in the leaves appears to vary to some extent. The following are some of the results obtained by combustion:—

1.	Per-centage of nitrogen in dry leaves,	3.31	—equal to	20.68	protein compounds.
2.	— —	3.41	—	21.31	—
3.	— —	3.87	—	24.19	—
4.	— —	3.49	—	21.81	—
5.	— —	3.54	—	22.12	—
6.	— —	4.02	—	25.12	—
7.	— —	3.45	—	21.56	—
	Average,	3.58	—	22.37	—

(*b.*) *In stalks.*—

1.	Per-centage of nitrogen in dry stalks,	1.14	—equal to	7.12	protein compounds.
2.	— —	1.00	—	6.25	—
3.	Average — —	1.07	—	6.69	—

The stems are thus far less nutritious than the leaves.

(*c.*) *In roots.*—

1.	Per-centage of nitrogen in dry roots,	1.72	—equal to	10.75	protein compounds.
2.	— —	1.86	—	11.62	—
3.	Average — —	1.79	—	11.19	—

According to these different determinations, the general average composition of the leaves, stalks, and roots of fresh rape may be expressed as follows:—

	Leaves.	Stalks.	Roots.
Water, ...	87.09	92.42	82.45
Nitrogenised substances (flesh-forming constituents), . . .	2.88	0.51	1.96
Non-nitrogenised matters (capable of producing fat, and fitted for support of respiration),	8.37	5.87	13.84
Inorganic matters (ash), . .	1.66	1.20	1.75
	100.00	100.00	100.00

And that of the dried portions of rape:—

	Leaves.	Stalks.	Roots.
Nitrogenised substances (flesh-forming constituents), ...	22.37	6.69	11.19
Substances free from nitrogen (heat and fat-producing matters), . . .	64.78	77.48	78.84
Inorganic substances (ash), . .	12.85	15.83	9.97
	100.00	100.00	100.00

Rape-leaves contain a considerable proportion of sulphur and phosphorus in a peculiar state of organic combination. I therefore suggested to my friend and pupil, Mr Faber, the propriety of determining the amount of sulphur and phosphorus in rape, and am also indebted to him for the subjoined ultimate organic analyses, and the ash analyses of rape-leaves.

In two different samples of rape the per-centage of sulphur and phosphorus was found for the dry substance :—

	I.	II.	Average.
Sulphur,	.79	.87	.83
Phosphorus,	.84	.73	.78

The dry leaves thus contain nearly one per cent of sulphur, and an equal amount of phosphorus in organic combination.

ULTIMATE ANALYSES OF RAPE-LEAVES.

The samples analysed, on an average, contained 9.20 per cent of ash, and contained in 100 parts—

Carbon,	41.05
Hydrogen,	5.80
Oxygen,	38.32
Nitrogen,	4.02
Sulphur,	.83
Phosphorus,	.78
Ash,	9.20
	100.00

In the following table the results of the detailed proximate analyses of rape in a fresh and in the dried state are contained :—

	In natural state.	In dry state.
Water,	87.050	—
Soluble albumen,	1.640	12.664
Insoluble protein compounds,	1.493	11.529
Cellular fibre,	3.560	27.490
Inorganic matters, attached to the fibre,	.432	3.335
Gum and pectin,	1.729	13.351
Salts insoluble in alcohol,	.990	7.645
Sugar	2.218	17.622
Salts soluble in alcohol,	.186	1.435
Fatty matters, with a little chlorophyll,	.649	5.016
	99.947	99.587

The ash of rape, analysed in my laboratory by Mr Faber, contained in 100 parts—

		After deduction of carbonic acid, sand, &c.
Potash,	31.51	38.42
Chloride of potassium,	5.88	7.17
Chloride of sodium,	.82	1.00
Lime,	16.97	20.69
Magnesia,	1.58	1.93
Oxide of iron,	1.27	1.55
Sulphuric acid,	12.54	15.29
Phosphoric acid,	9.40	11.46
Soluble silica,	2.04	2.49
Carbonic acid,	12.78	—
Sand,	4.32	—
Charcoal and loss,	.89	—
	100.00	100.00

These analytical results give rise to several observations:—

1. It will be seen that rape is much more nutritious than green rye, and contains as large a proportion of flesh-forming constituents as the best kinds of food which are used in a green state.

2. But not only is rape rich in protein compounds, but it contains also a considerable quantity of oily or fatty matters. The fatty matters extracted from rape by ether are semi-fluid, green of colour, and possess a smell resembling the oil of rape-seed, without being, however, so disagreeable as rape oil.

It will be observed that the fresh leaves contain of these fatty matters more than half a per cent, and the perfectly dry substance about five per cent. So large a proportion of fatty matters, as far as I know, does not occur in any other green food. The occurrence of so considerable a quantity of fatty matters explains at once, in an intelligible manner, the high fattening properties which distinguish rape as a sheep-feed.

3. Rape removes from the soil much potash, and next to it lime, sulphuric and phosphoric acid, whilst, at the same time, the total amount of inorganic constituents, or the ash of rape, is large. It is for this reason that rape requires to be grown on good land, or, at all events, on land in a moderate state of fertility. In poor soils rape never comes to anything, and it is not worth the trouble of cultivating. On land of moderate fertility, or on good rich land, an occasional crop of rape, I am inclined to believe, would supply the farmer with a larger amount of feeding materials than is afforded in a crop of turnips grown under the same circumstances. Weight for weight, rape is richer in flesh-forming constituents, and especially in fatty matters, than turnips; and as a crop of rape per acre is often heavier than a turnip-crop, the cultivation of rape, wherever it is advisable and admissible to introduce it, can be confidently recommended.

ON

THE COMPOSITION

OF

THE PARSNIP

AND

WHITE BELGIAN CARROT.

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ON THE COMPOSITION OF THE PARSNIP AND WHITE BELGIAN CARROT.

The parsnip has been analysed by Crome and the carrot by Hermbstädt. Both analyses, however, having been made at a time when the analytical processes with which chemists were acquainted were little calculated for giving accurate results, are necessarily very imperfect. They do not convey, therefore, a correct idea of the true composition of these roots.

The cultivation of both, especially that of the carrot, is gaining ground from year to year. It appeared to me, therefore, desirable to replace the former imperfect analyses by others, in which advantage has been taken of the more refined and accurate methods of investigation with which modern chemistry has made us acquainted.

The parsnips and carrots analysed were grown on the farm attached to the Royal Agricultural College, in the calcareous, rather stony, and by no means deep soil.

Carrots, as well as parsnips, succeed best in a deep, well-pulverized, loamy ground, but in a shallow, stony soil they scarcely reach half the size as when grown on a deep and sufficiently porous loam.

The soil in the neighbourhood of Cirencester on the whole is not favourable to the growth of these roots, it being, in most instances, too stony and too shallow. The roots for this reason remain comparatively small, and 18 tons per acre are deemed a good average crop of carrots in this part of the country.

Before stating the results of the analysis of parsnips and carrots, I shall briefly describe the method which I followed in determining the various constituents entering into the composition of both roots.

1. *Determination of Water and Ash.*—The quantities of water and ash in the parsnip and carrot were determined by drying a

weighed portion of the roots, at first in the air, subsequently at a gradually increased temperature, and finally in the water-bath at 212° F.

The loss in weight by calculation gave the percentage of water. The dried substance was then burned in a platinum capsule over a gas-lamp at a very moderate temperature. On account of the large proportion of alkaline salts in carrots and parsnips their ashes fuse readily. It is necessary, therefore, to apply in the preparation of these ashes but a moderate temperature, because too intense a heat has the effect of fusing them. The fusing salts surround particles of carbonaceous matter, and prevent their complete dissipation by fire by keeping out the atmospheric oxygen.

In order to obtain a fair average sample for the water and ash determinations, a whole root was cut into thin slices, from which a portion was taken for analysis after having been well mixed together.

2. *Determination of Cellular Fibre, insoluble Protein Compounds, and insoluble Inorganic Salts, attached to the Cellular Fibre.*—By a longitudinal cut a root was divided into two halves. One half was reduced into a homogeneous pulp by grating it on a fine grater. Of this pulp 1000 grains were digested with some cold distilled water, and the liquid, containing in solution gum, sugar, soluble casein, and other soluble matters, after some time was strained through a piece of fine linen. The impure cellular fibre remaining on the linen was washed with cold distilled water until a drop of the washings ceased to leave a perceptible stain, and evaporated on a piece of platinum foil. When washed clean the impure fibre was dried in the water-bath, and its weight ascertained.

A portion of the dried impure cellular fibre was burned subsequently in a platinum capsule, and by this means the proportion of insoluble inorganic matters attached to the fibre was ascertained.

Another weighed portion of the finely-powdered and dried impure fibre was burned in a combustion tube with soda-lime, and the proportion of insoluble protein compounds contained in parsnips and carrots, and obtained in the analysis with the impure cellular fibre, was determined by calculation from the percentage of nitrogen furnished by the combustion of the impure fibre with soda-lime.

By deducting the amount of insoluble protein compounds and inorganic matters thus obtained from the amount of impure fibre the percentage of pure cellular fibre was ascertained.

3. *Determination of Starch.*—The milky liquid which, in the case of parsnips, passed through the linen was mixed with the

washings of the fibre, and allowed to settle in a glass beaker for 24 hours. After that time the starch, which rendered the water milky, was completely deposited at the bottom of the beaker. The supernatant clear liquid was carefully passed through a previously dried and weighed filter, into which the starch was also transferred from the beaker. Being well washed with distilled water, it was first dried between blotting-paper, and finally in the water-bath at 212° F., and then weighed. Carrots, at least those examined, do not contain any starch, and the watery solution passing through the linen can therefore be heated at once for the determination of casein.

4. *Determination of Casein.*—The liquids from which the starch was separated by the process just mentioned were heated to the boiling point in a glass-beaker.

Not the slightest precipitate was produced on boiling, thus proving the total absence of soluble albumen, both in the carrot and in the parsnip.

A few drops of acetic acid were then added to the boiling liquid, when a copious flaky precipitate of casein was formed. This precipitate of casein was allowed to settle for 24 hours. After that time the clear liquid above it was passed through a weighed filter, on which the casein was also collected. The precipitate was washed with distilled water as long as anything was dissolved, and then dried at 212° until it ceased to lose in weight.

5. *Determination of Gum, Pectin, and Salts insoluble in Alcohol.*—The solution separated from the casein was evaporated on the water-bath to a thickish syrup, which was treated with strong alcohol to throw down pectin and gum. The gum, pectin, and salts insoluble in alcohol thus precipitated were boiled repeatedly with alcohol in order to remove any traces of adhering sugar. When washed quite clean with alcohol, the residue was transferred into a weighed porcelain crucible, dried at 212° F., and weighed. On burning, gum and pectin were dissipated, and the salts insoluble in alcohol were left behind, which, being deducted from the weight of the impure gum and pectin, gave the proportion of pure gum and pectin.

6. *Determination of Sugar.*—The alcoholic liquids obtained in determining the gum and pectin were introduced into a retort, and the alcohol distilled off in the water-bath. The residue in the retort was transferred into a porcelain crucible, and, after perfect evaporation on the water-bath, dried at 230° F., until it ceased to lose in weight. The drying process of the sugar is exceedingly tedious, as it takes a long time to expel the water completely from the sugar.

The sugar thus obtained contains a considerable proportion of inorganic salts, soluble in alcohol. The weight of the latter was determined by exposing the impure sugar to a strong heat, at which the organic part was destroyed, and the inorganic matters were left behind in the form of a white ash. The weight of the ash deducted from that of the impure sugar gave the proportion of pure sugar.

7. *Determination of Fatty Matters.*—In order to ascertain the proportion of oil or fatty matters contained in carrots and parsnips 100 grains of the dried roots were repeatedly digested with ether, which readily dissolves all fatty matters. The ethereal solutions were passed through a filter, upon which the powdered substance, now exhausted with ether, was washed with this solvent in order to remove all traces of adhering fat. By distillation in a retort the greater part of the ether of the ethereal extracts was obtained back again. The residue in the retort, evaporated to dryness, was found to contain some sugar, which had been dissolved with the oil by the alcohol usually contained in ether. The oil was separated from this sugar by digestion with a small quantity of anhydrous ether, free from alcohol. On evaporation of the ether the oil was left behind quite pure, and its weight determined. It is essential to examine carefully the residue which is left on evaporation of the first ethereal liquids, for commercial ether always contains some water and alcohol, which both dissolve a certain portion of sugar from the root. Unless care, therefore, is taken to extract the impure oil with ether perfectly free from alcohol and water, the oil contained in roots and other vegetable productions, furnishing sugar on analysis, will be estimated too high. Inattention to this point, perhaps, accounts for the great variations which are observable in the determinations made by different persons of the quantities of fat contained in the various articles of food.

8. *Determination of the whole Amount of Protein Compounds or Flesh-forming Constituents.*—As a check upon the direct determination of casein and the indirect determination of insoluble protein compounds, the whole amount of flesh-forming constituents in the carrot and parsnip was ascertained by the indirect method of combustion.

About 18 to 20 grains of the dried substance were burned with soda-lime. The amount of nitrogen obtained according to the method of Will and Varrentrapp, being multiplied by 6¼, gave the proportion of protein compounds in the roots.

9. *Determination of Ammoniacal Salts.*—Having found that the juices of many plants contained sometimes considerable quantities of ammoniacal salts, which necessarily must render the determination of the flesh-forming constituents in plants in-

accurate, I was led, therefore, to examine these roots for ammoniacal salts, and have succeeded in detecting in them small quantities. The plan adopted for finding out the presence of ammoniacal salts in parsnips and carrots and of ascertaining their relative quantities was as follows:—

About 1500 grains of the finely grated roots were digested with distilled water, and washed upon a piece of fine linen as long as anything was extracted by water. The clear liquids were immediately precipitated with basic acetate of lead, a re-agent which separates completely all protein compounds. The bulky precipitate thus produced was carefully washed on a filter with distilled water, and the liquid, passed through the filter, after having been slightly acidulated with sulphuric acid, was evaporated in a porcelain dish to a small bulk. Thus concentrated, it was introduced into a retort, connected with a convenient apparatus containing some hydrochloric acid, and destined to absorb the ammonia which is given off during the subsequent distillation of the contents of the retort with soda-lime. It is necessary to choose the receiving apparatus sufficiently large to contain all the liquid in the retort, as the contents of the retort have to be distilled to dryness in order to obtain the last traces of ammonia, which would remain dissolved in the water if no care were taken to evaporate the liquid completely to dryness. The ammonia, which is given off under these circumstances, is fixed by the hydrochloric acid in the receiving apparatus. Its quantity was easily ascertained by evaporating the liquid in the receiver to dryness on a water-bath, with the addition of bichloride of platinum. The precipitate of bichloride of platinum and ammonium thus produced was washed on a weighed filter with a mixture of alcohol and ether, in order to remove the excess of bichloride of platinum, which had been previously added. When quite clean, the filter with the insoluble double salt of chloride of platinum and ammonium was dried at 212° F., weighed, and the amount of ammonia which it contained calculated.

Having thus given a description of the mode in which the organic analyses were executed, we shall now proceed to state the results obtained in the analyses of both roots.

I. *Composition of Parsnips.*

Water.—1. Dried in the water-bath, the fresh roots lost 81·78 per cent. of water.

2. In another determination 82·32 per cent. were obtained; or, on an average, parsnips were found to contain 82·05 per cent. of water.

Ash.—1. 275·05 grains of fresh parsnip left, on burning, 2·60 grains of ash: 100 parts of the fresh root, therefore, contain ·941 per cent. of ash, or 5·16 per cent. in the dried state.

2. 275·7 grains of fresh parsnip left, on burning, 2·55 grains of ash: 100 parts of fresh parsnips consequently gave 0·924 per cent., or 100 parts in the dried state gave 5·23 per cent. of ash.

Protein Compounds.—1. 15·8 grains of substance, dried at 212°, burned with soda-lime, gave 2·88 grains of chloride of platinum and ammonium: or 100 parts of dry parsnips contain 1·14 per cent. of nitrogen, which is equal to 7·12 per cent. of protein compounds. In the natural state parsnips consequently contain 0·20 of nitrogen, or 1·25 per cent. of protein compounds.

2. 12·74 grains of substance, dried at 212°, burned with soda-lime, gave 2·42 grains of chloride of platinum and ammonium: or 100 parts of dry parsnips contain 1·19 per cent. of nitrogen, equal to 7·43 per cent. of protein compounds.

Fresh parsnips, according to this determination, therefore, contain 0·21 of nitrogen, or 1·31 per cent. of protein compounds. According to these determinations, the general composition of fresh parsnips may be represented as follows:—

	I. Experiment.	II. Experiment.	Average.
Water	81·780	82·320	82·050
Inorganic matters (ash) . .	0·941	0·924	0·932
Nitrogenised organic substances, capable of producing flesh . .	1·310	1·250	1·280
Substances free from nitrogen, and fitted for support of animal heat and the formation of fat . .	15·969	15·506	15·738
	100·000	100·000	100·000

And that of parsnips dried at 212° F.—

	I. Experiment.	II. Experiment.	Average.
Nitrogenised substances, capable of producing flesh . . .	7·43	7·12	7·27
Substances not containing nitrogen fitted for support of animal heat and the formation of fat . .	87·41	87 65	87·54
Inorganic matters (ash) . .	5·16	5·23	5·19
	100·00	100·00	100·00

A glance at these numerical results will show that parsnips contain 6 to 8 per cent. less water than turnips, and 5 to 6 per cent. less than mangolds. The quantity of flesh-forming substances in fresh parsnips is about the same as that contained in turnips. In a dried state, however, turnips are richer in protein compounds than parsnips.

In the following table the results of the detailed proximate analyses of parsnips are contained:—

Detailed proximate Composition of Parsnips.

	In natural State.	Calculated dry.
Water	82·050	——
Cellular fibre	8·022	44·691
Ash united with the fibre	·208	1·159
Insoluble protein compounds	·550	3·064
Soluble casein	·665	3·704
Gum and pectin	·748	4·166
Salts insoluble in alcohol	·455	2·535
Sugar	2·882	16·055
Salts soluble in alcohol	·339	1·888
Ammonia, in the state of ammoniacal salts	·033	·184
Starch	3·507	19·537
Oil	·546	3·041
	100·005	100·025

The ash of parsnips has been analysed by Dr. Richardson, with the following results:—

Composition of the Ash of Parsnips.

Potash	36·12
Soda	3·11
Magnesia	9·94
Lime	11·43
Phosphoric acid	18·66
Sulphuric acid	6·50
Silica	4·10
Phosphate of iron	3·71
Chloride of sodium	5·54

By moistening a transverse section of the root of parsnip with tincture of iodine the external layers are coloured deep violet-blue, whilst the remaining portion of the root is not discoloured. By this means three distinct circles can be distinguished on a transverse section of parsnip: one interior, formed by the heart of the root, an exterior coloured deep violet-blue by the production of iodide of starch, and an intermediate circle between the heart and the exterior blue coloured zone. This shows distinctly that starch does not exist in the heart, nor in the layers next to it, but that it is all deposited in the external layers of the root.

On further examination of these three sections of the root, I have also found that the intermediate layers contain much more protein compounds than either the heart or the outer layers, where the starch is deposited. The intermediate portions between the heart and the outer layers, indeed, contained in this instance one-half more of flesh-forming constituents than the other portions of the roots, as will be seen from the following determinations:—

	In outer Layers.	Heart.	Layers between the Heart and the outer Layers.
Percentage of nitrogen . . .	1·039	1·067	1·500
equal to			
Protein compounds . . .	6·493	6·668	9·375

It is worthy of notice, that the albuminous or protein compounds are not uniformly distributed throughout the whole mass of the root. I have not examined any other root in this respect; but, judging from analogy, we may expect to find a similar distribution in other kinds of roots.

In ascertaining the nutritive value of roots, which is now usually done by the indirect method of combustion, care must be taken to obtain for analysis a fair average sample of the whole root, for the nutritive value of the root will either be stated too high or too low if the portions analysed contain more of the exterior or the intermediate portions of the root, as actually contained in the whole root. For this reason I find it advisable to prepare the sample of the root to be used for combustion, by cutting the whole root into slices, which, on being dried, are powdered together. A fair average sample of the whole part is thus obtained for analysis, and all errors, arising from the want of uniformity of distribution of the albuminous matters in root-crops, are thereby avoided.

II. *Composition of the White Belgian Carrot.*

a. Carrots grown in 1851.

Water.—1. Dried in the water-bath fresh carrots lost 88·06 per cent. of water.

2. In a second determination 88·47 per cent. of water were found. On an average carrots thus contain 88·26 per cent. of water.

Ash.—1. 100 parts of fresh carrots were found to contain 0·74 per cent. of ash. In the dried state, accordingly, they contain 6·22 per cent. of ash.

2. In a second determination the percentage of ash in fresh carrots was ascertained to be 0·75, or in dried roots 6·56. On an average fresh carrots thus contain 0·74 per cent., and in the dried state 6·29 per cent. of ash.

Protein Compounds.—12·81 grains of dry carrots burned with soda-lime gave 1·66 grains of chloride of platinum and ammonium. 100 parts of fresh carrots accordingly contained 0·095 of nitrogen, equal to 0·596 of protein compounds; and in the dried state 0·813 of nitrogen, equal to 5·081 of protein compounds. According to these determinations the general composition of fresh carrots grown in 1851 may be represented as follows:—

	I. Experiment.	II. Experiment.	Average.
Water	88·060	88·470	88·260
Organic matters containing nitrogen, capable of producing flesh	·596	·596	·596
Substances not containing nitrogen, fitted to support respiration and for the formation of fat	10·604	10·184	10·399
Inorganic substances (ash) .	·740	·750	·745
	100·000	100·000	100·000

The dried carrot consequently has the following general composition:—

	I. Experiment.	II. Experiment.	Average.
Organic matters containing nitrogen (flesh-forming principles)	5·081	5·081	5·081
Substances free from nitrogen (heat and fat producing substances)	88·699	88·359	88·629
Inorganic matters (ash) . .	6·220	6·560	6·290
	100·000	100·000	100·000

b. Carrots grown in 1852.

Water.—1. Fresh carrots were found to contain 88·567 per cent. of water.

2. In a second experiment 100 parts of fresh carrots lost 88·867 per cent. of water. On an average the fresh carrots of 1852 growth contained 88·717 per cent. of water.

Ash.—1. In the first determination the percentage of ash in fresh carrots was found to amount to 0·697 per cent. The dried carrot accordingly contained 6·10 per cent. of ash.

2. In a second determination the percentage of ash in carrots in their natural state amounted to 0·706 per cent. In the dried state, according to this determination, carrots contain 6·26 per cent. of ash.

Protein Compounds.—15·79 grains of carrots, dried at 212° F., burned with soda-lime, gave 2·20 grains of chloride of platinum and ammonium. 100 parts of dried substance thus contain 0·875 per cent. of nitrogen, equal to 5·462 of protein compounds. In the natural state, consequently, these carrots contain 0·098 per cent. of nitrogen, or 0·612 of protein compounds. The general composition of the carrots in their natural state thus was as follows:—

	I. Experiment.	II. Experiment.	Average.
Water	88·567	88·867	88·717
Organic matters containing nitrogen, and capable of producing flesh	·612	·612	·612
Organic matters not containing nitrogen, and fitted to support animal heat and for the formation of fat	10·124	9·815	9·970
Inorganic substances (ash) .	·697	·706	·701
	100·000	100·000	100·000

Dried at 212° the general composition of carrots, grown in 1852, is as follows:—

	I. Experiment.	II. Experiment.	Average.
Nitrogenised substances (flesh-forming principles) . .	5·462	5·462	5·462
Substances not containing nitrogen (heat and fat producing matters)	88·438	88·278	88·358
Inorganic substances (ash) .	6·100	6·260	6·180
	100·000	100·000	100·000

It will be observed that the composition of the carrots grown in 1851 was almost identical with that of the carrots grown in 1852. In round numbers carrots may, therefore, be assumed to contain about 88 per cent. of water and 12 per cent. of solid matter.

Detailed proximate Composition of Carrots.

The carrots analysed were found to contain 87·234 per cent. of water in one experiment and 87·434 per cent. in a second. On an average they contained, therefore, 87·338 per cent. of water. In the following table the composition of carrots in their natural state, and dried at 212°, is represented:—

Table showing the Proximate Composition of Fresh and Dried White Belgian Carrots.

	In Natural State.	Dried at 212° F.
Water	87·338	——
Cellular fibre	3·471	27·412
Inorganic matters attached to the fibre .	·145	1·145
Sugar	6·544	51·682
Salts soluble in alcohol	·409	3·230
Gum and pectin	·885	6·989
Inorganic salts insoluble in alcohol . .	·293	2·314
Soluble caseïn	·498	3 934
Insoluble protein compounds . .	·169	1·334
Oil	·203	1·604
Nitrogen in the state of ammoniacal salts .	·008	·063
	99·963	99·707

The ash of Belgian carrots has been analysed by Professor Way, who gives the following results as representing the average composition of five analyses of the Belgian carrot:—

Silica	1·19
Phosphoric acid	8·55
Sulphuric acid	6·55
Carbonic acid	17·30
Lime	8·83
Magnesia	3·96
Piroxide of iron	1·10
Potash	32·44
Soda	13·52
Chloride of sodium	6·50
	99·94

A comparison of the composition of these white carrots with that of the parsnips, which has been stated above, suggests to us the following observations:—

1. There is a general resemblance in the composition of both roots.

2. Parsnips, however, differ in composition from white carrots chiefly by containing less sugar, the deficiency of which is replaced by starch, not occurring in carrots.

3. White Belgian carrots generally contain 5 to 6 per cent. more water than parsnips. Thus fresh carrots contain on an average but 12 per cent. of solid substances, whilst parsnips contain as much as 18 per cent. In their natural state parsnips, therefore, will be found much more nutritious than carrots.

4. The nutritive value of parsnips, in so far as it is dependent on the proportion of flesh-forming constituents which are found in the root, according to the above results appears to be greater than that of carrots. Whilst fresh parsnips contain 1·30 per cent., and dry 7·25 per cent. of flesh-forming constituents, Belgian carrots were found to contain only 0·612 per cent. of protein compounds in their natural state, and 5·46 per cent. in their dried state. Compared with other crops parsnips are about as rich in albuminous compounds as mangolds, and ought, therefore, to go as far as mangolds in producing flesh.

5. The proportion of ammoniacal salts which occurs in the parsnip and in the carrots amounts to mere traces, which do not render inaccurate the determination of the nutritive value of these roots by the indirect method of combustion. Parsnips, richer in protein compounds than carrots, also contain more nitrogen in the form of ammoniacal salts.

6. As compared with carrots parsnips contain a double pro-

portion of fatty matters. They ought, therefore, to be superior as a fattening material in the feeding of stock.

7. The differences in the relative proportions of cellular fibre in both roots are very great. The cellular fibre occurring in carrots, parsnips, turnips, mangolds, &c., must not be regarded as useless in the animal economy, for there can be little doubt that the soft and young fibres of these roots are readily converted in the stomach of animals into gum and sugar, and applied in the system to feed the respiration, or for the formation of fat.

Thus, on the whole, parsnips appear to possess greater value than white Belgian carrots as a feeding or fattening material. Parsnips are indeed very valuable as an article of food; they are liked by cattle, and highly esteemed by Continental farmers for fattening stock. Moreover, they stand the frost better than any other root-crop, and keep well for a long time, as they contain less water than almost any other root-crop usually cultivated in England. On these grounds I would, therefore, strongly recommend the field cultivation of parsnips.

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ON THE

COMPARATIVE VALUE OF DIFFERENT ARTIFICIAL MANURES

FOR RAISING

A CROP OF SWEDES,

WITH REMARKS ON THE COMPOSITION OF THE MANURES EMPLOYED
IN EXPERIMENTAL TRIALS MADE AT THE ROYAL
AGRICULTURAL COLLEGE, CIRENCESTER.

By Dr. AUGUSTUS VOELCKER,

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LONDON.

MDCCCLV.

FROM THE
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ARTIFICIAL MANURES FOR SWEDES.

It is strange, that whilst an extended experience has proved in the most positive manner the specific action of phosphatic manures, and the decided advantages which result from their application to root crops, the employment of manures either greatly deficient in phosphoric acid, or wanting altogether this important fertilizing agent, should still be recommended by some practical men for raising a crop of swedes, turnips, or any other root crop. No less strange appears the preference which some farmers give even to half-inch bones over superphosphate of lime, although the superior value of the latter fertiliser has been ascertained in numerous practical experiments, and consequently has been recommended by high agricultural authorities, as by far the most economical form in which bones ought to be applied to the land. Still more surprising appears the ready sale which many artificial manures find, although their composition plainly indicates the utter worthlessness of the manufactured article, or the great discrepancy between the price at which it is offered for sale, and its per centage of really valuable fertilising constituents. But strangest of all, it strikes us, is the fact that the sale of downright trashy manures, or to say the least of them manures of a very inferior description, is often perpetuated for a long time by high flourished testimonials, given by men of character, and possessed of a degree of practical skill which entitles them to a considerate hearing. It is further worthy of observation, that valuable artificial manures are often employed even by good farmers in the cultivation of crops on which, as experience has proved, they are used with far less advantage than on others. Thus for instance, in many parts of England, but more especially in Scotland, Peruvian guano is used extensively as a manure for turnips, in preference to superphosphate of lime, notwithstanding the publication of numerous comparative field experiments, which have established the superior value of superphosphate as a manure for root crops, and which have shown likewise that the greatest fertilising effect of guano is realised by applying it to a white crop or to grass land.

Strange as these facts may appear at first sight, yet a little consideration, I think, will point out the reasons on which the objectionable practices to which reference has just been made are founded. Is there not afforded a clear proof in these and similar practices, that a knowledge of the principles on which the fertilising effects of manuring matters depend is by no means so generally spread amongst the agricultural community as it is desirable it should be? Do they not show that the specific action even of our standard fertilisers is unknown to many, and that consequently the choice of a manure for a particular crop is more regulated by chance or habit than by a consideration of the peculiar effects on vegetation which characterise many manures? How often do we not see a manure which has been employed upon wheat with considerable benefit, indiscriminately applied on every description of crops? Do we not recognise in some of the facts to which allusion has been made a reluctance of many to change a manure which hitherto has been used with advantage for another, recommended by the best authorities as a superior fertiliser? and on the other hand a willingness in others to submit to an experimental test that which is not really worth the trouble of trial? I do not doubt most readers will reply to these queries in the affirmative. But, I think, we may recognise still more in the proffered observations. It strikes me, that a trial in the field with different manuring matters is often considered an easy thing, whereas it is in reality a difficult task to perform a good field experiment. The reasons of this are obvious. The neglect of a single point which ought to have been attended to in the execution of an experimental trial in the field, or the commission of a fault, which cannot in this instance be so readily remedied as many other mistakes, or uncontrollable circumstances which interfere, but which pass by unnoticed, at once spoil the final result of the experiment, and consequently the inferences deduced from it are erroneous and apt to lead astray. Indeed a review of most published experimental field trials has convinced me, that comparatively speaking few have been undertaken with that amount of caution, candour, care, practical and scientific skill, premeditation, power of observation and general intelligence, which is requisite for the performance of a field experiment from the result of which trustworthy practical inferences can be deduced; and I have no hesitation in saying that the suppression of the majority of our recorded field trials with different manures would be a benefit to the agricultural community, inasmuch as they are calculated to mislead instead of to direct the practical man in his operations on the farm.

Then again, often no regard is had to the composition and physical properties of the soil on which experiments are tried; no notice is taken of the mechanical state of preparation in which it is found at the time when the experiment is made; casualties, such as the partial destruction of the crop by insects, unpropitious weather, &c., are overlooked; manures differing widely from each other in composition, and consequently possessing totally different specific actions on vegetable life, are tried against each other; or powerful fertilisers occasionally are employed in quantities, or in a mode in which they injure instead of benefiting the plants; and a variety of other mistakes not seldom are committed, and other circumstances of importance overlooked, which all tend to affect the result of the trial. Thus for instance, experiments with different fertilisers occasionally are tried on land which is in so excellent a condition that the best manure hardly makes any impression on the yield of the crop. It is forgotten that the agricultural capabilities of soils cannot be increased *ad libitum* to any extent, and that consequently the addition of the most valuable fertiliser to land which has almost reached its maximum state of fertility, which it either possesses naturally, or into which it has been brought by long cultivation, will produce no more effect than the most worthless manuring mixture. Land in such a high state of fertility can be compared to the replenished stomach of a well fattened animal; the one is as little benefited by the best manure, as the other is by the choicest food. On the contrary, the most powerful fertilisers applied under such conditions are exactly those which may and do occasionally even produce undesirable effects on vegetation, just as the richest food is more apt to spoil a satiated stomach than a plainer dish.

Hence it is that statements to the effect that such or such a manure has produced as great an effect as the best Peruvian guano, or any other manure of well-known fertilising power, or has even surpassed the best manures in its effects, find their way into the hands of dealers in trashy manures, or to say the best of the manures of a very inferior description. For this reason the printed testimonials which accompany the offer for sale of artificial manures do not always possess that value which many attach to them, not even when they are the genuine emanations of well-known and strictly honest agriculturists; for as I have said already, trustworthy inferences from the results of experimental trials can only be drawn, if a vast variety of circumstances are taken into account, the recognition of which requires much experience, and I am almost inclined to believe, a special training for this branch of experimental inquiry. Comparatively speaking few men accustomed to practical pursuits during the greater part of their life, and dependent for the support of their families upon their business, are in a position to execute and direct field experiments with sufficient accuracy for the results to confer any permanent benefit on the farming community. It is indeed an unjust accusation which is sometimes made against the practical farmer, that he has little inclination for undertaking experimental trials in the field.

Another circumstance to which reference has been made as calculated to vitiate the results of field experiments, and to give rise to erroneous views with regard to the value of fertilising materials, is the improper state in which otherwise good manures are occasionally applied to the land. An example or two, which came under my personal observation, will I hope bear me out in making this remark. I have repeatedly heard it asserted by good farmers, who had tried both the ammoniacal liquor of gas-works, and the refuse tar at the same manufactories, that gas-tar produced a much better result on grass and wheat than the ammoniacal liquor, and that consequently the former refuse was worth more in an agricultural point of view. On further inquiry I learned the reason of the small estimation in which this liquid was held by those who preferred to employ the gas-tar as a manure. The ammoniacal liquor, I was told, burns up the grass, whilst gas-tar makes it look more green and succulent. Here we have a striking example in illustration of the entertainment of erroneous views, to which an improper application of manures is apt to lead. Ammoniacal liquor of gas-works is far too powerful a manure to admit of its application in an undiluted form, and when used unmixed with water or any other diluting substance, as was here the case, it invariably burns up vegetation almost completely, unless a continued fall of rain provides for the necessary dilution, which has been neglected by the farmer.

Ammoniacal liquor owes its chief fertilising value to the ammonia, which exists in it almost altogether as a carbonate, and contains nothing detrimental to vegetable life; but like oxygen, which is so essential for animal life, carbonate of ammonia must be considerably diluted in order that it may produce a beneficial effect. In gas-tar, on the other hand, but little carbonate of ammonia is present; and for this reason it may be applied to the land undiluted, without fear of burning up the young plants. But it does not follow from this that gas-tar is a more valuable manure than the ammoniacal liquor, for it is easy to prove that gas-tar is only in so far valuable as a manure, as it is mixed with the watery ammoniacal liquor of gas-works. Both these refuse matters are collected together in one tank, and some of the watery ammoniacal liquor therefore remains always mixed with the tar. In the tar itself there are present no substances which contain either nitrogen, phosphoric acid, or potash, nor indeed any constituent which has the slightest fertilising value; for the organic, resinous, and oily compounds occurring in gas-tar are all compounds of carbon and hydrogen, or carbon, hydrogen, and oxygen, and as such they will furnish, on ultimate decomposition, carbonic acid and water only. But as all cultivated soils contain vegetable remains, which afford a much more ready and liberal source for carbonic acid, and as, moreover, by far the greater proportion of the carbon in plants is derived from the carbonic acid existing in the atmosphere, it is needless to make special provisions for the supply of carbonic acid. I have admitted for brevity's sake that tarry matters are readily decomposed, which, however, is by no means the case, for every one knows that tar is extensively employed for preserving timber from decay. As far as tar itself is concerned, I am therefore inclined to ascribe to it an injurious effect as a fertiliser, for it must retard the decomposition of organic remains in the soil or in the compost heap to which it is added, and must thus delay the necessary preparation to which most organic refuse matters must be submitted before they can be assimilated by the growing plants. If notwithstanding gas-tar produces a good effect, it is only on account of the ammonia contained in ammoniacal liquor with which it is mechanically mixed. There cannot remain, however, a shadow of a doubt, that the ammoniacal liquor is a far more powerful and at the same time economical manure, which will produce no injurious effects, and just as beneficial effects as gas-tar, when properly diluted with water. And as ammoniacal liquor is cheaper than gas-tar, and as a fertiliser goes at least ten times as far as the tar, the utility of knowing on what principle the fertilising effects of both refuse manures depend will become at once apparent.

Again, shoddy, a wool-refuse of flock-works, is recommended by some as an excellent manure for wheat and corn crops in general, whilst others condemn it as quite useless. How can these differences of opinion be reconciled, when equally good men have ascertained practically the value of shoddy, and know by experience what it is worth as a manure? I have seen shoddy applied to wheat apparently without the slightest effect, and in other cases the effect produced by the same refuse on wheat was wonderful. A reference to the analysis of shoddy, and a consideration of the physical condition of the soils to which and the time at which it is applied, readily explain this contrariety of opinion. Shoddy often contains 20 to 25 per cent. of oil, which, by excluding air and moisture from the interior of the wool-hairs which compose this refuse, prevents its decomposition as effectually as the oil in the sardines à l'huile protects the fishes, or a cover of grease the potted meat. At all events, the oil in shoddy retards its decomposition for a very long time; and as it naturally contains hardly any constituent which is of much value as a fertilizer, no effect is produced if shoddy is applied to the land when the young blade of wheat has already made its appearance, or even if it is applied two to three months before that period. But if the same refuse is added to the land long before the sowing of the crop which it is intended to benefit, or if by some means or the other it is brought into a state in which it will readily ferment, in which case it may be applied at once to the young wheat, a very marked effect will be observed to follow the application of shoddy to corn crops. For under these circumstances shoddy, which contains from 3 to 5 per cent. of nitrogen, gradually will give rise to the formation of ammonia, which it is well known benefits cereals in an especial manner. In light and porous soils this necessary preparation proceeds much more rapidly than in stiff heavy soils, and consequently the condition of the land will likewise modify the action of this refuse manure. Under the most favourable circumstances, however, shoddy ought to be used in an unprepared state, for the interval between the ingathering of a green crop and the preparation of the land for the corn crop is generally too short to allow the wool refuse to enter into decomposition; its effects consequently are lost upon the crop which it is intended to benefit, and unless a second corn-crop is grown, shoddy will but little benefit the second crop in the rotation, for it is a refuse which owes its fertilising effect almost altogether to the nitrogen it contains, and which furnishes on decomposition ammonia, and as ammonia does not exhibit the same powerful effect on other crops which it does on the cereals, the chief advantages which may be derived from the application of shoddy are lost.

These examples, I hope, will be sufficient to prove the correctness of the remarks which have been made. They are remarks founded on actual facts which have come under my personal notice.

I might easily point out other cases, with which I have become personally acquainted, as bearing on this subject, but this will perhaps be superfluous, and I will therefore merely observe, in addition to the remarks already made, that when all care, attention, and labour have been applied, uncontrollable circumstances often interfere which spoil the experiments in the field.

It affords me, therefore, much pleasure to have the privilege of giving an account of some experimental trials which were made last season, under peculiarly favourable circumstances, on the farm attached to the Royal Agricultural College. These experiments were made on Swedish turnips, with the following fertilisers :—

1. Guano.
2. Mixture of guano and dissolved coprolites.
3. Bone-dust.
4. Home-made superphosphate of lime.

5. Economical manure.
6. Nut-refuse.
7. Dissolved coprolites.
8. Commercial dried night-soil.
9. A mixture of sand, guano, dissolved coprolites, and superphosphate of bones.

The field selected for the experimental trials with these manures was almost perfectly level, and throughout of a uniform depth. It had been cropped alike in every part in previous years, and otherwise uniformly cultivated. The surface soil is shallow, and rests on the great oolite limestone, from which it is separated by a clayey subsoil of small dimensions. Altogether it is a turnip soil of but moderate quality, belonging to the class of calcareous soils, as will be seen by glancing at the subjoined analyses.

1. *Mechanical Examination of Soil of Experimental Field, Cirencester.*

a. On passing 24 lbs. of the surface soil through a ½ inch sieve, there were separated:

Large stones, weighing	1 lb. 6 ounces.
Soil, passing through the sieve . . .	22 ,, 10 ,,
	24 lbs.

b. Of the soil passing through the ½ inch sieve, 1 lb. was riddled through a series of 4 perforated zinc cullenders, fitting into each other. The uppermost cullender was provided with apertures, measuring ¼ of an inch in diameter; the second with apertures ⅛ of an inch in diameter; the third was perforated with holes $\frac{1}{16}$ in. diameter; and the fourth with holes $\frac{1}{32}$ in. diameter. By this means it was divided into five different portions, the relative proportion of which was as follows:—

No. 1. On ¼ inch sieve were left	121	grains, fragments of limestones.
2. ,, ⅛ ,, ,,	643	grains of soil, including a large proportion of limestones.
3. ,, $\frac{1}{16}$,, ,,	2,246	grains.
4. ,, $\frac{1}{32}$,, ,,	1,192	,,
5. Through the last sieve passed	2,882	,,
	7,085	,,

A mechanical examination of this description is useful, inasmuch as it enables us to form some idea of the state of division in which the soil-constituents actually occur, and in experimental trials enables the reader to judge for himself whether or not the soil was sufficiently pulverised for the crop experimented upon. It will be observed by these data that the mechanical preparation of the experimental field has been carefully attended to.

c. The portion collected on the first sieve consisted entirely of fragments of limestones, and that of No. 2 nearly altogether of similar but smaller fragments. Both were rejected in preparing a fair average sample for chemical analysis, and the portions from Nos. 3, 4, were powdered in a mortar, passed through the $\frac{1}{32}$ inch sieve, and mixed with No. 5.

Before submitting it to chemical analysis, the average sample was separated by washing into the following portions:

100 parts of average soil contained—

Organic matter and water of combination	6·339
Burned deposit after standing 5 minutes	69·600
,, ,, 10 ,, ...	3·880
,, ,, 15 ,, ...	3·230
Remaining in suspension after standing longer than 15 minutes	16·951
	100·000

The first deposit consisted of a calcareous sand, whilst the second and third were coarse clay, and what remained in suspension fine clay.

The general composition of the soil can therefore be expressed as follows:—

Organic matter and water of combination	6·339
Clay	24·061
Calcareous sand	69·600
	100·000

2. *Chemical Examination.*

On analysis of the average sample prepared as described above, the following results were obtained:—

100 parts contained—

Organic matter and water of combination	6·339
Oxides of iron and alumina, with a trace of phosphoric acid	9·311
Carbonate of lime	54·566
Magnesia	trace
Sulphuric acid	ditto
Chlorine	ditto
Potash and soda	1·032
Insoluble siliceous matter.	28·947
	100·195

It will be observed that carbonate of lime greatly preponderates in this soil, and that the proportion of alkalies is but small, whilst mere traces of phosphoric and sulphuric acid were found in it. Calcareous soils of such a composition are generally unproductive.

The experimental field was carefully measured out, and divided into ten different plots of one-eighth of an acre each. These experimental plots were arranged side by side in continuous rows of drills, care being taken to reject the headlands from the experimental plots. The space of one-eighth of an acre was occupied by three rows of drills. The different manures were all applied to the land on the same day; and in order to secure their full efficacy and their even distribution, they were put on the ridges by hand in a groove, made by a hoe being drawn along the top; the different manures were then covered with some soil, and after passing a roller over the drill, all the swedes were sown by ridge-drill on the 20th of June. Subsequently, all experimental plots were treated in precisely the same way, and care was taken to render the experiments in every respect strictly comparative.

One of the experimental plots was left unmanured; the nine remaining were manured in the manner described, with the subjoined quantities of the manures, which have been mentioned already. These quantities of the different fertilisers were obtained in each case with an expenditure of 5*s.*, or each experimental plot was manured at the rate of 2*l.* per acre.

Thus to

			Cost, 5s. for each Plot.
Plot	I.	was applied .	56 lbs. of guano.
,,	II.	,, ,, .	84 lbs. of coprolites, dissolved in sulphuric acid, and 28 lbs. of guano.
,,	III.	,, ,, .	100 lbs. of bone-dust.
,,	IV.	,, ,, .	93 lbs. of home-made superphosphate.
,,	V.	,, ,, .	56 lbs. of economical manure.
,,	VI.	,, ,, .	120 lbs. of nut-refuse.
,,	VII.	,, ,, .	140 lbs. of dissolved coprolites.
,,	VIII.	,, ,, .	Nothing.
,,	IX.	,, ,, .	180 lbs. of commercial dried night-soil.
,,	X.	,, ,, .	A mixture of 1 bushel soot, 30 lbs. of guano, with dissolved coprolites, and superphosphate of bones.

Before stating the yield of each experimental plot, I may be permitted to offer some observations on the condition of the growing crops, and on the chemical composition of the different fertilisers used in these experiments. All have been analysed in my laboratory, either completely, or when a complete analysis appeared superfluous, only those substances were determined on which principally the efficacy of the manure depended.

Plot I. Manured with 56 lbs. of guano, or at the rate of 4 cwts. per acre.
Cost of manure 5*s.*, or 2*l.* per acre.

The young plants came up remarkably well, and looked for a considerable time as well, if not better than the rest of the experimental plots. When, however, the bulbs began to swell, it was evident to the eye that the guano turnips would be left behind by the superphosphate, and probably also by the dissolved coprolites, mixed with guano; and the result has proved that this was actually the case. The guano was best Peruvian, and was bought at the price of 10*l.* per ton. On analysis its composition was ascertained to be as follows:—

Water	12·420
Organic matter and ammoniacal salts	52·980
Phosphates of lime and magnesia (bone-earth)	25·065
Alkaline salts, chiefly chloride of potassium and sodium, with a small quantity of alkaline phosphates and sulphates	8·262
Insoluble siliceous matter	1·507
	100·234
Containing nitrogen	14·177
equal to	
Ammonia	17·215

The guano employed in the experimental trial, as shown by its analysis, was genuine Peruvian guano of good qualities.

Inferior kinds of guano, such as Saldanha-bay and Patagonian, I think, would have given a better result, for they are richer in phosphates than Peruvian; and as the commercial value of guano is principally regulated by the proportion of ammonia it contains or furnishes on decomposition, and as ammonia does not benefit root crops in an equal degree as white crops, whereas phosphatic manures exercise a specific action on roots, which causes them to swell and thus to increase the crop, it would appear that, to the extent to which Peruvian guano is richer in nitrogenized matters than other kinds of guano, it becomes less valuable. Indeed, it appears to me a great waste to apply Peruvian guano alone to swedes or turnips; and I hope to support this opinion by the practical proofs which will presently be mentioned.

Plot II. Manured with 84 lbs. of coprolites dissolved in sulphuric acid and 28 lbs. of guano, or at the rate of 6 cwts. dissolved coprolites and 2 cwts. of guano.

Cost of manure 5*s.*, or 2*l.* per acre.

At first no difference in the appearance of the swedes, when compared with those grown with guano alone, could be observed; but at a more advanced season the roots looked decidedly better than those of Plot I., and, indeed, of most other experimental plots.

The dissolved coprolites were made on the farm by digesting the finely ground, so-called Suffolk coprolites, with one-third their weight of sulphuric acid, and allowing this mixture to become nearly air-dry by keeping. It was then mixed with guano, and thereby obtained in a perfectly powdered and air-dry state.

On analysis the ground coprolites were found to contain in 100 parts—

Hygroscopic water	1·20	
Water of combination, and a trace of organic matter	3·20	
Oxides of iron and alumina	4·84	
Lime	39·81	
Magnesia	5·68	
Phosphoric acid	23·48	equal to 47·82 of bone earth.
Carbonic acid	5·82	
Insoluble siliceous matter	12·56	
Alkalies, sulphuric acid, and loss	3·41	
	100·00	

The price of the dissolved coprolites made on the premises was 4*l.* per ton. At the present prices of the raw coprolites, the dissolved article would be more expensive.

Plot III. Manured with 100 lbs. of bone-dust, or 7 cwts. and 16 lbs. per acre.
Cost of manure 5*s.*, or 2*l.* per acre.

The swedes on this plot looked healthy, but, it struck me, rather unequal. A distinct difference in the average size of the roots, as compared with the two preceding plots, soon became apparent to the eye when the root began to swell. On analysis the bone-dust was found to contain in 100 parts—

Moisture	18·12
Organic matters (gelatine and fat)	29·29
Phosphates of lime and magnesia (bone-earth)	44·22
Carbonate of lime	5·49
Alkaline salts (chiefly common salt)	1·49
Sand	1·39
	100·00
Containing nitrogen	4·28
equal to Ammonia	5.23

Previous to crushing they had undergone no preparation whatever, and contained consequently a great deal of fat, which circumstance explains their slow action. 2*s.* more per quarter was paid for obtaining the bone-dust in a finer state than it is usually sold. A bushel on an average weighed 44 lbs., and the price per ton was 5*l.* 12*s.*

Plot IV. Manured with 93 lbs. of home-made superphosphate of lime, or at the rate of 6 cwts. and 72 lbs. per acre.
Cost of manure 5*s.*, or 2*l.* per acre.

The seed came up well, but at the first stage of growth the swedes sowed with guano appeared somewhat better. At a later period the difference in the appearance of these two plots was less striking; and when the bulbs began to swell, it was evident that in all probability superphosphate of lime would surpass the other manures in its effects upon Swedes. Experience has proved it to have been the case.

In the preparation of the superphosphate the fine bone-dust, of which an analysis has been given already, was first moistened with one-third its weight of boiling water, and after the water had been thoroughly soaked in by the dust, one-third of its weight of brown oil of vitriol was added. The mixture was made in a wooden trough, from which it was removed and placed in a heap, after it had become sufficiently consolidated. It was made a considerable time before the sowing of the turnips, and had thus time to become thoroughly disintegrated in the heap and dry on keeping. Before its application to the land, it was broken down with a wooden mallet into a fine powder.

Boiling water was found to assist the dissolving action of the oil of vitriol in a very high degree: it can therefore be recommended as greatly preferable to cold water. The cost of the dry home-made superphosphate was 6*l.* per ton.

Plot V. Manured with 56 lbs. of economical manure, or at the rate of 4 cwts. per acre.
Cost of manure 5*s.*, or 2*l.* per acre.

In a very short time after the bulbs had begun to swell, this plot was left behind by all the other experimental plots, the undressed portion excepted. The difference in the appearances between this plot and the other manured plots became more and more striking as the crops approached maturity, when the most unexperienced eye could observe that the economical manure had done little good to the swedes. It was, indeed, impossible to observe the slightest difference between the unmanured plot and the one dressed with economical manure. This unfavourable result cannot surprise any one who knows that phosphoric acid applied in a form in which it can be readily assimilated by the growing plant, more than other fertilizing constituent, benefits root crops, if he throws a glance at the following analysis:—

Composition of Economical Manure.

Water	36.525
Protosulphate of iron (green vitriol)	23·756
Sulphate of lime	·860
Sulphate of magnesia	·204
Bisulphate of potash	4.677
Bisulphate of soda	10·928
Sulphate of soda (Glauber salt)	15·143
Sulphate of ammonia	2·648
Insoluble siliceous matter (sand)	5·850
	100·591
Containing ammonia	·683

This manure, it will be observed, consists principally of crystallized green vitriol and bi-sulphate and sulphate of soda. These sulphates of soda are obtained at a cheap rate, as a refuse in several chemical manufactories. Both the crystals of green vitriol and Glauber salt or sulphate of soda contain much water of crystallization; hence the large amount of water (36½ per cent.) in a tolerably dry substance. The economical manure has a strongly acid taste and reaction, and might therefore be supposed to contain a great quantity of soluble or acid phosphate of lime; but whilst it contains only about 7-10ths per cent. of ammonia, phosphoric acid is excluded entirely from its composition. We need not, therefore, feel astonished that it produced scarcely any effect upon swedes.

The price at which the economical manure sold last season, and is again sold this season, is 12*l.* per ton. Its constituents can be furnished at about 3*l.* a ton; the manufacture of a manure of the above composition thus might even pay well if sold at 5*l.* per ton instead of 12*l.* per ton, its actual price.

Plot VI. Manured with 120 lbs. of nut refuse, or at the rate of 8 cwts. 64 lbs. per acre.
Cost of manure 5*s.*, or at the rate of 2*l.* per acre.

The swedes upon this plot had as healthy an appearance as any of the experimental plots, and it was difficult to observe any difference in the relative average size of the bulbs of this plot and those of the next and the tenth plot.

This refuse was the powdered cake of an oily nut, probably cocoa-nut. It was submitted in my laboratory by my pupil, Mr. Louch, to a partial analysis, who found in 100 parts—

Water	11·60
Organic matters	79·12
Inorganic matters (ash)	9·28
	100·00

This quantity of organic matter on combustion gave in two experiments—

	1 Exp.	2 Exp.	Average.
Nitrogen	4·826	4·90	4·863

In the 9·28 of ash were found—

Earthy phosphates	4·12
Phosphoric acid, combined with alkalies	·13
Sand and soluble silica	2·42
Alkalies, magnesia, &c.	2·61
	9·28 grs.

It will be observed that this nut-cake manure contains a very large amount of nitrogen, and also a quantity of phosphates and alkalies which is by no means inconsiderable. It was sold in small quantities at the rate of 5*l.* per ton; but I am told in large quantities it may be had at 3*l.* a ton. At the latter price it certainly is very cheap and well worthy the attention of the farmer, as it is a powerful manure, which, however, is more economically applied to wheat or grass-land than to turnips.

Plot VIII. *Unmanured plot.*

As mentioned already, a very great difference was soon perceptible between this and most manured experimental plots (except the economical plot). The swedes were very small, but otherwise in good condition.

Plot IX. *Manured with* 180 *lbs. of commercial dried night-soil,* or at the rate of 12 cwts. and 96 lbs. per acre.
Cost of manure 5*s.*, or 2*l.* per acre.

No difference in the probable yield of this plot and the next could be observed. Plots IX. and X., however, did not promise so good a crop as Plots I., II., VII., and especially IV.

The effect produced by the dried night-soil was not so great as might have been expected. Pure night-soil is a powerful manure, which contains a considerable proportion of phosphoric acid, and for this reason ought to benefit root-crops in a decisive manner. It must be borne in mind, however, that the dried night soil was a commercial article, which, like many commercial articles, possessed a better name than it was entitled to by its composition. For the preparation of this manure a good deal of water was retained, and no doubt a large proportion of rubbish besides common salt was employed, as will be seen by glancing at the subjoined analysis:—

Composition of Commercial dried Night-Soil Manure.

Water	19·712
Organic matters	17·484
Carbonate of lime	9·229
Magnesia	·168
Oxides of iron and alumina	20·061
Phosphoric acid	4·399
Common salt with some sulphate of soda and potash	11·864
Insoluble siliceous matter (sand and brick-dust)	16·941
	99·858

It was sold at 3*l.* 2*s.* per ton.

Plot X. Manured with a mixture of 1 bushel of soot, 30 lbs. of guano and dissolved coprolites, and bone superphosphate to make up the 5*s.* expenditure.
Cost 5*s.*, or 2*l.* per acre.

Guano, dissolved coprolites, and bone-superphosphate, are of the same description as the materials used for the other experiments.

The soot on analysis was found to contain 3·833 per cent. of ammonia: it was procured at the rate of 6*d*. per bushel.

It having been found on previous trials that it was quite impossible to calculate the yield of each plot by weighing only a small number of roots, the whole produce of each experimental plot was weighed on a weigh-bridge.

The following table exhibits the yield of each experimental plot and the weight of the trimmed roots calculated per acre:—

Table showing the Produce of trimmed Swedes of Experimental Plots of one-eighth of an Acre, and Weight of Crop per Acre.

			Per ⅛ of an Acre.			Per Acre.		
			tons.	cwts.	lbs.	tons.	cwts.	lbs.
Plot	I.	(Guano) yielded	1	9	7	11	12	56
,,	II.	(Guano and dissolved coprolites) yielded	1	12	2	12	16	16
,,	III.	(Bone-dust) . . . ,,	1	2	0	8	16	0
,,	IV.	(Bone superphosphate) ,,	1	14	2	13	12	16
,,	V.	(Economical manure) ,,	0	15	2	6	0	16
,,	VI.	(Nut-refuse) . . . ,,	1	5	0	10	0	0
,,	VII.	(Dissolved coprolites) ,,	1	9	0	11	12	0
,,	VIII.	(Nothing) . . . ,,	0	13	0	5	4	0
,,	IX.	(Commercial dried night-soil)	1	3	0	9	4	0
,,	X.	(Mixture of soot, guano, dissolved coprolites, and bone-superphosphate) . ,,	1	5	1	10	0	8

The results obtained in these experimental trials are both interesting in a practical and scientific point of view, and I may therefore be allowed to offer a few remarks which are suggested by them. Before doing this, however, a point of some moment demands special notice. It will be observed that the unmanured portion of the experimental field only gave a produce of 5 tons 4 cwts. per acre. The natural inference which may perhaps be drawn from so small a crop is, that the land was not in a proper state of preparation for the turnip-crop, and that, consequently, all the experiments are not to be depended upon; I have shown, however, by the mechanical analysis of the soil on which the experiments were tried, that it was well pulverized, and have been assured moreover by our farm-manager, that the experimental field was in a fit state of preparation for the swedes. The soil, it is true, was naturally poor, shallow, and rested on lime-stone rock, from which it was separated by a clayey subsoil of inconsiderable depth. But far from considering this circumstance as being calculated to vitiate the results of the trials, there is much reason to believe that a soil of such a description is peculiarly well adapted for the making of experiments from which legitimate and trustworthy inferences may be derived. A poor soil, it strikes me, is much better adapted to bring out the full manurial effect of different fertilizers than land in the highest state of fertility. For the productive powers of soils, let it be remembered, cannot be increased to an unlimited extent; when, therefore, a soil is naturally as productive as it can be under any circumstances, or when by good cultivation it has reached its maximum state of fertility, the addition of the most valuable manure, it is evident, cannot produce any perceptible effect. Under these conditions the best fertilizer would produce no greater effect than an utterly worthless and inexpensive manure Now the closer a soil approaches this condition the less it is adapted for the performance of experiments with manures, and *vice versa;* land not very productive, or naturally poor, is just in a condition in which the full effects of different fertilizers can be best discerned, and I am inclined therefore to consider the fact of the experiments having been tried on a naturally poor soil as peculiarly fortunate.

A reference to the tabulated statement which has just been given will exhibit very considerable differences in the weight of the bulbs raised by an equal money-value of different manures. Thus whilst 2*l.* worth of home-made superphosphate of lime gave an increase of 8 tons 8 cwts. 16 lbs. per acre, 2*l.* worth of economical manure produced merely 16 cwts. 16 lbs. more per acre than the unmanured portion of the field. Again, it will be observed, that whilst 2*l.* worth of dried night-soil gave only 9 tons 4 cwts. of roots, a mixture of guano and dissolved coprolites gave 12 tons 16 cwts. 16 lbs., and dissolved coprolites alone 11 tons 12 cwts.

These differences are still more strikingly exhibited in the following table, in which the different plots are arranged according to the increase which the various fertilizers employed upon each produced: the table likewise shows the cost at which 1 ton of increase was produced in each experimental trial.

Table showing Increase per Acre, and Cost of 1 *Ton of Increase, in* 10 *experimental trials upon Swedes.*

		Increase per acre.			Cost of 1 ton of increase.		
		tons.	cwts.	lbs.	£	*s.*	*d.*
No. 1.	Home-made superphosphate . .	8	8	16	0	4	9
2.	Dissolved coprolites and guano .	7	12	16	0	5	3¼
3.	Guano	6	8	56	0	6	2½
4.	Dissolved coprolites	6	8	0	0	6	3
5.	Mixture of guano, soot, dissolved coprolites, and bone superphosphate	4	16	8	0	8	3½
6.	Nut-refuse	4	16	0	0	8	4
7.	Commercial night-soil	4	0	0	0	10	0
8.	Bone-dust	3	12	0	0	11	1¼
9.	Economical manure	0	16	16	2	9	6¾
10.	Nothing.						

(Natural produce 5 tons 4 cwts.)

We thus see that well-made superphosphate was by far the most economical manure in these experimental trials, and the "economical manure" the worst of all; for whilst 1 ton of increase raised with the agency of superphosphate of lime was obtained with an expenditure of 4*s.* 9*d.*, 1 ton of increase raised with "economical manure" would cost no less than 2*l.* 9*s.* 6¾*d.* for the manure.

It is worthy of observation that the land in the preceding year was not manured with farm-yard manure, nor indeed with any manure whatever, and we thus see that with superphosphate alone a better crop of swedes may be raised than with guano. It will be seen that guano produced nearly 2 tons less of swedes per acre than home-made superphosphate, a difference which, considering the small crop furnished by the unmanured land, is considerable. Peruvian guano alone, indeed, should not, as is so often the case, be employed for root-crops, for when employed in small quantities the per-centage of phosphates contained in it is not adequate to enlarge the roots sufficiently, and when used in large quantities it is apt to produce an excess of leaves, which is generally the case with all manures containing like guano a large amount of nitrogenized constituents. Had the experiments been tried on wheat instead of swedes, there can be little doubt but that the results would have been different, and guano, in all probability, would have carried off the palm, for it is on the cereals and upon grass-land that highly nitrogenized manures like guano, soot, blood, &c., produce the most beneficial effects. Next to superphosphate made from bones, the mixture of dissolved coprolites and guano gave the greatest increase, the crop weighing 12 tons 16 cwts. 16 lbs. per acre; whilst dissolved coprolites employed alone furnished 11 tons 12 cwts. per acre. This is an exceedingly interesting result, for it shows that a purely mineral phosphatic manure, even when applied in a form in which it can readily be assimilated by plants, does not produce, at least on a poor soil, so large a crop as a mixture in which a portion of the mineral phosphate is replaced by a manure, which, like guano, is rich in nitrogenized constituents. A small amount of an ammoniacal manure, or a fertilizer rich in organic matters, readily furnishing ammonia on decomposition, appears to be sufficient to secure the assimilation of the mineral phosphate; for it will be observed, by glancing at the experiment in which a mixture of soot, guano, superphosphate, and dissolved coprolites was used, that if the amount of organic fertilizing matters in a mixture is increased at the expense of its phosphatic constituents, the produce will be reduced. Thus this mixture, in which a portion of superphosphate was replaced by soot and guano, both containing much ammonia, or furnishing it on decomposition, only gave 10 tons 8 lbs., whilst the produce of the dissolved coprolites amounted to 11 tons 12 cwts.

Dissolved coprolites, which follow guano in the above list, virtually produced as great a crop as guano, for the difference of 56 lbs. is not worthy of consideration. Whenever coprolites therefore can be had at a cheap rate, they may be employed as a substitute for bone-dust, provided care is taken to dissolve them properly in sulphuric acid and to mix them with some nitrogenized organic manure.

The nut-refuse gave as nearly as possible the same produce as the mixture in experimental plot No. X., and commercial night-soil follows next in the list. A comparison of the crop yielded by bone-dust with that yielded by bone-dust dissolved in sulphuric acid, will forcibly exhibit the advantages of applying bones in the latter form; for whilst an equal money value of bone-dust only gave an increase of 3 tons 12 cwts., dissolved bone-dust gave an increase of 8 tons 8 cwts. 16 lbs.; or whilst 1 ton of increase raised with the agency of superphosphate only cost 4*s.* 9*d.*, 1 ton of increase raised with bone-dust implied an expenditure of 11*s.* 1¼*d.* The form in which an artificial manure is applied to the land thus greatly influences its action.

On the whole, we may learn from these experiments that the value of different artificial manures for a crop of swedes, and no doubt also for other root-crops, principally depends on the amount of phosphoric acid contained in them in a form in which it can be readily assimilated by the plants. In bone-dust there is much phosphoric acid; but when it is used in an unprepared state, in which it still contains all the fat naturally present in fresh bones, it often remains in the soil for a very long time without readily undergoing decomposition, or that preparation so necessary to bring out its full fertilizing effect. All the experiments confirm the general conclusion which has just been expressed; but more especially the experiment with the economic manure, in which the absence of phosphoric acid was proved by analysis, shows the necessity of applying to root-crops a fertilizer containing a good deal of phosphoric acid. Whatever else the virtues of the economical manure may be, it certainly proved the least economical dressing of all, as it produced only 6 tons 16 lbs. of swedes per acre, or only 16 cwts. 16 lbs. more than the unmanured portion of the experimental field.

In conclusion I will observe that I have carefully determined the chemical composition of the roots of each experimental plot, in so far at least as it appeared desirable in order to form some idea as to the nutritive value of the swedes raised with different manuring matters.

The results of these examinations are embodied in the following table:—

Table showing the Proportion of Water in Swedes grown with different Manures.

Weight of Roots.	Per centage of water.	Average amount of water.
Plot I. Guano.		
a. Large sized root, weighing 2 lbs. 11 ounces	88·717	87·667
b. Average sized root, weighing 1 lb. 8 ounces	87·450	
c. Small sized root, weighing 11 ounces	86·834	
Plot II. Dissolved coprolites and guano.		
a. Large sized root, weighing 1¾ lb.	88·420	88·484
b. Medium sized root, weighing 15 ounces	88·600	
c. Ditto root, weighing 15 ounces	88·434	
Plot III. Bone-dust.		
a. Large root, weighing 2 lbs. 2 ounces	88·034	88·467
b. Medium size, weighing 1 lb. 13 ounces	89·967	
c. Small root, weighing ¾ lb.	87·400	
Plot IV. Superphosphate of lime.		
a. Large root, weighing 2½ lbs.	88·350	88·556
b. Average sized root, weighing 1 lb. 10 ounces	89·284	
c. Small root, weighing 10½ ounces	88·034	
Plot V. Economical manure.		
a. Large root, weighing 2 lbs. 2 ounces	87·717	87·661
b. Average size, weighing 14 ounces	88·067	
c. Small root, weighing 8 ounces	87·200	
Plot VI. Nut-refuse.		
a. Large sized root, weighing 2¼ lbs.	87·900	88·306
b. Average size, weighing 1 lb. 1 ounce	88·384	
c. Small root, weighing 9 ounces	88·634	
Plot VII. Dissolved coprolites.		
a. Large root, weighing 2½ lbs.	89·417	88·578
b. Medium size, weighing 1 lb. 11½ ounces	88·117	
c. Small root, weighing 9½ ounces	88·200	
Plot VIII. Nothing.		
a. Large root, weighing 1 lb. 11 ounces	88·800	87·803
b. Average sized root, weighing 12 ounces	87·460	
c. Small root, weighing 5 ounces	87·150	
Plot IX. Night-soil manure.		
a. Large root, weighing 1 lb. 10 ounces	88·917	88·506
b. Ditto, weighing 1 lb. 10 ounces	88·767	
c. Small root, weighing ½ lb.	87·834	
Plot X. Mixture of soot, guano, dissolved coprolites, and superphosphate.		
a. Large sized root, weighing 2 lbs. 5 ounces	88·841	87·376
b. Medium sized root, weighing 1 lb. 14 ounces	87·131	
c. Small root, weighing ½ lb.	86·156	

It will be observed that the proportion of water and solid matter is pretty nearly the same in all the roots of the different experimental plots. The differences in the amount of water in roots of different size also are very trifling: generally, but not always, the larger roots were somewhat richer in water.

In the following table the proportion of ash and nitrogen in swedes in natural and dry state is given:—

Table showing the Amount of Ash and Nitrogen in Swedes of Experimental Plots.

	Ash.			Nitrogen.		
	In Natural State.		In Dry State.	In Natural State.	In Dry State.	
				Mean.		
Plot No. 1	1st deter. .	·561	4·98		1st deter. .	2·372
	2nd deter. .	·552	4·40		2nd deter. .	2·457
	3rd deter. .	·641	4·87	·298	Mean . .	2·414
Plot No. 2	1st deter. .	·540	4·67		1st deter. .	2·434
	2nd deter. .	·548	4·81		2nd deter. .	2·401
	3rd deter. .	·512	4·43	·278	Mean . .	2·417
Plot No. 3	1st deter. .	·568	5·20		1st deter. .	2·402
	2nd deter. .	·639	6·37		2nd deter. .	2·355
	3rd deter. .	·655	4·75	·274	Mean . .	2·378
Plot No. 4	1st deter. .	·498	4·28		1st deter. .	2·286
	2nd deter. .	·516	4·82		2nd deter. .	2·181
	3rd deter. .	·589	4·93	·255	Mean . .	2·233
Plot No. 5	1st deter. .	·596	4·86		1st deter. .	
	2nd deter. .	·582	4·96		2nd deter. .	
	3rd deter. .	·558	4·36	·300	Mean . .	2·435
Plot No. 6	1st deter. .	·534	4·42		1st deter. .	2·401
	2nd deter. .	·581	5·01		2nd deter. .	2·348
	3rd deter. .	·576	5·07	·277	Mean . .	2·374
Plot No. 7	1st deter. .	·484	4·58		1st deter. .	2·143
	2nd deter. .	·628	5·29		2nd deter. .	2·459
	3rd deter. .	·554	4·70	·263	Mean . .	2·301
Plot No. 8	1st deter. .	·561	5·01		1st deter. .	2·748
	2nd deter. .	·559	4·46		2nd deter. .	2·793
	3rd deter. .	·627	4·88	·338	Mean . .	2·770
Plot No. 9	1st deter. .	·538	4·86		1st deter. .	2·379
	2nd deter. .	·540	4·72		2nd deter. .	2·545
	3rd deter. .	·498	4·10	·283	Mean . .	2·462
Plot No. 10	1st deter. .	·562	5·04		1st deter. .	2·505
	2nd deter. .	·532	4·12		2nd deter. .	2·592
	3rd deter. .	·654	4·73	·321	Mean . .	2·548

I do not think the variations indicated by these determinations are sufficiently great to entitle us to say that the swedes of one plot were more nutritious than those of another.

On the whole these analyses show that the different fertilizers employed in the experimental trials did not affect the composition of the swedes in any material degree; consequently the question as to the comparative economy of using superphosphate of lime in preference to all the other manures employed in the experimental trials remains simple, and the general conclusions to which these experiments have led are not affected by any differences in the nutritive value of the roots.

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ON THE
AGRICULTURAL AND COMMERCIAL VALUE
OF SOME
ARTIFICIAL MANURES,
AND ON THEIR ADULTERATION.

BY

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ON THE

VALUE OF ARTIFICIAL MANURES.

If there ever was a time when the agriculturist had need to exercise especial caution in purchasing artificial manures, that time is the present; for the practice of adulterating standard artificial fertilizers, such as guano, superphosphate of lime, nitrate of soda, &c., has reached an alarming point.

The increasing demand for these manures, their inadequate supply, the general favour in which artificial fertilizers are now held by farmers, the deficiencies of natural sources from which a really valuable manure can be prepared; disregard for the difference of the practical effects of a manure and its real money-value; the difficulty of arriving in a single season at a positive conclusion with regard to its efficacy, and other similar circumstances, are fruitful causes of the shameful adulterations in artificials of recognised value, and of the many inferior or worthless new compounds which are found in the manure-market at the present time. Some artificial manures are actually sold and bought at double or triple the price which they are worth. This is especially the case with certain saline compound manures. Some of these manures contain 30 to 40 per cent. of water, notwithstanding their dry appearance, which is easily accounted for by the fact that many salts in crystallising bind 50 per cent., or even more, water. A large quantity of a useless material thus remains concealed in the saline compound, into the composition of which such salts largely enter, and thereby its value is greatly diminished.

It is well known, moreover, to all who have watched the state of the manure-market how easily testimonials can be obtained even from high agricultural authorities, notwithstanding the comparative inferiority of the manure. Indeed, the dealer or manufacturer has so many chances to reap a large profit for a season from the sale of an all but worthless article that it is not surprising to find so many unscrupulous persons engaged in a course of fraudulent pursuits. Whilst thus on the one hand the unsuspecting farmer is swindled out of his money, and runs the risk of losing his crops too; on the other hand, enterprising, well-qualified, and honest persons are deterred from employing their capital, energy, and skill in an undertaking which, under more favourable conditions, could not fail to benefit alike the manufacturer and purchaser. It is but right, however, to mention that it is far from us to censure indiscriminately the whole class of manure-manufacturers and dealers; for we know many highly respectable fair-dealing and skilled parties who well deserve the support and encouragement of the agriculturist, and who are as anxious as every right-minded person to put a stop to the scandalous proceedings which are now and then revealed to us through the medium of the agricultural press, but which, alas! but too often remain buried in darkness.

During the past season we have had the opportunity of becoming practically acquainted with several instances of gross fraud, which cannot fail to startle the unsuspecting. The publication of several of the subjoined cases lately brought under our notice, we trust, will address a word of caution to the agriculturist, and have the effect of protecting him from imposition, by helping to put a stop to the fraudulent dealings of the unprincipled, and by giving encouragement to the honest and skilful manufacturer of artificial manures.

Before entering into details, however, we may be permitted to make a few general observations on the practical efficiency and commercial value of manures.

The effects which a manure is capable of producing on vegetation, it is evident, mainly depend on its constituents; and as the composition of the various fertilizers usually employed for restoring the impaired fertility of the land greatly varies, their effects on vegetation necessarily must vary likewise considerably. In well-made farmyard manure all the elements are found which are required for the healthy and luxuriant growth of all the different cultivated plants. Practical experience having shown that all the different kinds of vegetable products can be greatly increased by the application of farmyard-manure, it is justly esteemed as a universal manure. But this is not the case with many artificials, which, containing a preponderating amount of one or two fertilizing constitutents, and a deficiency of others, often fail to produce any marked effects on some crops, whilst their application to others is followed with the most beneficial results. Indeed, most artificial manures are characterised by a specific action: some exercise a highly beneficial effect on root-crops; others on a grain-crop, or on pasture-land. Hence they are called special manures. Thus, whilst superphosphate of lime produces striking results on turnips and root-crops in general, its effects on wheat, oats, or barley are less apparent. Again, whilst nitrogenized and ammoniacal manures, such as guano, soot, nitrate of soda, animal refuse matters, &c., favour in a special manner the abundant produce of wheat, oats, or barley, they do not, like phosphatic manures, promote the development of bulbous roots, such as swedes or mangolds, to an equal extent. A thorough knowledge of the composition of special artificials, and of the conditions under which they act most beneficially, is therefore of much value to the farmer, as it enables him to apply fertilizers of that description with the greatest advantage. There are, however, others which, notwithstanding the deficiency of some constituents, can be, and are, used successfully for various kinds of crops. In reality, the deficiency of some constituents, instead of being a defect, is a recommendation to these manures; for several of the constituents which greatly preponderate in farmyard-manure are present in most soils in abundant quantities; they need not therefore be supplied to the land in the form of manure; or should they be wanting in the soil, they can be readily obtained almost everywhere at a cheap rate. If, therefore, these inexpensive and more widely-distributed substances are dispensed with in compounding a manure, and only those are selected which occur in soils in minute quantities only, a very valuable and efficacious fertilizer is obtained, which possesses the great advantage of containing in a small bulk all the essential fertilizing substances of a large mass of home-made dung.

In one sense, all the fertilizing agents are alike valuable; for they are all indispensable for the healthy condition of our cultivated crops, and consequently the absence of one is attended with serious consequences, though all others may be present in abundance. Thus the deficiency of lime in the land may be attended with as much injury as that of phosphoric acid. In this sense lime is as valuable as phosphoric acid; but inasmuch as lime is generally found in most soils in abundant quantities, or, if deficient, can be applied to the land more economically in the form of slaked lime, marl, shell-sand, &c., its presence in an artificial manure is by no means a recommendation to it.

The efficacy of manure therefore depends not only on its composition but also on that of the soil, and let us add, likewise, on the requirements of the crops intended for cultivation. It is well, also, to bear in mind that the substances which soils generally contain only in minute quantities are exactly those which plants require in much larger proportions than the constituents which abound in soils.

The efficacy of a manure consequently depends in a great measure on the amount of the more rare and valuable constituents. In estimating the probable effects of a manure, it is very important to entertain correct views with respect to the comparative value of the component parts of manures.

It has been shown by practical experience that nitrogen in the form of ammonia or nitric acid, phosphoric acid, and potash are the most efficacious and valuable constituents of all manures.

1. *Nitrogen*—in the form of ammonia, nitric acid, or animal

and vegetable matters—without doubt is the most valuable of all fertilizing substances, and ought therefore to be present in every good artificial general manure.

Ammonia, nitric acid, and more or less decomposed nitrogenized organic matters, closely resemble each other in their action. They all exercise a peculiar forcing effect, especially when supplied to the plant at an early stage of its growth: at a later period they appear much less effective. For this reason nitrogenized manures, such as guano or soot, ought to be applied to wheat, either in autumn or early in spring, immediately after the young blade has made its appearance above ground.

The effects of ammonia have been so well ascertained by numerous experiments in which it has been applied, with the exclusion of all other substances, that few practical men at the present time will hesitate to ascribe the rapid forcing effects of guano, soot, sulphate of ammonia, ammoniacal liquor of gas-works, &c., to the ammonia which they contain. These manures, as well as nitrate of soda and nitrates in general, induce a luxuriant development of leaves, and may therefore be called leaf-producing manures. Grass-land, wheat, and other grain-crops are benefited by them in a striking manner; but on account of their special action they ought to be used with caution in the case of corn-crops, and always more sparingly on light than on heavy land; otherwise, splendid straw, but little and an inferior sample of grain, will be obtained.

As yet the question, whether nitrogen is more useful to plants in the form of ammonia or nitric acid, has not been decided. As the solution of this question is of considerable practical importance, it is very desirable that the relative effects of nitrates and ammoniacal salts should be ascertained by a series of well-conducted comparative field experiments.

Animal and vegetable organic substances containing nitrogen in an unfermented state scarcely exhibit any fertilizing effects on vegetation; and it is only after their nitrogen has become changed into ammonia or nitric acid that they become powerful fertilizers. As the value of a manure depends in some degree on the rapidity of its effects, the nitrogen in fresh animal or vegetable substances is not quite so valuable as in the form of ammonia or nitric acid. Nitrogenized manures likewise appear to facilitate the assimilation of the mineral matters found in the ashes of plants. As our fields are generally deficient in ammonia or nitric acid, their presence in an artificial manure is of great importance. Nitrogen, moreover, in either of the stated combinations, is very expensive, and is therefore justly regarded as the most valuable ingredient of artificial manures.

2. *Phosphoric Acid.*—Next in value follows phosphoric acid. In artificial manures it generally exists in the form of bone-

earth or phosphate of lime. Like ammonia, phosphoric acid occurs in soils but in small quantities, and as it is required abundantly not only for grain and root-crops but for all vegetable produce raised as food for man or beast, the application of phosphatic manures to nearly all crops is followed with beneficial results. Whilst, however, phosphoric acid benefits more or less all the crops usually grown on the farm, it promotes the development of bulbous roots, such as turnips, carrots, mangold, &c., in an extraordinary manner.

3. *Potash.*—This alkali, also, is an important fertilizing constituent, inasmuch as it is largely required by all our cultivated plants, and frequently is deficient in soils. Root-crops, and herbaceous plants in particular, appear to require much potash; for which reason turnips, carrots, and other green crops are much benefited by wood-ashes, burnt clay, and liquid manure, which all contain considerable quantities of soluble potash. Potatoes especially require a good supply of potash. Much less valuable constituents of artificial manures are soda, common salt, glauber salt, magnesia, lime, gypsum, oxide of iron and silica.

Nitrogen in a proper state of combination, phosphoric acid and potash, thus principally determine the efficacy of a manure. We have seen, however, that the composition of the soil to which it is applied, and the requirements of the crop for which it is used, affect in a great measure the effects which an artificial manure is capable of producing. Other circumstances, such as a wet or a dry season, the time at which, and the mode in which, it is applied, likewise exercise a decided influence on the efficacy of a manuring substance; and it remains, therefore, for the judicious farmer to determine whether the actual fertilizing effects of an artificial manure justify the expenditure of a certain amount of money or not. But there is another consideration to which we would direct special attention, as it is often overlooked altogether by the practical man. As many artificial manures are very efficacious, the purchasers of such manures are generally quite satisfied with the results, and do not trouble themselves with the inquiry, "At what price can I obtain the different fertilizing constituents in the manure separately?" or in other words, what is its commercial value?

Hence we can explain that frequently fertilizing mixtures find purchasers at prices twice or three times as great as their intrinsic money-value. A few illustrations will show that the immediately apparent efficacy of a manure does not necessarily determine its money-value.

Nobody in his senses would think of paying the same price for lime as for guano; and yet there are instances on record in which the parallel effects realised by lime were greater than those of guano. It does not follow, however, that lime possesses a greater commercial value than guano, because under peculiarly favourable circumstances it produces more beneficial results.

Bones have been known to fail altogether on some soils, for the very obvious reason, that these soils contained already a more than sufficient supply of phosphates to meet all the wants of the plants, or because the closeness of the soil hindered the decomposition of the bone; but surely failures of that kind do not imply that bone-dust is worth nothing. A few years ago we examined an artificial manure, which was sold at 8*l.* per ton. Several testimonials from practical men expressed a very favourable opinion of its merits. However, on analysis it was found to contain mere traces of ammonia and phosphoric acid, and no less than 88 per cent. of carbonate of lime, with some charred spent tanner's bark, and sand. It was in reality a mixture of road-scrapings with some charred tan refuse, and hardly was worth the carriage from London to Gloucester. Notwithstanding its exceedingly low commercial value, its efficacy on soils greatly deficient in lime was very marked. But it is evident that the beneficial effects it produced under certain favourable conditions did not entitle the manufacturer to demand the exorbitant price at which this manure was actually sold. Again, let us suppose the money-value of Peruvian and Saldanha-bay guano were to be determined by their effects on turnips. In this case Saldanha-bay guano, which is much richer in phosphates than Peruvian, would produce the heavier crop, and we would arrive at the absurd conclusion that Saldanha-bay guano was worth more money than Peruvian. Both guanos tried upon wheat would reverse the result; for wheat is more benefited by ammonia than by phosphates; and as Peruvian guano contains 16 per cent. of ammonia, and Saldhana-bay only 4 to 5 per cent., we can readily explain the superior efficacy of the latter upon wheat. Does not this plainly show that the commercial value of guano does not necessarily depend on the effects which it is capable of producing on certain crops? Indeed, for turnips the cheap Saldanha-bay guano is more valuable than the more expensive Peruvian.

Another instance brought lately under our notice may be mentioned in illustration of the necessity of distinguishing between the practical effects of a manure and its commercial value. A guano, for which the full price of the best Peruvian was paid, on analysis was found to contain only 11 instead of 16 per cent. of ammonia and 14½ per cent. of sand. Now, though it was evident that the commercial value of this guano was considerably reduced by the latter impurity alone, we were told by the purchaser that he had obtained a better crop of wheat with this guano than with any other sample he had tried in previous years, and that he therefore considered it a first-rate article.

These examples, we trust, will be amply sufficient to prove that the practical effects which a manure is capable of producing do not necessarily determine its money-value.

The question, however, How much money is an artificial manure worth? is one of paramount importance to the farmer; and happily it is one the solution of which chemistry greatly facilitates. Any good analytical chemist can ascertain the exact amount of the different constituents of the manure, and, knowing the market-price at which they can be obtained separately, he is enabled to calculate with tolerable accuracy its commercial value. In chemical analysis the farmer therefore possesses a sure means of ascertaining, before effecting a purchase, whether the price demanded is reasonable or exorbitant.

It would lead us too far to enumerate all the reasons which could be assigned for fixing the price of some of the more frequently-occurring manuring substances which follow. However useful the subjoined table may be to the practical man, considerable latitude must be allowed in estimating the real commercial value of an artificial manure; and as all articles of commerce are subject to considerable fluctuations, it follows necessarily that the price-list subjoined can have no permanent value:—

Table for determining the Money value of Artificial Manures.

1.	Nitrogen in the form of ammonia	8*d.* per lb.
2.	Nitrogen in animal or vegetable substances	6*d.* ,,
3.	Nitrate of soda	2*d.* ,,
4.	Phosphate of lime (bone-earth)	1*d.* ,,
	or phosphoric acid alone	2*d.* ,,
5.	Soluble phosphate of lime, or bi-phosphate of lime	4½*d.* ,,
6.	Salts of potash	1¼*d.* ,,
	or potash alone	2*d.* ,,
7.	Gypsum	1*d.* per 10 lb.
8.	Lime	1*d.* per 12 lb.
9.	Carbonate of lime	1*d.* per 25 lb.
10.	Magnesia	1*d.* per 10 lb.
11.	Organic matters (humus)	1*d.* per 20 lb.
12.	Common salt	1*d.* per 10 lb.

For all practical purposes the determination of the value of the remainder of the substances which are usually indicated in the analyses of artificial manures, such as oxide of iron, alumina, silica, may be entirely neglected.

It is surprising that farmers, whilst they possess in chemical analysis a sure means of having the money value of an artificial manure correctly ascertained, should more generally be guided in their purchases by printed testimonials. These testimonials are often fictitious, and, even when genuine, cannot be relied upon in estimating the real money-value of a manure. Under favourable circumstances, the application of the most worthless manure occasionally is attended with an abundant crop; and as the dealer or manufacturer takes good care to select for publication only those opinions which are favourable to the sale of the manufactured article, and does not tell us how many expressions of opinion he has received, which, when published, would damage his business, it is evident that little dependence can be placed on printed testimonials.

It now remains for us to substantiate the truth of the assertions contained in the above pages by some instances which have lately come under our notice.

Peruvian Guano.—During the last season we have met not only with several samples of guano of inferior qualities, sold as the best Peruvian, but also with an instance of gross fraud. In order to enable the reader to form a just estimate of the difference between good and inferior guano, we will state the result of a few analyses of good Peruvian guano:—

Composition of good Peruvian Guano.

	I.	II.	III.
Water	12·420	12·00	17·40
Organic matter and ammoniacal salts*	52·980	59·11	49·97
Phosphates of lime and magnesia (bone-earth)	25·065	19·31	23·66
Alkaline salts, chiefly chlorides of potassium and sodium ..	8·262	8·13	7·43
Insoluble silicious matter (sand)	1·507	1·45	1·54
	100·236	100·00	100·00
*Yielding ammonia ..	17·215	19·30	18·96

These are excellent guanos, and yield more than the average proportion of ammonia which may be fairly expected in good Peruvian guano, the average being 16 per cent.

The following two analyses exhibit the composition of two inferior samples of guano:—

Composition of two inferior Guanos.

	I.	II.
Water	11·32	11·54
Organic matter and ammoniacal salts* ..	53·94	19·79
Phosphates of lime and magnesia (bone-earth)	30·98	42·93
Alkaline salts, chiefly chlorides of potassium and sodium	6·62	14·78
Gypsum	—	1·70
Insoluble silicious matter (sand)	14·50	9·36
	100·36	100·00
*Yielding ammonia	11·80	4·35

Neither of these two samples, we believe, was purposely adulterated. The first is genuine Peruvian guano, of an inferior description. The large amount of silicious matter (fragments of granitic rock) no doubt arises from the rock having been too closely scraped in collecting it.

The second sample, which was likewise sold for Peruvian by a Bristol firm of some reputation, at 12*l.* per ton, however, appears to be a Saldanha-bay guano, of medium quality.

If the directions given above for calculating the commercial value of manures be followed, it will be seen that the money-value of these different guanos varies considerably. Thus, for instance, whilst the first-mentioned good Peruvian guano is worth in ammonia and phosphates 15*l.* 3*s.* 8*d.* per ton, the value of the last-mentioned inferior sample is only 7*l.* 5*s.* 3*d.*, as the following calculations show:—

1 ton contains—	No. I.		No. II.	
Ammonia	385½ lbs.,	worth £12 17 0	.. 97½ lbs.,	worth £3 5 0
Phosphates ..	560 lbs.	,, 2 6 8	.. 963 lbs.	,, 4 0 3
Value		£15 3 8	.. ..	£7 5 3

We thus see that the first is cheap at 12*l.* per ton, whilst the other, sold at the same price, possessed only half the intrinsic value of the first.

Occasionally farmers are induced to buy guano, offered for sale at a reduction of its market-price, as slightly damaged. It is not safe, however, to invest money in the purchase of a manure of that description, without having ascertained by analysis the amount of damage it has sustained. But especially we would caution the agriculturist to beware of investing money in the purchase of "concentrated guano," "essence of guano," and similarly-named mixtures, which profess to be more valuable than the best Peruvian. Such an issue of guano lately has been analysed by us with the following results:—

Composition of Essence of Guano, sold at 11*l.* *per ton.*

Water	8·282
Organic matter*	13·111
Phosphates and oxides of iron and alumina †	5·947
Sulphate of lime (gypsum)	15·179
Carbonate of lime (chalk)	8·003
Chloride of sodium (common salt)	15·803
Insoluble siliceous matter, principally sand and brickdust	34·297
	100·622
* Containing ammonia	·643
† Containing phosphoric acid, ...	1·088
and equal to bone-earth	2·357

It will be observed that instead of 16 per cent. of ammonia this "essence of guano" contained only 6-10ths per cent., and instead of 20 per cent. of bone-earth only 2 and 3-10ths per cent. To make up for this deficiency, no less than 34 per cent. of sand and brickdust, 15 per cent. of gypsum, 8 per cent. of chalk, and 15 per cent. of common salt, have been added.

A more fraudulent case has scarcely ever come under our notice. The exceedingly small amount of ammonia (not quite 7-10ths per cent.) shows that, if any, a mere trace of Peruvian guano was incorporated in this worthless mixture, which, indeed, when examined under the microscope, appeared to have been compounded by mixing together gypsum, lime, sand, brick-dust, common salt, and sheep's dung. So clumsily was the mixture made that the last-mentioned ingredient could be readily identified by its characteristic globular form.

Genuine Peruvian guano, we may observe, should contain from 50 to 60 per cent. of organic matter, yielding at least 16 per cent. of ammonia, 18 to 20 per cent. of bone-earth, 6 to 8 per cent. of alkaline salts, and no more than 2 to 3 per cent. of insoluble silicious matter (sand). Genuine guano, on burning, leaves a perfectly white ash, which does not effervesce with an acid; whilst adulterated guano generally produces, on burning, a reddish-coloured ash, or a white ash, which either does not readily dissolve in acid (showing the adulteration with gypsum), or strongly effervesces with an acid (proving the adulteration with chalk).

But perhaps the easiest way to ascertain if Peruvian guano is genuine or adulterated is to weigh a bushel. If pure, it will weigh from 68 lbs. to 72 lbs. If much adulterated, considerably more, no cheap material having been discovered with which guano can be readily adulterated without increasing its specific gravity.

Nitrate of Soda.—We are glad to mention that none of the samples which we examined during the last season were in any way adulterated.

By far the most common adulteration in nitrate of soda is common salt, the presence of which can be detected, if it is contained in the nitrate in somewhat considerable quantities, by throwing some of it on red-hot coal, when it will burn with a green flame, whereas pure nitrate of soda burns with a bright yellow flame.

Soot.—The efficacy and commercial value of soot mainly depends on the amount of ammonia which it contains in combination with sulphuric acid. Commercial soot frequently is adulterated with finely-sifted coal-ashes; different samples, moreover, naturally contain variable quantities of ammonia. It is advisable, therefore, to select a sample which on an analysis exhibits the greatest amount of ammonia and the smallest of mineral or incombustible matters. The following determinations will show that the proportion of ammonia in soot varies greatly in different samples :—

100 lbs. of soot,	No. I., contained ammonia	1·872 lbs.
„ „	No. II. „ „	3·833 „
„ „	No. III. „ „	5·360 „

In a rough manner the comparative value of different samples of soot may be ascertained by mixing each with some quicklime and a little water: that which gives off the most pungent smell of ammonia will be the most valuable.

Sulphate of Ammonia is now frequently used as a top-dressing for grass, spring-wheat, and other crops, which are benefited by ammoniacal matters.

Occasionally it is adulterated with the cheap sulphate of soda or glauber-salt. A table-spoonful heated on a shovel in the grate should leave no residue, which is the case if it is adulterated with glauber-salt, or any other cheap fixed salt.

Two different specimens, on analysis, were found to contain in 100 parts :—

	I.	II.
Moisture	·11	2·17
Fixed salts	·11	3·08
Sulphate of ammonia	99·88	94·75
	100·00	100·00

No. I., it will be observed, was nearly pure sulphate, whilst No. II. contained about 5 per cent. of impurities. Sulphate of ammonia is sold at present at 18*l.* per ton; No. II. consequently was worth 18*s.* less than No. I.

Ammoniacal Liquor of Gasworks.—This refuse liquor of gasworks contains carbonate of ammonia, a little sulphide of ammonium, and traces of tarry matters, and owes its efficacy and value solely to the carbonate of ammonia.

In some localities it is a favourite manure with the farmers, whilst in others it is hardly employed at all for manuring purposes. At times of great demand, occasionally a stream of pump-water is directed into the tank in which this liquor accumulates at the gasworks. As, moreover, the amount of carbonate of ammonia naturally varies with the kind of coal employed in gasworks, it is necessary to ascertain the amount of ammonia in the liquor, in order to obtain the data from which its value may be calculated.

Two specimens of ammoniacal liquor, obtained at different times from the Cirencester gasworks, were found to contain in 100 gallons—

Ammonia, No. I.	18 lbs.
„ No. II.	27 „

At 8*d.* per lb. the ammonia in one gallon of No. I. was worth 1½*d.*, and in No. II. about 2*d.*

A considerable deduction, however, should be made for the carriage of the large quantity of water in which the carbonate of ammonia is dissolved in the gas-liquor. The expense for carriage, indeed, will amount to more than the liquor is worth, if it has to be carted away several miles from the gasworks; and even in the immediate neighbourhood of the works a penny per gallon for gas-liquor, of the strength of the second sample, is a sufficiently high price.

The price asked for the liquor was 3*d.* per gallon; but its strength having been determined by analysis, it was obtained at 1*d.* per gallon.

Shoddy is the sweepings of the mills and other mixed refuse from cloth manufactories. It is used occasionally for wheat and hops. On account of the large amount of oil (26 to 30 per cent.) which it contains it decomposes but slowly in the soil, and for this reason fails to produce an immediate effect. It should therefore be applied to the land a considerable time before the crop which it is intended to benefit has made its appearance aboveground; or better still, it should be brought to a state of fermentation by the addition of putrid urine. It varies exceedingly in composition, and consequently in value. Thus four different specimens were found to contain in 100 parts:—

	Nitrogen.	Ash.
No. I...	3·02	35·50
No. II.	2·82	25·52
No. III.	2·12	28·40
No. IV.	6·16	15·53

A ton of each sample therefore contained:—

No. I. nitrogen	67·6 lbs. worth, at 6*d.* per lb. ..	£1	13	9
No. II. „	63·1 lbs. „ „ ..	1	11	6
No. III. „	47·5 lbs. „ „ ..	1	3	8½
No. IV. „	138·0 lbs. „ „ ..	3	9	0

Though the best sample was worth almost exactly three times as much as the worst, all were sold indiscriminately at 30*s.* per ton.

Wheat-Manure, supplied by a London manufacturer at 8*l.* per ton: the composition of this manure in 100 parts is as follows:—

Water	9·65
Chloride of sodium (common salt)	68·63
Nitrate of soda	·47
Sulphate of soda	3·85
Chloride of magnesium	·67
Sulphate of ammonia	9·74
Organic matter	5·72
Sand	1·27
	100·00

It will be observed that this manure principally consists of common salt, with which is mixed some sulphate of ammonia and soda, and a small proportion of nitrate of soda. A calculation of its money-value shows that 8*l.* is too high a price for a manure of that description.

A much better wheat-manure is supplied by a well-known Bristol firm. The composition of this manure was found to be as follows:—

Composition of Wheat-Manure manufactured at Bristol.

Water	32·80
Soluble organic matter, or ammonia	12·44
Soluble or bi-phosphate of lime	6·47
Soluble fixed alkaline salts	3·70
Insoluble phosphate of lime (bone-earth)	12·60
Sulphate of lime (gypsum)	11·43
Magnesia	·02
Insoluble organic matter	15·34
Sand	5·20
	100·00
Percentage of nitrogen in manure	4·24
equal to ammonia	5·15

The proportion of nitrogenized organic matters and of ammonia in this manure is considerable. It is rich also in soluble and insoluble phosphate of lime, but contains rather too much water.

Superphosphate of Lime.—The composition of superphosphate of lime varies very much, and with it its commercial value. Some samples are prepared from fresh, others from boiled bones, and still others from bone-ash. Hence the differences in the amount of organic matter which are found in commercial superphosphate. But still greater are the differences in the proportions of soluble and insoluble phosphate of lime, two constituents which principally determine the commercial value of superphosphate.

A good sample should contain from 6 to 8 per cent. of soluble or bi-phosphate of lime, and double that amount of insoluble or bone phosphate.

The following table exhibits the composition of four samples of good superphosphate, recently sent to us for analysis:—

Composition of 100 *parts of good Superphosphate of Lime.*

	I.	II.	III.	IV.
Water	19·26	24·10	20·53	14·04
Organic matter	16 12	13·79	14·76	19·38
Soluble phosphate of lime ..	6·38	8·58	10·31	9·82
equal to bone-phosphate ..	(9·94)	(13·36)	(16·09)	(15·29)
Insoluble bone-phosphate ..	22·16	21·30	17·72	20·01
Hydrated sulphate of lime (gypsum)	25·10	20·33	28·39	24·76
Alkaline salts	5·16	6·60	1·56	2·33
Sand	5·82	5·30	6·73	6·66
	100·00	100·00	100·00	100·00
Percentage of nitrogen	1·66	not	·853	not
Equal to ammonia	2·01	determined.	1·065	determined.

The two former samples were obtained from two different Southampton manufacturers, and the two last from a Bristol manufacturer.

In the next table the analyses of two adulterated samples are given:—

Composition of two adulterated samples of Superphosphate.

	I.	II.
Water	14·40	22·03
Organic matter*	8·93	trace.
Soluble, or bi-phosphate of lime	3·60	8·55
equal to bone-earth	(5·61)	(13·33)
Insoluble, or bone-phosphate	6·83	none.
Hydrated sulphate of lime (gypsum) ..	44·20	24·42
Burned gypsum	——	40·43
Alkaline salts	2·52	2·41
Insoluble siliceous matter (principally quartz sand)	19·50	2·16
	100·00	100·00
* Containing nitrogen	1·44	·17
Equal to ammonia	1·75	·20

No. I., it will be observed, is very much adulterated with sand and gypsum, and contains only 3·6 per cent. of soluble and 6·8 per cent. of insoluble phosphate of lime.

No. II. evidently was prepared by dissolving bone-ash in sulphuric acid, and drying up the pasty mass with no less than 40 per cent. of burned gypsum.

The adulteration of sand in superphosphate is readily detected, but not that of gypsum. When bone-dust or bone-ash is dissolved in sulphuric acid, sulphate of lime or gypsum necessarily is formed; it being thus present in all samples of superphosphate, the adulteration of gypsum cannot be recognised by simple inspection; and nothing short of a quantitative determination of the amount of gypsum can decide whether superphosphate has been adulterated with gypsum, or whether it contains only the legitimate proportion which is produced in every instance when bone-dust or burnt bones are digested with sulphuric acid.

Desiccated Fish-Manure.—Under this name a manure has been sent to us for analysis, which was found to contain in 100 parts:—

Water	15·084
Organic matter*	19·643
Soluble, or bi-phosphate of lime	10·478
equal to bone-earth	(16·345)
Insoluble bone-phosphate	17·844
Hydrated sulphate of lime (gypsum)	27·552
Alkaline salts	3·000
Insoluble siliceous matter (sand)	6·399
	100·000
* Yielding ammonia	1·490

This manure, it will be observed, is in reality a superphosphate of excellent qualities, which was prepared by dissolving fish-bones and other fish-refuse in sulphuric acid.

Pilchard Refuse-Manure.—The following analysis represents the composition of the refuse-salt of pilchard fisheries:—

Composition of Pilchard Refuse-Manure.

Water	5·725
Common salt, with traces of lime, magnesia, and sulphuric acid	85·609
Pilchard scales, with fish-oil and animal matter *	6·275
Earthy impurities, principally calcareous shell sand	2·391
	100.000
* Containing nitrogen	·294
Equal to ammonia	·357

A glance at these analytical results will show that this manure contains about 85 per cent. of common salt, and 6 per cent. of pilchard scales, which will yield on decomposition only ·357 per cent. of ammonia. Its commercial value, therefore, is not greater than that of common salt (15*s.* to 18*s.* per ton), but inasmuch as it contains some shell-sand, it may be applied in preference to common salt to soils naturally poor in lime.

Bone-Black.—A sample of bone-black, the refuse of a sugar-refinery of Bristol, on analysis was found to contain in 100 parts:—

Organic matter and water	18·02
Silica and insoluble siliceous matter	17·26
Phosphate of lime	64·66
Carbonate of lime	·06
	100·00

It was offered for sale at 5*l.* 10*s.*; but as boiled bones, which contain, in addition to about the same proportion of phosphate of lime, 1½ to 2 per cent. of nitrogen, are sold at 5*l.* to 5*l.* 10*s.*, refuse bone-black is rather too dear at this price.

Heller's Fertilizing Powder.—Some time ago we examined a black powder, which, under the name of Heller's fertilizing powder, is sold at Manchester in tin canisters and packets, at various high prices.

Thus the specimen of which the subjoined analysis was made is sold at 2*s.* 6*d.* per pint, and recommended for watering shrubs and trees; for wheat, oats, and barley, seven pints of powder, costing 6*s.*, are recommended for one bushel of seed; for peas, beans, &c., six pints, costing 5*s.*; for potatoes, five pints, costing 3*s.*, &c.

In the printed circular, addressed to agriculturists, gardeners, and florists, this powder is puffed up as a new discovery in agricultural science. The circular contains some extraordinary statements. Thus it is said: "By the use of the powder an immense saving will be realised by farmers and others, who have been in the habit of using guano, bone-bust, &c., at an immense cost, and which has been found in many cases of little avail."

Again, we find the following statement: "It will be found efficacious when applied to waste and other land, which, by the medium of this powder, may be made very productive, and at a trifling expense, superseding the more costly and laborious methods hitherto required for tillage. It may also be remarked of land upon which this powder has been applied, that after the second year it need not be again used on the same land, the soil retaining its fertilizing properties."

Several favourable testimonials accompany this curious document. On analysis the powder was found to contain:—

Water	14·40
Organic matter (principally soot), yielding 1·859 of nitrogen	51·60
Bone-earth	15·56
Gypsum	5·89
Carbonate of lime	·60
Alkaline salts, chiefly common salt	5·00
Sand	7·16
	100·21

We shall leave it to the reader to decide whether or not a powder of that composition is likely to verify the above extraordinary statements. If he should be inclined to try the effects of manuring the seed instead of the land with some such powder (which we by no means recommend), he may procure it at an infinitely smaller cost by blending together soot, bone-dust, common salt, and gypsum, in the proportions indicated in the above analysis.

Economical Manure.—For some time past a manure has been advertised in almost every agricultural newspaper under the inviting name of "Economical Manure," as a cheap substitute for guano.

It is stated to be a chemical compound, in a highly "concentrated state, and to contain a large proportion of ammonia, which it also has the property of fixing in the soil, as well as the carbonic acid."

"This ingredient," it is said, "offers a good and efficient manure for all green and other crops, as well as for top-dressings, at one-third the cost of an ordinary manuring with Peruvian guano, and will produce all the results, by the application of from 1 cwt. to 1¼ cwt. per statute acre, which will cost 12*s.* to 15*s.*, while 4 cwt. of Peruvian guano (an ordinary manuring) costs 36*s.*"

Numerous testimonials, as usual, accompany these advertisements. We have carefully analysed this manure, and found it to contain in 100 parts:—

Composition of Economical Manure, 12l. per Ton.

Water	36·525
Sulphate of iron (green vitriol)	23·756
Sulphate of lime	·860
Sulphate of magnesia	·204
Bisulphate of potash	4·677
Bisulphate of soda	10·928
Sulphate of soda	15·143
Sulphate of ammonia *	2·648
Insoluble siliceous matter (sand)	5·850
	100·591
* Containing ammonia	·682

It will be observed that instead of a large proportion of ammonia the economical manure contained less than 7-10ths per cent.; and that it consists principally of green vitriol and sulphate of soda or glauber-salt, two equally cheap salts; whilst the more expensive and efficacious salts, namely, sulphate of ammonia and potash, enter but sparingly into the composition of this so-called chemical compound.

There are, besides, no less than 36½ per cent. of water, and 5½ per cent. of sand; or together 42 per cent. of valueless matters.

We have yet to learn that a manure which does not contain any phosphates is particularly useful for the turnip-crop, and wonder how the manufacturer can reconcile it with his conscience to demand 12*l.* per ton for a mixture of salts, which every farmer may obtain separately at about 4*l.*

These examples, we trust, will be regarded as sufficiently proving the fact, that whilst there are artificial manures which are equally cheap and efficacious, adulterated or inferior samples are frequently sold and bought at extravagant prices.

In conclusion, we would observe that the presentation of a chemical analysis by the dealer is in itself no guarantee of the genuineness or value of a manure. What we would recommend to the purchaser is, to demand an analysis of the dealer, and, in case he should not understand the meaning of chemical terms, to have the analysis explained by somebody who does. If satisfactory, he should order the manure according to the furnished analysis. On delivery of the manure, a sample from the bulk should be selected for analysis. A comparison of this analysis with that furnished by the dealer then will show whether or not the contract has been fulfilled, and measures can be taken accordingly.

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ON

THE CHEMISTRY OF FOOD.

BY

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ON THE CHEMISTRY OF FOOD.

We are indebted to Professor Mulder, Boussingault, Dumas, and, above all, to Liebig, for a number of elaborate and beautiful researches into the chemistry of food; and to several of our most distinguished feeders of stock, especially to Mr. Lawes, for a series of carefully conducted and highly valuable feeding experiments. But though it cannot be denied that these scientific investigations and practical experimental trials have led to the establishment of several important scientific principles, and given us clearer views of the nutritive value of food, it must be confessed that our knowledge of the mysterious process of nutrition and the adaptation of the various kinds of feeding-stuffs to particular purposes, is still in its infancy. It would be ingratitude not to acknowledge the services rendered already by the above-mentioned distinguished chemists, and by others who have laboured successfully in the field of animal physiology, but still I am bound to confess at the outset that practice is in advance of science. It may appear, therefore, useless to occupy the time of the reader by the following pages. However, considering that no scientific investigation in which the chemist or animal physiologist engages is more intimately connected with the successful practice of farming than the inquiry into the processes of nutrition and the practical value of feeding substances, I trust this paper will be found not without interest to the practical man.

Within the last few years several of our best agricultural chemists have been busily engaged in attempts to ascertain more accurately than before the composition of those substances which the farmer usually employs for the rearing and fattening of stock. Their labours have been eminently successful owing to the more advanced state of chemistry and the more refined methods of analytical processes. Unfortunately the results of their investigations are inaccessible to the majority of practical men, being scattered in isolated fragments in agricultural publications, or deposited in journals specially devoted to physiological or other strictly scientific literature. Having had frequently occasion to observe the difficulty under which the practical man labours in finding that information which he is anxious to obtain with respect to the composition and practical value of food, it has appeared to me desirable to facilitate in some measure his search for information on this subject. To this end I have collected the most trustworthy analyses, and I hope, after rejecting all those which bear upon them the impress of imperfection or impracticability, to present to you in a systematic order a sufficiently correct account of our existing knowledge of the composition and practical feeding value of the more important feeding-stuffs employed by the farmer for maintaining the animals on a farm, or for rearing and fattening of stock. With a view of lessening much that is necessarily tedious in such an account, I shall endeavour to intersperse it with some general practical remarks which the various headings will suggest, and shall conclude by pointing out a few considerations which ought to be well weighed in estimating the economical value of feeding-materials. Before entering into details, however, it will be necessary for me briefly to allude to the principal divisions of the constituents of food, and to their respective adaptation to the wants of the living animal.

If we expose to a strong heat in an open vessel wheat, oats, or barley, turnips and mangolds, clover, artificial or natural grasses, and indeed all kinds of food raised for the use of man or animals, they are dissipated for the greater part, and but a small quantity of a generally white ash is left behind. The incombustible portion, or ash, amounting rarely to more than 6 per cent. of the whole mass of the dry substance, consists principally of two classes of substances: namely, first of earthy matters, insoluble in water; secondly, of saline and soluble substances. The earthy insoluble matters, in the majority of cases, consist chiefly of a combination of phosphoric acid with lime, which, constituting two-thirds of the bones of animals, is called bone-earth. The earthy portion of the ash supplies the animal with the materials for the formation of its bony skeleton. The saline constituents of the ash of food consist chiefly of common salt and of phosphate of soda, which two combinations enter largely into the composition of blood, and likewise of salts of potash which abound in the juice of flesh. The saline matters thus supply the blood, juice of flesh, and various animal juices, with the necessary mineral constituents. The organic or combustible part of all food is composed of a great variety of organic compounds, such as starch, gum, sugar, cellular fibre, albumen, casein, gluten, &c. But all these compounds may be grouped together into two classes. The first class includes constituents rich in nitrogen, or nitrogenized matters; and the second, constituents free from nitrogen, or non-nitrogenized compounds. To the former, the nitrogenized compounds, belong:—

Vegetable albumen, a substance identical in composition with the white of egg.
Gluten or vegetable fibrin, a compound occurring in considerable quantity in wheat, and giving elasticity to the dough made with wheaten flour.
Vegetable casein, a substance identical in composition with the curd of milk.
Legumin, a peculiar vegetable principle, which derives its name from its occurrence in large quantity in peas, beans, and other leguminous seeds.

A few other nitrogenized compounds of rarer occurrence need no special mention.

To the second class, or to the non-nitrogenized substances, belong:—

1. All oily and fatty matters.
2. Starch or amylum, which constitutes the principal part of wheaten flour, oat and barley meal, rice, Indian corn, and the dry matter of potatoes.
3. Sugar, which abounds in mangolds, carrots, and turnips.
4. Gum and mucilage, constituents of every kind of food.
5. Pectin, the jelly-like substance, which is found in carrots, mangolds, turnips, and many other bulbous roots.
6. Cellular and woody fibre, substances which constitute chiefly the bulk of straw and hay, and occur abundantly in every other vegetable produce.

These, with a few other compounds of less general occurrence, constitute the class of non-nitrogenized matters. The nitrogenized compounds constitute a remarkable class of organic substances. They contain all about 16 per cent. of nitrogen and small quantities of sulphur or phosphorus, or both, and resemble each other so closely in their general properties and composition, that they can scarcely be distinguished from each other. As the type of this interesting class of compounds we may regard vegetable albumen, a substance analogous, if not identical, in properties and composition with the white of eggs. On account of the close resemblance of vegetable casein, gluten, and legumin with albumen, all the compounds of this group are often called albuminous matter, and as they all furnish by a simple chemical process a substance called protein, they are likewise frequently described as protein compounds. The discoverer of protein (Professor Mulder) was the first to suggest this name, as he regards albumen and the other albuminous substances as compounds of protein, with small and variable quantities of sulphur or phosphorus, or both. Not only are these substances nearly identical in composition and properties with each other, but they resemble so intimately animal albumen, casein and fibrin, or those materials of which the flesh and blood of animals principally consist, that they have been called with much propriety flesh or muscle forming principles. Oilcake, peas and beans, and other leguminous seeds, are very rich in flesh-forming principles; oats, barley, and wheat, likewise contain a considerable proportion of these substances. In smaller quantities they occur in roots, grass, hay, and all other kinds of feeding-stuffs. On the whole, however, the plants which serve as food to animals are, comparatively speaking, poor in albuminous compounds, but rich in starch or gum, sugar, cellular and woody fibre, or any other non-nitrogenized substance. Plants thus present the animal with a mixture in which the substance of the muscle, so to speak, exists ready-formed; for without undergoing great changes in the stomach of the animals, the albuminous compounds are readily assimilated and converted into blood and muscular fibre.

No food entirely destitute of flesh-forming constituents is capable of supporting animal life for any length of time: hence the great importance which is attached to these compounds by the physiologist. Many careful experiments have proved nearly beyond dispute the fact that the animal organism does not possess the power inherent in plants, of compounding and preparing the substance of the muscles from its elements; unless, therefore, food is presented to animals which contains ready-made muscle, they soon become emaciated and rapidly perish.

Thus it has been shown that dogs fed upon arrowroot, sugar, gum, butter, and other food, entirely destitute of flesh-forming principles, rapidly lose all flesh and die at the end of the fifth or sixth week, or a little later than they would if no food of any description were given. Similar experiments have been tried with sheep and geese. Thus Macaire and Marcet fed a sheep weighing 53 lbs. with food perfectly free from nitrogen. On the 20th day after the beginning of the experiment death occurred, and the weight of the sheep was found reduced to 31 lbs.

Tiedeman and Gmelin obtained similar results with geese: a goose weighing 6 lbs. 1 oz. was fed with sugar, and died on the 22nd day after the experiment had begun, and then weighed only 4 lbs. 8 oz. Another goose weighing 8½ lbs. was fed with starch, and a third weighing 5 lbs. 12 oz. with gum: the latter died even after 16 days, and was then found to weigh 4 lbs. 12 oz.; and the former after 27 days, when its weight amounted to only 6¼ lbs.

Practical experience, moreover, has made us acquainted with the high feeding value of oilcake, beans, and grain, articles of food very rich in albuminous compounds, and with the inferiority of food poor in nitrogenized compounds. It may therefore be laid down as a principle established both by practice and science, that the nutritive value of food depends in a great measure upon the amount of albuminous compounds which it contains.

Non-Nitrogenized Principles.—Neither the health nor indeed the life of all our domesticated animals, we have seen, can be maintained by food destitute of nitrogenized or flesh-producing matters. Though absolutely necessary to the very existence of animal life, long experience and direct experiments have proved alike that food consisting entirely of muscle-producing matters cannot support the life of herbivorous animals for any length of time. Thus a goose, it has been found by experiment, when fed with albumen or white of egg, died after 46 days, her original weight of 8 lbs. 1 oz. having sunk to 4½ lbs. Similar experiments have shown that herbivorous animals, when fed upon nitrogenized food, containing no starch, sugar, or other non-nitrogenized compound, notwithstanding the liberal supply of the highly nutritive albuminous matters, become emaciated, and die almost as soon as others fed upon food containing no nitrogen at all. Experience thus teaches that starch, fat, sugar, gum, and other organic compounds not containing nitrogen, are almost as essential to the well-being of herbivorous animals as the flesh-forming principles.

The various non-nitrogenized substances are all characterized by a large proportion of carbon, for which reason they are sometimes called carbonaceous constituents of food. Their use in the animal economy is of a two-fold character. They supply either the materials for the formation of animal fat, or they are employed to support respiration, and with it animal heat. According to the fitness and ease with which the non-nitrogenized compounds fulfil the one or the other function, they may be divided into two classes, namely, into fat-producing matters and into principles of respiration. To the first belong the fatty and oily matters which occur in all our cultivated plants, in some in larger, in others in smaller quantities. The oily and fatty vegetable substances are eminently well adapted to the laying on of fat in animals, inasmuch as the composition of vegetable fat is analogous if not identical with the several kinds of fat which form part of the bodies of animals. The fatty matters of food, without undergoing much change, are therefore readily assimilated by the animal organism, and applied when given in excess to the storing up of animal fat. Vegetable oils and fats, given along with a scanty supply of starchy food, are used to support respiration; and, on the other hand, starch, gum, and sugar, when given to fattening beasts in excess, are transformed into animal fat. There is thus no essential difference in the fatty or the starchy constituents of food, in so far as their use is concerned. According to circumstances, vegetable fatty matters are either stored up in the animal system or employed to support respiration; on the other hand, starch or sugar, which are usually employed to feed the respiration, are, under favourable conditions, changed into animal fat. The proportion of carbon in fatty matters amounts to about 80 per cent., and is much larger than in starch or sugar. On account of this deficiency in carbon the latter compounds are not so well adapted for the laying on of fat. On the other hand, all food containing much ready made fat or oil is justly esteemed for fattening beasts. The changes which starch, sugar, gum, and similarly constituted substances undergo in the animal system are readily explained. These compounds consist of carbon and water only, and on account of the simplicity of their composition are well adapted to feed the respiration. In breathing, the atmospheric air taken in by the lungs supplies the oxygen, which, combining with the carbon of starch or sugar, produces carbonic acid in abundance, which is thrown off with watery vapours in exhaling. The quantity of carbon consumed during respiration of animals varies at different times, in different species, according to rapidity of breathing and mode of living. Under all circumstances, however, it is considerable. Thus a horse, according to Boussingault, throws off daily 45 lbs. of carbon in the form of carbonic acid gas; and in the case of the cow four-ninths of the carbon contained in the daily food is consumed during the process of respiration. Animals therefore require food not merely to support or to increase the weight of their bodies, but also to furnish the necessary amount of carbon required for supporting respiration. When starch or sugar is burnt in the air, the oxygen of the latter unites with the carbon of the former, and both together are dissipated in the form of carbonic acid, with the production of much heat. The process of respiration resembles intimately the act of combustion. It is in fact a slow combustion, and, like all processes of that description, is attended with evolution of heat. The amount of heat thus generated is proportionate to the quantity of carbon consumed during respiration, and by this provision the uniform temperature of warm-blooded animals is preserved throughout winter and summer. If it were not for this constant source of heat the bodies of warm-blooded animals would soon become cold and stiff as the bodies of dead animals do. Respiration thus is necessary to supply heat to the animals.

In recapitulation of the above remarks it may be briefly stated:—

1. The earthy substances contained in food, consisting chiefly of phosphate of lime and magnesia, present the animal with the materials of which the bony skeleton of its body principally consists. They may be called, therefore, bone materials.
2. The saline substances—chlorides of sodium and potassium, sulphate and phosphate of potash and soda, and some other mineral matters occurring in food—supply the blood, juice of flesh, and various animal juices with the necessary mineral constituents.
3. Albumen, gluten, legumin, and other nitrogen-containing principles of food, furnish the animal with the materials required for the formation of blood and flesh; they are called, therefore, flesh-forming substances.
4. Fats and oily matters of the food are employed to lay on fat, or to support respiration and animal heat.
5. Starch, sugar, gum, and a few other non-nitrogenized substances, consisting of carbon, hydrogen, and oxygen, are used to support respiration—(hence they are called elements of respiration), or they produce fat when given in excess.
6. Starch, sugar, and the other elements of respiration alone cannot sustain the animal body.
7. Albumen, gluten, or any other albuminous matter alone does not support the life of herbivorous animals.
8. Animals fed upon food, deficient in earthy phosphates or bone-producing principles, grow sickly and remain weak in the bone.
9. The healthy state of an animal can only be preserved by a mixed food which contains flesh-forming constituents as well as heat-giving principles, and earthy and saline mineral substances in proportion, determined by experience and adapted to the different kinds of animals, or the particular purpose for which they are kept.

Having explained the different purposes to which the proximate constituents of food are applied in the animal economy, I shall now proceed by directing attention to the composition of the principal varieties of feeding-stuffs which are used by the British farmer either for rearing or fattening of stock.

1. LINSEED.—According to Anderson, linseed contains in 100 parts:—

Moisture	7·50
Oil	34·00
Nitrogenized or flesh-forming constituents	24·44
Substances not containing nitrogen—	
Heat-producing principles	30·73
Mineral matters (ash)	3·33

The ash of linseed is rich in phosphates or in bone-materials. It will be observed that linseed is both very rich in ready-made fat and in muscle-producing substances. Linseed, for these reasons, is admirably well adapted both for young growing stock and fattening beasts. There is, indeed, hardly any other feeding substance which equals linseed in nutritive power. Whether it is superior to good linseed-cake or not is a point on which there seems to exist some diversity of opinion among practical feeders. Good oil-cake, we shall see presently, contains a larger amount of flesh-forming principles, and may therefore be better adapted to feeding when it is wished rather to produce muscle than to lay on fat. For fattening beasts, I am decidedly of opinion linseed is preferable to cake, for it contains a much larger proportion of ready-made fat than cake, and the oils and other constituents of linseed have not undergone those changes to which they are so liable in the preparation of linseed-oil and cake, especially if heat is employed in the manufacture of the latter. Whilst linseed is always free from any rancid oil, and consequently possesses a sweet, agreeable taste, the oil still remaining in the cake is often so rancid that the cake becomes unpalatable to beasts. In linseed, moreover, the albuminous substances and the mucilage exist in a more soluble condition than in cake; heat, which renders these substances less soluble, being generally employed in the extraction of the oil from the seed. Linseed thus is more easily digested than cake—a circumstance of considerable importance in estimating the nutritive value of both.

Made into a jelly, linseed is often given to weaned calves, who are very fond of it, and get on upon it remarkably well. Linseed-jelly, mixed with chaff, meal, and sliced turnips, is also recommended by practical feeders as one of the best mixtures that can be given to fattening beasts; and for the preparation of this well-known mess many prefer linseed to the cake.

In using linseed for feeding or fattening purposes, however, care ought to be taken not to allow too large a proportion of seed to the animals, inasmuch as linseed-oil exercises, when given in quantities, a relaxing effect on the bowels. This effect of linseed-oil no doubt is beneficial when the seed is given with much chaff or other not very digestible food; but it counteracts the rapid fattening of the animal if too much linseed is mixed with the chaff or other dry food.

As a rule, therefore, linseed ought to be given to fattening beasts more sparingly than cake, which, containing much less oil than the seed from which it is obtained, is not so liable to cause the effects which an overdose of seed produces.

2. Oil-cakes (Linseed, rape, poppy, cotton-seed, and mustard-cake).—Of all the various oil-cakes which are used for feeding or fattening, linseed-cake is employed most abundantly, and justly prized as the most valuable kind of cake. Rape-cake, lately imported in large quantities from the Continent, where rape is much grown, is now also much employed for feeding cattle and sheep. Poppy-cake likewise is a valuable feeding-material, but occurs only occasionally in trade.

Of the other varieties of oil-cake which are now and then offered for sale, we will only mention here cotton-seed-cake and mustard-cake. Cotton-seed-cake has lately been introduced into England, and been found a very valuable feeding-substance. Allusion is made here to mustard-cake because it is frequently sold as rape-cake, which it indeed resembles closely.

Many samples of these different oil-cakes, from various countries, have lately been analysed by Professors Way, Anderson, and myself. These analyses have shown that the composition of even one and the same kind of cake is liable to considerable fluctuations, arising principally from the mode in which the cake is manufactured. But as the observed differences in composition do not materially affect the practical deductions to which the analyses of oil-cakes give rise, I shall content myself by presenting in the subjoined table the average composition of oil-cakes, as calculated from a large number of analyses:—

Average Composition of Oil-cakes.

	Linseed Cake.	Rape Cake.	Poppy Cake.	Cotton-seed-cake.	Mustard Cake.
Moisture	12·44	10·68	11·63	11·19	11·90
Oil	12·79	11·10	5·75	9·08	6·69
Nitrogenized or flesh-forming principles	27·28	29·53	31·46	25·16	23·48
Substances not containing nitrogen—					
Heat-giving substances ..	41·36	40·90	38.18	48·93	52·14
Mineral matters (ash) ..	6·13	7·79	12·98	5·64	5·79
	100·00	100·00	100·00	100·00	100·00

The ash which remains behind on burning any of these oil-cakes contains a large proportion of phosphoric acid, lime, and potash. Oil-cakes thus contain much of the constituents of which the bony skeleton of the animal body is made up.

In explanation of the preceding table, I would observe that the differences in the proportion of oil and flesh forming matters obtained in the analyses of different samples of cakes of the same kind are quite as large, or sometimes even larger, than the differences which are here stated in the average composition of cakes of different kinds. Thus, for example, it is stated in the above tabulated results that linseed-cake contains on an average 12·79 per cent. of oil, and rape-cake 11·10 per cent.; but it does not follow from this that linseed-cake always contains more oil than rape-cake. Generally it does contain somewhat more oil; but, on the other hand, there are some rape-cakes which contain more oil than most linseed-cakes.

This remark, indeed, applies to all feeding materials. We are too much in the habit of speaking of the composition of cake, turnips, mangolds, or hay, as if these complex mixtures of substances were simple chemical combinations, presenting us with a fixed composition, whereas the differences in two samples of the same produce are often very great. Any one who has tried practically the nutritive effect of good and badly-made hay, or of turnip grown on good turnip land and on peaty land, knows well that there is a vast difference between hay and hay, or a turnip and a turnip. In speaking of the nutritive value of any article of food too precise a language is out of place; and it is simply absurd to draw nice general conclusions from small differences which the analyses of different feeding-materials may have yielded. Unless the differences are strongly-marked and constantly observed in a great number of cases, it is unsafe and irrational to attach a precise nutritive value to different articles of food, especially if the opinion is founded solely upon analytical data, and not corroborated by actual experimental trials: for, after all, the chemical composition alone of an article of food is insufficient to determine its practical value.

The history of oil-cakes presents us with a striking example illustrating the truth of these remarks.

Good rape-cake contains nearly as much oil, and even more flesh-forming principles, than the best linseed-cake. In a purely chemical point of view, rape-cake ought to be, if not superior, at least quite as nutritious as linseed-cake. Notwithstanding a certain diversity of opinion entertained by practical men respecting the merits of both cakes, I believe an extended experience of the best stock-farmers has proved beyond dispute that, weight for weight, linseed-cake is much better than rape-cake. It is not, I believe, difficult to account for this superiority.

In the first place, I would observe that rape-cake has a strong, hot taste, and is not liked much by cattle ; whereas good linseed-cake is sweet and agreeable to the taste. The natural appetite of animals, to a certain extent, it strikes me, may be regarded by us as a guide to what is good or bad for them ; and though a dislike for a certain food may be overcome in time, I believe an animal will never get on so well upon food which it naturally dislikes as upon another for which it is greedy.

2. In the second place, it may be stated that the oil of rape-seed naturally possesses a disagreeable smell and taste, and is apt to turn rancid. Rape-cake, which contains about 11 per cent. of this oil, thus has a great tendency to become rancid, and consequently unpalatable to cattle.

3. In the third place, I would observe that rape-cake contains a much larger proportion of indigestible woody fibre than linseed-cake ; whereas the latter contains on an average about 9 per cent. of woody matter, the former contains as much as 20 per cent., and even more.

As stated above, the proportion of substances not containing nitrogen is almost as great in rape as in linseed-cake. But as in the case of rape-cake, about one half of these substances consists of woody fibre, which is of no use whatever to the animal, and as linseed-cake contains only 9 per cent. of indigestible fibre, it is clear that linseed-cake must be superior in this respect to rape-cake.

4. Lastly, it may be as well to bear in mind that good linseed-cake is hardly if ever adulterated, and seldom mixed with foreign seeds, whereas rape-cake contains more frequently than any other description of cake the seeds of weeds. The experienced eye will find no difficulty in recognizing in rape-cake the seeds of mustard, charlock, and other weeds. Some of these seeds possess a disagreeable, bitter, or acrid taste, and possibly may possess poisonous properties.

I would direct special attention to the fact that rape-cake often contains a considerable proportion of mustard-seed. In Belgium, France, and Germany, where much rape is grown on account of the oil which its seed furnishes, the fields are often very foul with mustard ; but as mustard itself is grown on account of its oleaginous seed, no care is taken to eradicate it, and hence it is that rape-cake contains frequently much of the expressed seeds of mustard. This admixture is injurious if the cake is given to fattening cattle in any quantity. Sheep do not appear to be affected so much as cattle by mustard. Rape-cake, which is rarely quite free from mustard, therefore may be given with greater advantage to sheep than to cattle.

The fact that some samples of rape-cake are full of mustard and others comparatively free from it, perhaps accounts also for the differences of opinion which farmers who have tried rape-cake entertain respecting its feeding value. Rape-cake, free from foreign seeds and well kept, may indeed be a valuable and economic article of food; but there is often rape-cake sold to farmers which contains so much mustard that it is difficult to decide whether the cake is rape or a mustard cake. Such cake should never be used for feeding-purposes, for it is certain to injure the condition of the animals to which it is given.

Linseed-cake is manufactured in England; in America, France, Holland, Germany, Russia, Belgium, Italy, and other continental countries, and imported into England under names denoting the country in which they have been manufactured.

English cake is generally preferred to all other varieties, and fetches usually a higher price in the market. However, much depends upon the fancy of the purchaser: thus, whilst in most localities English cake is preferred to American, I am told the latter fetches a higher price in Exeter market than English.

This circumstance led me to ascertain whether there was any real difference in the composition of two samples of American and English linseed, which were bought last season at Exeter, with a greater expenditure of 1*l.* per ton for the American cake. Without mentioning the details of my examination, I will briefly state that both cakes were of excellent qualities, and that the differences in the composition were so trifling, that both might be regarded, for practical purposes, to be identical. Neither in their chemical composition, nor in their physical properties, could any marked difference be detected which might account for the higher price paid for the American cake in Exeter market.

English cake, it is true, generally, though by no means always, contains more oil than American or other foreign linseed-cakes, but the differences in the relative proportions of oil in various cakes are too inconsiderable to account for the higher estimation in which English or American cakes are held. The superior value of home-made and also of most American cakes, I believe depends not so much on their chemical composition, as upon the condition in which the cake is found in the market. Good home-made cake, and most American cakes, are always dry and free from mouldiness and rancid smell; they have an agreeable flavour and mild sweet taste, and for these reasons are more highly appreciated than other foreign cakes, which generally possess a more or less rancid smell and taste, and appear often mouldy or damp. Moreover, on the Continent the extraction of the oil from the linseed is frequently aided by a degree of heat which impairs the flavour, and consequently deteriorates the value, of the cake. On the whole, greater care is bestowed on the manufacture of English cake than on that of cakes imported from other countries. Besides, English cake is prepared only in a limited extent, and always finds a ready sale; no time is therefore allowed for the oil still remaining in the cake to become rancid. Foreign cakes, on the contrary, in passing through different hands before they reach their final destination, often attain a considerable age, which impairs the flavour and deteriorates greatly the value of the cake, especially if it is kept in damp places. Like all organic substances, oil-cake is subject to changes, which do not improve its qualities. The fresher it is, the better it is adapted for feeding-purposes.

Foreign linseed-cakes, with the exception of American cakes, are seldom so free from foreign seeds as English cakes, and this no doubt is another reason why home-made cake is more highly prized by the practical feeder.

Mustard-cake.—Mustard-cake is imported into England from the Continent, and extensively used in the hop districts of Kent as an excellent manure. This is the only safe use to which it can be applied. But as it is much cheaper than linseed or rape-cake, and resembles intimately rape-cake, it is now and then mixed with this cake by unscrupulous dealers; and instances are on record that even pure mustard-cake has been sold as rape-cake.

When mustard-cake or rape-cake, containing much mustard-seed, is made with cold water into a thick paste, and this paste is kept for about six hours, it acquires the pungent taste and strong irritating smell peculiar to mustard-seed. This pungent taste and smell is caused by the volatile or essential oil of mustard, which is produced under the influence of cold water from myronic acid and myron, two inodorous and tasteless constituents of mustard-seed. Myronic acid is peculiar to mustard; myron resembles in its chemical characters albumen, and, like all nitrogenized substances, gradually changes myronic acid in the presence of cold or moderately warm water and air into the essential oil of mustard. At the temperature of boiling water myron becomes coagulated, and in this state is incapable of changing myronic acid into essential oil of mustard.

Mustard-cake in a dry state has neither a pungent smell nor taste. It resembles, indeed, in its appearance, smell, and taste, rape-cake. If mustard-cake is kept, however, for some time in the mouth, it tastes bitter, acrid, and becomes more and more pungent the longer it is kept between the teeth. On grinding, moreover, it gives a bright yellow powder, altogether different in appearance from powdered rape-cake. By these characters, and especially by the pungent smell which mustard-cake developes when mixed with cold water, mustard-cake is readily distinguished from rape-cake.

Neither mustard, nor rape-cake containing much mustard-seed, should ever be used for feeding-purposes, inasmuch as the pungent oil of mustard, which is gradually generated in the stomach of the beast fed upon such cakes, acts as an irritating poison, which may cause serious injury, and even death.

Not long ago a case of poisoning with mustard-cake was brought under my notice. A gentleman residing at Bibury, a village eight miles from Cirencester, Gloucestershire, lost three valuable beasts, which had been supplied with a small quantity of oil-cake, a portion of which was forwarded to me for examination. The day before the cake was given to them they were perfectly well; and after having eaten some cake, they became suddenly so ill that two died before the veterinary surgeon could administer an efficient remedy. The examination showed that the cake which caused this mischief was either altogether a mustard-cake, or contained a very large proportion of mustard-seed. There remained thus no doubt that the beasts died from the effects of the pungent oil of mustard.

As the formation of the essential oil of mustard is prevented by boiling water, and rape-cake often contains mustard-seed in a degree which cannot but exercise an injurious effect upon the health of animals, I would recommend to mix all rape-cake with boiling water before it is given to cattle. By this simple means any injury which rape-cake containing mustard-seed would produce, when not submitted to the action of boiling water, may be entirely prevented; but unless the water is in a state of perfect ebullition, it will fail to accomplish this desirable end.

In conclusion of these remarks on oil-cakes, I suggest to purchasers of cake to submit it to the following easy tests:—

1. Examine a bit of the cake as to its taste and smell; observe that it is fresh, and free from any mouldiness.

2. Examine another piece with a common pocket lens. This examination will show whether the cake is a linseed or rape-cake, inasmuch as the form of linseed and rape-seed are widely different. Much more difficult is it to distinguish by the lens mustard from rape cake.

3. Mix in a tumbler about 1 oz. of the cake, broken into small pieces, with 6 oz. of cold water. Good linseed-cake will form, under these circumstances, a stiff, agreeably-tasting jelly, without

separating any water. Rape-cake will become much less gelatinous, and separate a yellowish or brown, rather bitter-tasting liquid. Mustard-cake likewise will become little gelatinous, and separate a brown liquid, which possesses the characteristic taste and smell of essential oil of mustard. Rape-cake, fraudulently or naturally mixed with mustard-seed, under these circumstances will exhibit a similar behaviour to that of mustard-cake, and by the degree of pungency of taste and smell when compared with pure mustard-cake, will afford means of estimating approximately the amount of mustard which the cake contains.

3. LEGUMINOUS SEEDS (Beans, Peas, Lentils, Tares, and Fenugreek-seed).—The average composition of beans, peas, and lentils, as calculated from the analyses made by Horsford, Krocker, Einhof, Braconnot, and Boussingault, is represented in the following table :—

	Peas.	Field-beans.	Lentils.
Legumin	23·4	23·3	24·0
Starch	37·0	36·0	38·0
Fatty matters	2·0	2·0	2·5
Grape sugar	2·0	2·0	8·5
Gum	5·0	4·5	
Woody fibre	10·0	10·0	12·0
Pectic acid	4·0	4·0	
Inorganic matters (ash)	2·5	3·4	2.5
Water	14.1	14·8	12·5
	100·0	100·0	100·0

These analytical results, arranged in groups, yield the following average numbers :—

	Peas.	Field-beans.	Lentils.
Nitrogenized or flesh-forming constituents ..	23·4	23·3	24·0
Substances free from nitrogen, fitted to support respiration, and to lay on fat—			
a. Starch, sugar, fat, &c.	50·0	48·5	52·0
b. Woody fibre	10·0	10·0	9·0*
Ash (bone-materials)	2·5	3·4	2·5
Water..	14·1	14·8	12·5
	100·0	100·0	100·0

Still more recently, several kinds of beans, peas, lentils, and tares have been analysed by Dr. Anderson. The principal results of this analytical investigation are contained in the subjoined table :—

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* No separate determination of woody fibre having been made, this number has been assumed in this calculation.

	Water.	Legumin.	Fatty Matters.	Starch, Sugar, &c.	Ash.
Field-beans grown in Scotland ..	12·56	27·05	1·58	55·69	3·12
Foreign field-beans	12·21	23·49	1·51	59·65	3·14
Hopetoun tares, grown in 1849 ..	16·09	28·32	1·49	52·61	1·49
Summer tares, foreign	12·13	26·54	1·26	57·72	2·35
Winter tares, foreign	15·80	26·73	1·59	53·04	1·59
Grey field-peas	11·94	24·25	3·30	57·99	2·52
Maple peas	13·63	19·43	1·72	63·18	2·04
Large Scottish lentils	12·51	24·25	1·78	58·78	2·68
Lentils, foreign	12·31	24·57	1·51	58·82	2·79

It will be observed that all these leguminous seeds resemble each other so closely in composition, that for all practical purposes, the nutritive value of beans, peas, lentils, and tares, in so far as this can be determined by analysis, may be considered identical.

The characteristic constituent of leguminous seed is legumin—a substance which resembles so intimately the cheesy matter or curd of milk, that it has received the name of vegetable casein.

Tares appear to be richer in legumin than the other leguminous seeds, which, on an average, contain as much of this flesh-producing substance as good oil-cake.

As far as the power of animals to lay on muscle is dependent on the nitrogenized principles contained in the food they eat, peas, beans, lentils, and tares are as valuable as oil-cakes, but as they contain much less oil, and are not so easily digested, these leguminous seeds are decidedly inferior to oil-cake as feeding materials. Compared with oats, barley, and other grain, peas, beans, lentils, &c., are much richer in muscle-producing matter. Notwithstanding this, oat and barley meal are much better adapted to fattening beasts than peas or bean-meal.

In feeding experiments with sheep, fed in conjunction with bulky food upon lentils and upon oats, I found oats to produce a much more considerable increase in the life-weight of the sheep than an equal weight of lentils. These, and other actual feeding experiments, have convinced me that the increase in life-weight of the animals is much more regulated by the supply of easily-digested starchy or fat-producing food than by the supply of the muscle-forming constituents of food, provided the latter are furnished in the food in moderate quantities.

Beans, peas, and lentils, given to fattening beasts in moderate quantities, along with some bulky food, such as chaff, hay, or roots, I believe constitute a valuable addition to such food. Beyond a certain degree, however, the supply of beans or bean-meal cannot be increased with advantage; for the well-known binding and heating effects of peas and bean-meal show plainly that the organism of cattle requires for its healthy condition a more bulky and less concentrated food.

On the other hand, working horses cannot be fed with a more economic or better food than with beans—a fact which is well known to every farmer. The high feeding value of beans, when given to working horses, is readily explained by the great waste of muscle to which working horses are subject, which waste is readily and cheaply supplied in beans, a food very rich in flesh-forming constituents.

Fenugreek-seed.—Fenugreek is the seed of Trigonella fœnugræcum—a plant which is much grown in the East, on account of the leguminous seed which it furnishes. This seed has a peculiar aromatic smell, and a slightly bitter aromatic taste. Ground into a powder, it is frequently employed by veterinary surgeons to promote the appetite of horses, and also enters into the composition of curry-powder. Fenugreek-seed is used occasionally in England for feeding purposes, and is described by those who have tried it as an excellent food for fattening sheep. A sample of the seed forwarded to me by E. Holland, Esq., of Dumbleton, on analysis yielded the following results:—

Composition of Fenugreek-seed.

Water	11·994
Flesh-forming constituents (chiefly legumin)	26·665
Starch, gum, and pectin	37·111
Sugar	2·220
Fatty matters and some essential oil	8·320
Woody fibre	10·820
Inorganic matter (ash)	2·870
	100·000

It will be observed that, like all leguminous seeds, fenugreek contains a large amount of flesh-forming constituents: it resembles thus in composition peas, beans, and lentils, but is distinguished from these seeds by a much larger amount of fatty matters. This fully explains its high value as a feeding-material. I am informed by Mr. Holland, that sheep to which it was given got fat in a remarkably short time. But a curious circumstance connected with the use of this seed was brought to light, which showed that, notwithstanding its highly nutritious qualities, it is unavailable for practical purposes. It was found, namely, that it imparted a peculiar disagreeable flavour to the mutton. This flavour no doubt arose from the essential oil contained in the seed. An interesting example is thus presented to us in fenugreek-seed, which illustrates that purely practical considerations will often guide the feeder of stock in the selection of food, and that it is impossible to predict by analysis, or even by actual feeding experiments, the economic value of an article of food.

4. CEREAL GRAINS (Wheat, Oats, Barley, Indian Corn).—The average composition of the cereal grains generally employed in England for feeding purposes is stated in the following table:—

	Wheat.	Oats.	Barley.	Indian Corn.
Water	12·26	13·09	14·65	14·96
Flesh-forming constituents	11·64	11·85	10·84	11·27
Heat and fat producing substances ..	68·74	63·34	68·31	67·48
Woody indigestible fibre	2·61	9·00	3·45	5·02
Inorganic matters (ash)	1·75	2·72	2·75	1·27
	100·00	100·00	100·00	100·00

It deserves to be noticed likewise, that wheat and barley contain but a small proportion of ready-made fatty matters (about 2 per cent.), whereas oats contain on an average 6 per cent. of oil, and Indian corn from 8 to 9 per cent.

In these analyses the indigestible fibre has been determined separately, and thus a much better opinion of the real nutritive value of grain can be formed than would have been possible had the determination of this important point been neglected. In explanation of these results, it must be stated that the proportion of woody fibre does not vary much in different samples of wheat, but that exceedingly great differences in the amount of woody fibre are observed in barley, and especially in oats.

I am inclined to attribute to this circumstance the diversity of opinion which is entertained by practical feeders respecting the feeding properties of barley and oats. There can indeed be no doubt that in some localities of England, where the soil is peculiarly well adapted to the growth of barley, this farinaceous grain is superior in nutritive power to oats; and, on the other hand, a district remarkable for good and plump oats may well produce more nutritious oats than barley. We are thus not entitled to say in a general way that oats are more nutritious than barley, or *vice versâ.* Both opinions may be perfectly true in special instances. In Scotland, celebrated for excellent oats, farmers are much more in the habit of giving oats to fattening beasts than the English farmer, who prefers barleymeal to oatmeal for that purpose. There are good grounds for this choice of food, for English oats, I believe, are generally greatly inferior in nutritive power to Scottish oats. On the other hand, the soil and climate of Scotland appear to be much less favourable to the production of a fine sample of barley than the rich barley soils which abound in several counties of England. The examination of several samples of English barley, of Scotch and of English oats, has indeed shown me that the predilection for oats by the farmers of Scotland, and that for barley by the English feeder of stock, is not merely a whim, but is founded on strictly scientific principles. Thus I found good English barley quite as rich in nutritive substances as Scottish oats, and a marked difference in the oats produced by the two countries. To mention only one instance, I would observe that, in the analysis of two samples of oats, one grown in England, the other in Scotland, I found about 1 per cent. more flesh-forming substances in the Scottish oatmeal than in the English. The white Scottish oats, moreover, weighed 42 lbs. per bushel, and yielded, per 100 lbs., 71½ lbs. of fine oatmeal, and 28½ lbs. of husk; whilst the black English oats weighed only 37½ lbs. per bushel, and yielded 66¼ lbs. of oatmeal and 33¾ lbs. of husk. The superior oats were sold 4*s.* 6*d.* dearer per bushel; but notwithstanding this higher price, a careful calculation, of which I need not mention here the particulars, has led me to the conclusion that it is more economical to pay 4*s.* 6*d.* more per bushel for the Scottish oats than for the English. This example thus affords a direct proof of the correctness of the prevailing opinion that Scottish oats are better than English, and I have no doubt that in those counties of England where barley or barleymeal is preferred to oats or oatmeal by the farmer, the former will be found in reality superior to the oats grown in the district. It likewise shows that a practice generally followed by good farmers in one locality ought not to be lightly discarded, and that apparent practical differences of opinion often may be reconciled by judicious scientific inquiry.

The analyses mentioned above show that the cereal grains have an analogous composition, and contain a large amount of fat-producing substances. This general character distinguishes them from the leguminous seed, containing a large proportion of flesh-forming principles, and therefore not so well adapted to fattening purposes as oat or barley meal. Indian corn, in addition to much starch, which in the animal system is readily transformed into fat, contains more ready-made fatty matter than any other cereal grain. For this reason, Indian corn is superior in fattening properties to oats and barley, and deserves to be employed as a food for fattening beasts much more extensively than it is at present. It also has been found a most useful fattening material when given to pigs.

As it may be interesting to compare the composition of wheaten flour and oatmeal with that of the whole grain, I append the following tabular statements. The results represent the composition of wheaten flour and oatmeal used as human food. In the best fine Scottish oatmeal as much as 18 per cent. of muscle producing substances has been detected, whereas in the finest wheaten flour the proportion of these substances hardly amounts to 9 per cent. The more thoroughly the husk is removed by sifting from oatmeal, the more nutritious it becomes; but the contrary holds good in the case of wheaten flour. Hence it follows that bread made of the whole grain of wheat is more nutritious than bread made of the finest flour.

Average Composition of Wheaten Flour and Oatmeal.

	Wheaten Flour.	Oatmeal.
Water	13·50	13·09
Flesh-forming substances	11·48	15·68
Fat and heat producing substances ..	73·52	68·17
Woody fibre	0·68	1·89
Mineral matters (ash)	0·82	1·17
	100·00	100·00

5. REFUSE GRAIN, &c. (Bran, Malt-dust, Barley-dust, Oat-dust, Rice-dust, Brosemeal Brock, Pea-hulls, Distillery refuse, Brewers' Grains).—The above materials are the more important refuse substances from various grains, which are now and then employed for feeding-purposes.

In the subjoined table the composition of several materials of that description is given:—

	Bran.	Malt-dust.	Oat-dust.	Brose-meal Brock.	Pea-hulls from Maple Peas.	Barley-dust.	Rice-dust.
Water	12·86	6·24	9·31	9·12	10·12	11·03	12·02
Flesh-forming constituents . .	13·80	25·62	6·92	10·66	5·64	8·46	6·69
Oil	5·56	59·44	3·21	1·65	0·66	3·47	5·61
Woody fibre	11·50		72·86	75·08	80·21	69·73	36·67
Starch, gum, &c.	50·17						25.52
Inorganic matters (ash) . . .	6·11	8·70	7·70	3·49	3·37	7·31	13·49
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

These refuse grains are naturally liable to considerable variations in composition. Some of them possess a high feeding value, whilst others are not characterized by great nutritive qualities, but all may be used by the farmer with more or less considerable advantage for feeding-purposes.

Bran.—It is worthy of observation, that bran contains a larger amount of fatty matters and flesh-forming constituents than the whole grain of wheat, and for these reasons it constitutes a valuable refuse. It is mostly given to horses, but may also be given with advantage to milking-cows and to pigs. Bran contains much less woody fibre than most of the above-enumerated refuse materials, and, with the exception of malt-dust, is decidedly the most nutritious of the substances in that list.

Malt-dust is obtained in the preparation of malt from barley. The small rootlets or radicles which protrude from sprouted barley, after being kiln-dried, constitute the commercial malt-dust, which of course can only be obtained in limited quantity. It is used principally as food for sheep, which like it, and get on upon it very well, if it is supplied to them along with some hay and turnips.

Malt-dust, it will be observed, contains a very large amount of flesh-forming constituents, and ought therefore to possess a very high nutritive value. However, I believe its practical value as an article of food, though by no means distinctly ascertained, is much smaller than from its composition might be expected.

Barley-dust is used to some extent in feeding cattle, as well as pigs. Now and then it can be obtained at a price which renders it a much more economical food than barleymeal, from which it is distinguished principally by a larger amount of woody fibre.

Oat-dust.—Mixed with chaff and thoroughly saturated with water, this refuse is extensively employed either alone or with roots in feeding cattle. It ought not to be given to cattle in a dry state, for it is very slowly moistened, and therefore apt to form dust-balls in the stomach. When given to dairy cows it is found to increase the yield of butter.

Brose-meal Brock is the refuse obtained in making peasmeal. Brose-meal brock contains about as much muscle substance as barley-meal, but too much indigestible fibre, and too little starch and fat-producing substances. It is employed in feeding, as a cheap substitute for bean-meal, and used like it.

Pea-hulls from Maple-peas.—In making split peas, the outer skins of the pea are removed and sold under the name of pea-hulls, as another cheap substitute for bean-meal. Pea-hulls, however, do not possess much value as a feeding-substance, and ought therefore not to be employed unless they can be got at a very cheap rate.

Rice-dust, or rice-meal, is a refuse obtained in cleaning rice for our market, and consists of the husks and external layers of rice, together with fragments of the grain itself, with some accidental foreign impurities. In Liverpool it is produced in large quantity, and often sold much above its real value.

Rice-dust is said to increase the yield of milk, and is employed therefore to some extent by Cheshire farmers for feeding milk-cows. It has also been found to be a good food for fattening pigs.

The above analysis shows that rice-dust is rich in ready-made fat, a circumstance which fully explains its adaptation for fattening purposes. It will be observed likewise that rice-dust contains nearly half its weight of woody fibre, which possesses little or no value as a feeding substance. Compared with oats and barley, these grains appear to be at least twice as valuable as rice-dust.

Brewer's Grains.—A hundred pounds of fresh brewer's grains were found, by Johnston, to contain—

Water	75·85
Gum	1·06
Husk	21·28
Flesh-forming substances ..	0·62
Inorganic matter, or ash ..	1·19

Brewer's grains weigh about 46 lbs. to the bushel, and cost 3*d.* to 3½*d.* for this weight. The proportion of water present in brewer's grains is large, whilst that of flesh-forming constituents is but small. The greater part of the solid matter consists of husk. For these reasons the nutritive value of this refuse does not range high. But though the solid part consists principally of husk, the experience of cow-feeders shows that it is not by any means worthless for the feeding of milk-cows. Turnips are the kind of food most usually given with brewer's grains; half a bushel of the latter and 25 lbs. of turnips per day being a fair allowance for a dairy cow.

Distillery Refuse.—The liquid which remains in the still after the spirit has been drawn off, when the fermented worts are distilled by the spirit manufacturer, is called distillery refuse. It is a muddy, more or less thick, liquid, which may be turned to profitable account by employing it as a feeding material for cows or pigs. Kept for some time in tanks it turns sour, and in this state is generally given to pigs. It is highly esteemed by dairymen, according to whose experience it promotes the abundant secretion of rich milk.

Two samples of distillery refuse from a whisky distillery in the island of Islay were analysed some years ago by the late Professor Johnston. The one contained the more fluid portion of the liquid, the other the thicker matter, which subsides in the tank into which the liquid runs when it is first drawn from the stills.

The following results were obtained in the analysis of these two liquids:—

1*st*, *The thinner liquid.*—An imperial gallon left on evaporation 4235 grains, or every 5 gallons contained upwards of 3 lbs. of dry solid matter, consisting of—

	Grains.
Organic matter	3871
Inorganic matter	364
	4235

The organic matter consisted of some unchanged sugar and gum, and albuminous and other compounds in a more or less altered condition.

The inorganic part was found, upon analysis, to contain—

	Per Cent.	Or an Imperial Gallon contained
		Grains.
Potash and soda, with a little sulphuric and muriatic acid	46·24	168
Phosphoric acid (combined in the liquid with some of the above potash and soda)	21·67	79
Phosphates of lime and magnesia (bone-ash)	28·88	104
Silicious matter	2·56	10
Loss	·65	3
	100·	364

It will be observed that every gallon of this refuse contained upwards of ½ lb. of organic nourishment, and a very considerable proportion of phosphates—constituents which occur in large quantities in milk.

2*ndly*, *The thicker liquid*, which is deposited at the bottom of the tank, is of sufficient consistence to be given alone as food for pigs.

An imperial gallon of this liquid left 10,884 grains of dry solid matter, or no less than 3 lbs. of dry food in every 2 gallons.

This solid matter consisted of

	Grains.
Gum, sugar, albuminous and other organic compounds	10,290
Inorganic matters (ash)	594
	10,884

The inorganic matter, or ash, was found to contain—

	Per Cent.	Or an Imperial Gallon contained
		Grains.
Potash and soda, with a little sulphuric and muriatic acid	38·36	226
Phosphoric acid (combined in the liquid with potash and soda)	24·35	145
Phosphates of lime and magnesia (bone-ash)	15·90	94
Silicious matter	20·95	124
Loss	·44	5
	100·00	594

Like the thinner liquid, the thicker is rich in phosphates and in organic substances which tend to produce milk.

Professor Johnston remarks on these analytical results:—"It may be interesting to present a comparative view of the relative proportions of water and of organic and inorganic matters in each of the liquids, and in turnips of average constitution. 100 lbs. of each contain these three kinds of matter nearly in the following proportions:—

	Turnips.	Distillery refuse.	
		Thick.	Thin.
Water	89	85¼	93½
Organic matter	10⅕	14	6
Inorganic matter	⅘	¾	½
	100	100	100

"This table shows that, both as respects the organic and inorganic constituents, the thin liquid is equal in nutritive value to half its weight of turnips; and the thicker liquid to fully its own weight of the same root."

These analyses thus fully demonstrate the value of this refuse as food, especially for dairy cows.

6. ROOTS (Potatoes, Parsnips, Carrots, Swedes, Mangolds, and Turnips).—All the roots which are grown as food for man or beast are distinguished from most articles of food described above by a large amount of water. The proportion of water in roots varies in the different species from 75 to 90 per cent., and it is principally on account of the small amount of solid matter that roots are much less nutritious than an equal weight of most of the feeding materials which have been described above.

We shall mention first the composition of potatoes; then state that of carrots and parsnips; next, that of mangolds; and lastly, in a separate table, the average composition of swedes and turnips.

Potatoes.—The different species of potatoes vary considerably in composition, and even one and the same variety of potatoes, when grown on different soils, or with different manures, or, in short, under different circumstances, will exhibit great variation in its composition. Since this is the case, it would be of no practical value to transcribe here the analyses which have been made with the various species of potatoes that are cultivated in this country. We shall, therefore, leave these details unnoticed, and state at once the average composition of potatoes, as calculated from a great number of the most trustworthy analyses.

Average Composition of Potatoes, in round numbers.

	In Natural State.	Calculated Dry.
Water	75·0	..
Starch	15·5	62·0
Fatty matters	·2	·8
Gum and sugar, &c.	3·0	12·0
Albumen and casein	2·3	9·2
Fibre	3·0	12·0
Inorganic matters (ash) ..	1·0	4·0
	100·0	100·0

Arranged in groups according to the chief classes of food-constituents, the average composition of potatoes may be expressed as follows:—

	In Natural State.	Calculated Dry.
Flesh-forming constituents	2·3	9·2
Substances free from nitrogen, and fitted to support respiration or to lay on fat:—		
a. Starch, sugar, &c.	18·7	74·8
b. Fibre	3·0	12·0
Inorganic matters (ash)	1·0	4·0
Water	75·0	..
	100·0	100·0

It follows from these average results that good potatoes consist of ¾ of water, and ¼ of solid matter. Occasionally the proportion of water in potatoes rises as high as 80 per cent.: the best mealy potatoes often, on the contrary, contain but 70 per cent., and even 68 per cent. of water. With the variations in the amount of water and solid matter, the proportions of the various constituents composing the solid matter must, of course, be subject to more or less considerable variations. Thus, whilst one sample of potatoes yields from 15 to 16 per cent. of starch, another may yield only 12 per cent.; or whilst one kind contains 2½ per cent. of flesh-forming constituents, another contains only 1½ per cent. On account of these variations in composition it is extremely difficult to attach a precise nutritive value to potatoes. No kind of agricultural produce is liable to greater changes in composition,—a circumstance which, I believe, well explains the diversity of opinions which practical men entertain with respect to the feeding qualities of potatoes. But though it is impossible to state in precise language what is the feeding value of potatoes, it may be observed that they are beyond dispute the most valuable of all roots grown for food, and especially well adapted for fattening purposes.

In general it may be remarked in this place, that for all practical purposes the comparative nutritive value of different roots may be estimated with tolerable accuracy by the amount of water which the various species contain. Following this simple rule we obtain, as the most nutritious of roots, potatoes; next follow parsnips, then carrots, after which mangold follows; next we have swedes, and last turnips. Practical experience, if I am not mistaken, has shown that the different roots follow each other as regards their nutritive value in the same order, namely,—1. Potatoes; 2. Parsnips; 3. Carrots; 4. Mangolds; 5. Swedes; 6. Turnips.

Parsnips and Carrots.—Parsnips and carrots are justly esteemed as valuable feeding-substances, which are in this country generally given to pigs or to horses. Not long ago I submitted both kinds of roots grown on the farm attached to the Royal Agricultural College to a minute analysis. The calcareous soil in the neighbourhood of Cirencester, on the whole, is not favourable to the growth of these roots, it being in most instances too stony and too shallow: the roots for this reason remain comparatively small; and though on some of the better soils as much as 30 tons are grown, 18 tons per acre are deemed a good average crop of parsnips or carrots in this part of the country.

The results of these analyses are contained in the subjoined table:—

	Parsnips.		White Belgian Carrots.	
	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	82·050	..	87·338	..
Cellular fibre	8·022	44·691	3·471	27·412
Ash united with the fibre ..	·208	1·159	·145	1·145
Insoluble albuminous compounds	·550	3·064	·169	1·334
Soluble casein	·665	3·704	·498	3·934
Gum and pectin	·748	4·166	·885	6·989
Salts insoluble in alcohol	·455	2·535	·293	2·314
Sugar	2·882	16·055	6·544	51·682
Salts soluble in alcohol	·339	1·888	·409	3·230
Ammonia in state of ammoniacal salts	·039	·184	·008	·063
Starch	3·507	19·537	..	..
Fatty matters	·546	3·041	·203	1·604
	100·005	100·025	99·963	99·707

According to these detailed results the general composition of fresh and dry parsnips and carrots may be represented as follows:—

	Parsnips.		White Belgian Carrots.	
	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	82·050	..	87·338	..
Nitrogenised organic substances, capable of producing flesh ..	1·280	7·27	·667	5·268
Substances not containing nitrogen, fitted for support of animal heat and the formation of fat	15·738	87·54	11·250	88·442
Inorganic matters (ash)	·932	5·19	·745	6·290
	100·000	100·00	100·000	100·000

A comparison of these numerical results with each other will show:—

1. That there is a general resemblance in the composition of parsnips and carrots.

2. That parsnips, however, differ in composition from white carrots by containing less sugar, the deficiency of which is replaced by starch, a substance not occurring in carrots.
3. That white Belgian carrots generally contain 5 to 6 per cent. more water than parsnips. Thus fresh parsnips contain on an average 18 per cent. of solid substances, whilst fresh carrots on an average contain but 12 per cent. Hence the greater nutritive value of parsnips as compared with carrots.
4. That parsnips contain twice as much ready-formed fat as carrots. They ought, therefore, to be superior as a fattening material in the feeding of stock.
5. That the proportion of cellular fibre in parsnips is very much greater than in carrots. In both it is large.

The cellular or woody fibre in parsnips, carrots, turnips, mangolds, and swedes, must not be regarded as useless in the animal economy, for there can be little doubt that the soft and young fibres of these roots are readily converted in the stomach of animals into gum and sugar, and applied in the system to feed the respiration, or for the laying on of fat. Compared with turnips we find that parsnips contain 6 to 8 per cent. less water, and with mangolds 5 to 6 per cent. less. There is thus nearly twice as much dry solid matter in parsnips as in turnips, and consequently a ton of parsnips ought to go as far as a fattening material as two tons of white turnips.

Mangolds.—Mangolds have been analysed by Professor Way, Johnston, Wolff, and myself, but as it will be of no practical utility to mention these various analyses in detail, I shall leave them unnoticed, and state at once the average composition of good mangold wurtzel, which has been calculated from 13 published analyses of this root:—

	In Natural State.	Calculated Dry.
Water	87·78	..
Flesh-forming constituents ..	1·54	12·60
Woody fibre	1·12	9·16
Sugar	6·10	49·91
Pectin, gum, &c.	2·50	20·45
Inorganic matters (ash) ..	·96	7·88
	100·00	100·00

Mangolds, it will be observed, contain on an average as much water and dry matters as carrots, and, on the whole, are almost as nutritious as carrots, if they are given to fattening beasts after a few months' keeping. When newly taken out of the ground mangold wurtzels contain a peculiar acrid substance, which has a tendency to scour animals fed upon the fresh root. Although it has not yet been shown whether or not this acrid principle disappears on storing away mangolds for some time, it is a well known fact that, after a few months' keeping, mangolds have not this tendency to scour, and are much more nutritious than in a fresh state. The superior fattening value of stored mangolds, when compared with the fresh root, may be due to the absence of this acrid principle in old roots, but doubtless it must be attributed also to the larger amount of sugar which stored mangolds contain. An examination of fresh and old mangolds, namely, has shown me that, on keeping, the pectin in the fresh roots is gradually transformed into sugar, which appears to be more conducive to the rapid fattening of beasts than pectin. For these reasons mangold wurtzel ought not to be supplied to animals before the latter end of December or the beginning of January.

Before stating the composition of turnips and swedes I would draw attention to the remarkable fact, which perhaps may be new to some, that mangolds appear to be about the worst description of roots that can be given to sheep. Two years ago I found this to be the case, when feeding various lots of sheep, with a view of ascertaining practically the relative value of different feeding materials. For several days the sheep refused to eat the sliced mangolds, and were content with the small quantity of hay which was given to them at the same time, and only after 4 weeks they became in some degree reconciled to the taste of mangolds, but did not get on well upon this food. Although these sheep were supplied with a fixed and limited quantity of hay, and as much sliced mangolds as they would eat, I found at the end of four months that they had not increased a single pound, whilst my experimental sheep fed upon swedes and hay increased on an average at the rate of 2½ lbs. per week. On further inquiry I have learned that this observation is confirmed by many practical feeders. Mangolds, therefore, ought not to be given to sheep. This peculiarity of mangolds thus shows that a feeding substance which, like this root, is justly esteemed on account of its fattening properties when given to beasts, may not possess any great nutritive value when given to sheep. Another direct proof is here afforded of the fact, that the chemical composition of food does not solely determine its adaptation to a particular purpose, for, like mangolds, other feeding materials may be rich in nutritive substances, and valuable when given to fattening beasts, whilst it does not agree at all with the constitution of sheep.

Turnips and Swedes.—The composition of different kinds of turnips, and consequently their nutritive value, present us with great variations. But inasmuch as one and the same variety, when grown upon different soils, often presents us with quite as great variations in the amount of the various constituents which are found in general in turnips or swedes, we cannot attach a fixed nutritive value to each variety of turnip. Indeed practical experience has shown that in one locality a particular kind of turnip succeeds better, and is found to go further as an article of food, than another variety, whilst the same kind of turnip which is much appreciated in one place is held in very low estimation by the farmers of another district. It is thus, strictly speaking, incorrect to pronounce one kind of turnip to be always less or more nutritious than another. The following table exhibits at a glance the variations that we meet with not only in the compositions of different kinds of turnips, but also in that of one and the same kind.

TABLE showing the Proportion of Water, Solid Matter, Flesh-forming Substances, and Ash, in different kinds of Turnips.

		Percentage of Water.	Percentage of Dry Matters.	Percentage of Flesh-forming Matters.	Percentage of Ash.
Dr. Anderson.	Purple-top yellows, grown in East Lothian in 1849:				
	With farmyard manure	91·20	8·80	1·127	·63
	With farmyard manure and guano ..	89·72	10·28	1·581	·64
	With guano alone	92·50	7·50	1·060	·64
	Aberdeen yellows, grown in Perthshire:				
	In 1849, on clay land	91·19	8·81	1·217	..
	,, on black do.	90·47	9·53	1·094	..
	,, on hill do.	90·57	9·43	1·769	..
	In 1850, on clay do.	94·26	5·74	·681	..
	,, on black do.	90·59	9·41	1·044	..
	,, on hill do.	93·99	6·01	·962	..
	White globe turnips, grown in Lothian in 1849:				
	With farmyard manure	91·41	8·59	1·358	·910
	With farmyard manure and guano ..	92·20	7·80	1·198	·838
	With guano alone	92·85	7·14	1·279	·830
	Swedes grown in Perthshire :				
	In 1849, on clay land	90·58	9·42	·987	..
	,, on black do.	88·78	11·22	1·137	..
	,, on hill do.	87·12	12·88	1·781	..
	In 1850, on clay do.	92·73	7·27	·769	..
	,, on black do.	92·78	7·22	·619	..
	,, on hill do.	92·78	7·22	·919	..
Dr. Voelcker.	Swedes grown at Cirencester in 1852 ..	89·80	10·20	1·174	·744
	,, ,, ,, ..	89·46	10·54	1·443	·623
	,, ,, ,, ..	91·00	9·00	..	·635
	,, ,, 1853 ..	86·15	13·85	2·006	·654
	,, ,, ,, ..	86·33	13·17	1·862	·641
	,, ,, ,, ..	87·20	12·80	1·875	·558
	,, ,, ,, ..	87·40	12·60	1·712	·655
	,, ,, ,, ..	88·11	11·89	1·643	·628
	,, ,, ,, ..	88·35	11·65	1·593	·498
	,, ,, ,, ..	88·60	11·40	1·737	·548
	,, ,, ,, ..	87·28	10·72	1·593	·516
	,, ,, ,, ..	89·96	10·04	1·712	·639
	White globe, grown at Cirencester in 1852	90·43	9·57	1·143	·628
	,, ,, ,,	90·38	9·62	..	·620
	Norfolk bell ,, ,,	92·28	7·72	1·737	1·021

On account of these variations, which are often observed in one and the same species of turnips, it is difficult to fix precisely the nutritive value of these roots. The following average analyses must, therefore, be regarded simply as illustrations of the proximate composition of some kinds of turnips:—

Proximate average Composition of some kinds of Turnips.

	Analysed by Dr. Voelcker.			Analysed by Dr. Anderson.	
	White Globe.	Norfolk Bell.	Swedish Turnip.	Purple-top Yellows.	Aberdeen Yellows.
Water	90·430	92·280	89·460	91·200	90·578
Flesh-forming substances	1·143	1·737	1·443	1·117	1·802
Fatty matters..	not	deter	mined.	·103	·441
Sugar, pectin, gum, &c.	5·457	2·962	5·932	4·333	4·181
Woody fibre	2·342	2·000	2·542	2·607	2·349
Inorganic matters (ash)	·628	1·021	·623	·640	·649
	100·000	100·000	100·000	100·000	100·000

On an average, turnips thus contain from 89 to 92 per cent. of water, and 8 to 12 per cent. of dry solid matter. Swedes, usually, though by no means always, contain less water than any other variety of turnips; they are generally firmer and keep better than white turnips. On the whole swedes are more nutritious than other species of this root. In white and yellow turnips the percentage of water is generally higher, and averages 90 or 91 per cent. The nutritive value of turnips is often estimated by the amount of nitrogen which they contain. The best roots, however, do not always contain a very high percentage of nitrogen, and it is therefore impracticable to determine the nutritive value of these roots by the amount of nitrogen which they contain. Mr. Lawes, of Rothamsted, indeed, has shown lately in some well-conducted feeding experiments, that those turnips which are richest in nitrogen are by no means the most nutritious. The influence which the soil exercises on the qualities of swedes and turnips is well known to practical men. Thus roots grown on peaty or very stiff clay soils are not near as good as others of the same kind grown on good turnip loam. The climate and season likewise in a remarkable degree affect the qualities of turnips. As these roots succeed best in a moist climate, we can explain why they produce a more abundant and nutritious crop in Scotland than in the south of England.

Another circumstance which affects the qualities of turnips is the mode of growth. Roots grown rapidly, generally speaking, are not as nutritious, and do not keep so well as turnips, the growth of which is not forced so rapidly by stimulating manures.

It has been asserted that turnips grown with guano are less nutritious than those grown with farmyard manure, and Dr. Anderson's analyses indeed appear to countenance this very prevalent opinion. However, this must be received with considerable latitude, for although it is quite true that many turnips grown with guano are very watery, and therefore not very nutritious, it does not follow that invariably roots grown with farmyard manure are more valuable. It depends entirely on the nature of the soil and the quantity of guano employed, whether a watery root is produced or not. As far as our present experience goes, it would follow that a crop of turnips raised entirely by means of a large amount of Peruvian guano is watery, and does not keep well; whereas no difference in the qualities is observed in roots grown with farmyard manure and turnips raised with guano, if this manure is sparingly employed and the land is in good condition. Peruvian guano, moreover, for economical reasons, ought not to be used in large quantities for raising a crop of turnips, as it is apt to produce abundance of tops at the expense of the bulbs. The cheaper Saldanha Bay guano, however, which contains a very large amount of phosphates, or those constituents which benefit root-crops in a special manner, may be used with advantage, and no fear need be entertained that this description of guano will produce a watery root.

7. Green Food (Natural Grasses).—The nutritive value of the various natural grasses and of green food in general was formerly determined simply by ascertaining what preparation of substances, soluble and insoluble in water, green food contained. The green food was considered the more nutritious, the greater the proportion of substances which it yielded to water. In this way Sinclair endeavoured to determine the nutritive value of most natural and artificial grasses. The method employed by Sinclair, however, is very defective, and yields results which are inconsistent with practical experience. Sinclair's method of analysis and results thus are obsolete, and have to be rejected. The more refined methods of chemical investigation with which we are at present acquainted, and the increased knowledge of the process of nutrition, have enabled Professor Way to supply the agriculturist with a series of trustworthy analyses of most natural and artificial grasses. The details of this important investigation are recorded in the 'Journal of the Royal Agricultural Society of England,' 1853, part i., p. 171.

The following tables exhibit the composition of a number of the most frequently occurring natural grasses in a recent state and in a dried condition:—

Natural Grasses in a Fresh State.

	Water.	Albuminous or Flesh-forming Principle.	Fatty Matters	Respiratory Principles: Starch, Gum, Sugar.	Woody Fibre.	Mineral Matter or Ash.	Date of Collection.
Anthoxanthum odoratum—Sweet-scented vernal grass	80·35	2·00	·67	8·54	7·15	1·24	May
Alopecurus pratensis—Meadow foxtail-grass . . .	80·20	2·44	·52	8·59	6·70	1·55	June
Arrhenatherum avenaceum—Common oatlike grass .	72·65	3·54	·87	11·21	9·37	2·36	July
Avena flavescens—Yellow oatlike grass	60·40	2·96	1·04	18·66	14·22	2·72	June
,, pubescens—Downy oat-grass	61·50	3·07	·92	19·16	13·34	2·01	July
Briza media—Common quaking-grass	51·85	2·93	1·45	22·60	17·00	4·17	June
Bromus erectus—Upright brome-grass	59·57	3·78	1·35	33·19		2·11	June
,, mollis—Soft brome-grass	76·62	4·05	·47	9·04	8·46	1·36	May
Cynosurus cristatus—Crested dogstail-grass	62·73	4·13	1·32	19·64	9·80	2·38	June
Dactylus glomerata—Cocksfoot-grass	70·00	4·06	·94	13·30	10·11	1·54	,,
Ditto, seeds ripe	52·57	10·93	·74	12·61	20·54	2·61	July
Festuca duriuscula—Hard fescue-grass	69·33	3·70	1·02	12·46	11·83	1·66	June
Holcus lanatus—Soft meadow-grass	69·70	3·49	1·02	11·92	11·94	1·93	,,
Hordeum pratense—Meadow barley	58·85	4·59	·94	20·05	13·03	2·54	July
Lolium perenne—Darnel grass	71·43	3·37	·91	12·08	10·06	2·15	June
,, italicum—Italian rye-grass	75·61	2·45	·80	14·11	4·82	2·21	June
Phleum pratense—Meadow catstail-grass	57·21	4·86	1·50	22·85	11·32	2·26	..
Poa annua—Annual meadow-grass	79·14	2·47	·71	10·79	6·30	·59	May
,, pratensis—Smooth-stalked meadow-grass . . .	67·14	3·41	·86	14·15	12·49	1·95	June
,, trivialis—Rough-stalked ditto . . .	73·60	2·58	·97	10·54	10·11	2·20	,,
Grass from water-meadow	87·58	3·22	·81	3·93	3·13	1·28	April
Ditto, second crop	74·53	2·78	·52	11·17	8·76	2·24	June
Annual rye-grass	69·00	2·96	·69	12·89	12·47	1·99	,,

Natural Grasses in a Dry State.

	Albuminous or Flesh-forming Principle.	Fatty Matters.	Respiratory Principles: Starch, Gum, Sugar.	Woody Fibre.	Mineral Matter o Ash.
Anthoxanthum odoratum—Sweet-scented vernal grass	10·43	3·41	43·48	33·36	6·32
Alopecurus pratensis—Meadow foxtail-grass . . .	12·32	2·92	43·12	33·83	7·81
Arrhenatherum avenaceum—Common oatlike grass .	12·95	3·19	38·03	34·24	11·59
Avena flavescens—Yellow oatlike grass	7·48	2·61	47·08	35·95	6·88
,, pubescens—Downy oat-grass	7·97	2·39	49·78	34·64	5·22
Briza media—Common quaking-grass	6·08	3·01	46·95	35·30	8·66
Bromus erectus—Upright brome-grass	9·44	3·33	82·02		5·21
,, mollis—Soft brome-grass	17·29	2·11	38·66	36·12	5·82
Cynosurus cristatus—Crested dogstail-grass	11·08	3·54	52·64	26·36	6·38
Dactylis glomerata—Cocksfoot-grass	13·53	3·14	44·32	33·70	5·31
Ditto, seeds ripe	23·08	1·56	26·53	43·32	5·51
Festuca duriuscula—Hard fescue-grass	12·10	3·34	40·43	38·71	5·42
Holcus lanatus—Soft meadow-grass	11·52	3·56	39·25	39·30	6·37
Hordeum pratense—Meadow barley	11·17	2·30	46·68	31.67	6·18
Lolium perenne—Darnel grass	11·85	3·17	42·24	35·20	7·54
,, italicum—Italian rye-grass	10·10	3·27	57·82	19·76	9·05
Phleum pratense—Meadow catstail-grass	11·36	3·55	53·35	26·46	5·28
Poa annua—Annual meadow-grass	11·83	3·42	51·70	30·22	2·83
,, pratensis—Smooth-stalked meadow-grass . . .	10·35	2·63	43·06	38·02	5·94
,, trivialis—Rough-stalked ditto . . .	9·80	3·67	40·17	38·03	8·33
Grass from water-meadow	25·91	6·53	32·05	25·14	10·37
Ditto, second crop	10·92	2·06	43·90	34·30	8·82

In explanation of these tables, it may be observed that most of the grasses here mentioned were analysed when in flower; they were collected in 1849 from meadows in the neighbourhood of Cirencester.

Natural and artificial grasses are much more nutritious when in a young state than at the period when they are in full flower, inasmuch as the woody fibre increases towards the period of maturity so extremely rapidly, that often a few days' difference in the time of cutting grass for hay greatly affects the nutritive value of the latter. For this reason, perhaps, it would have been better to submit all the grasses to analysis at haymaking time. However, a good many grasses have been examined at that period, and we are thus enabled to form an opinion of the qualities of the hay which these grasses will produce.

The differences exhibited in the above-mentioned analytical results are considerable in some instances, and clearly point out the inferiority of some grasses. It must be borne, however, in mind, that the same grass which here has furnished a large amount of woody indigestible fibre and little fat or albumen, when grown on another soil or reaped earlier, will, no doubt, give different results. We require, indeed, a large number of analyses of grasses before we can speak decisively of the comparative nutritive value which they severally possess. Still Professor Way's analyses afford useful indications respecting the feeding value of some natural grasses, especially if we assume in each the same amount of water. Hay on an average contains 14·3 per cent. of water. If we calculate the above results by assuming in each case 14·3 per cent. of moisture, we obtain the composition of the hay which each grass would produce.

The subjoined table in which this calculation has been introduced enables us still better to compare the relative merits of these grasses:—

Composition of Hay, containing 14·3 per cent. of Water.

	Flesh-forming Matters.	Fat.	Respiratory Principles.	Woody Fibre.	Ash.
Anthoxanthum odoratum—Sweet-scented vernal grass	8·94	2·92	37·27	31·17	5·42
Alopecurus pratensis—Meadow foxtail-grass . . .	10·56	2·50	36·96	29·00	6·69
Arrhenatherum avenaceum—Common oatlike grass .	11·10	2·73	32·60	29·35	9·93
Avena flavescens—Yellow oatlike grass	6·41	2·24	40·35	30·81	5·90
,, pubescens—Downy oat-grass	6·83	2·05	42·67	29·69	4·47
Briza media—Common quaking-grass	5·21	2·58	40·24	30·26	7·42
Bromus erectus—Upright brome-grass	8·09	2·85	70·30		4·47
,, mollis—Soft brome-grass	14·82	1·81	33·14	30·96	4·99
Cynosurus cristatus—Crested dogstail-grass	9·51	2·83	45·12	22·59	5·47
Phleum pratense—Meadow catstail-grass	9·74	3·04	45·73	22·68	4·53
Dactylis glomerata—Cocksfoot-grass	11·60	2·69	37·99	28·89	4·55
Ditto, seeds ripe	19·78	1·34	22·74	37·13	4·72
Festuca duriuscula—Hard fescue-grass	10·37	2·86	34·65	33·18	4·65
Holcus lanatus—Soft meadow-grass	9·87	3·05	33·64	33·69	5·46
Hordeum pratense—Meadow barley	9·57	1·97	40·01	27·15	5·30
Lolium perenne—Darnel grass	10·16	2·72	36·21	30·17	6·46
,, italicum—Italian rye-grass	8·66	2·80	49·56	16·94	7·76
Poa annua—Annual meadow-grass	10·14	2·93	44·30	25·90	2·43
,, pratensis—Smooth-stalked meadow-grass . . .	8·87	2·25	35·88	32·59	5·09
,, trivialis—Rough-stalked ditto	8·40	3·15	34·43	32·60	7·14
Grass from water-meadow	22·21	5·60	27·47	21·55	9·03
Ditto, second crop	9·36	1·77	37·63	29·40	7·56
Mean	9·40	2·56	38·54	29·14	5·84

According to these analyses, the natural grasses may be grouped together in the following three classes, which, however, are not separated from each other by definite lines of demarkation:—

Grasses of Superior Quality.	Grasses of Medium Quality.	Grasses of Inferior Quality.
Lolium italicum — Italian rye-grass. Poa annua — Annual meadow-grass. Hordeum pratense — Meadow barley. Cynosurus cristatus — Crested dogstail-grass. Dactylis glomerata — Cocksfoot-grass. Bromus mollis — Soft brome grass. Phleum pratense—Meadow catstail-grass.	Anthoxanthum odoratum — Sweet-scented vernal grass. Alopecurus pratensis — Meadow foxtail grass. Arrhenatherum avenaceum — Common oat-like grass. Lolium perenne—Darnel grass. Poa pratensis—Smooth-stalked meadow-grass. Poa trivialis — Rough-stalked meadow-grass.	Avena flavescens—Yellow oat-like grass. Avena pubescens—Downy oat-grass. Briza media — Common quaking-grass. Bromus erectus—Upright brome-grass. Festuca duriuscula—Hard fescue grass. Holcus lanatus—Soft meadow-grass.

The above analyses refer to grasses in a wild state; in a cultivated condition there can be no doubt many will exhibit a different composition. Thus I found in a specimen of Italian rye-grass, grown on a well-manured soil, 12·75 per cent. of flesh-forming substances and 8·61 per cent. of ash, calculated for the substance in an air-dry state, whilst Professor Way obtained only 8·66 per cent. of flesh-forming matters and 7·76 per cent. of ash in the analysis of air-dry Italian rye-grass, grown in a wild state.

It is further worthy of observation that the grasses of irrigated meadows are much more nutritious than those of non-irrigated meadows. This, no doubt, is due to the disappearance of inferior grasses from irrigated meadows, but perhaps also to the circumstance that the grass on such meadows is always cut earlier than on ordinary meadows.

8. ARTIFICIAL GRASSES.—Under this head we have to consider the composition of the various kinds of clover, sainfoin, lucerne, vetch, rib-grass, Burnet, and of millefoil.

We possess three series of analyses of artificial grasses. The most complete series has been undertaken by Professor Way, the second by Dr. Anderson (in 'Transactions of Highland Society,' March, 1853, p. 440), and the third by myself (in 'Journal of Highland Society,' July, 1853, p. 56). As these are the only analyses that have been made with artificial grasses, and as the results obtained by Way, Anderson, and myself somewhat differ, I shall give the analyses of each experimenter separately in a tabulated form:—

Composition of Artificial Grasses in Natural State. By Professor Way.

	Water.	Albuminous or Flesh-forming Principles.	Fatty Matter.	Respiratory Principles: Starch, Gum, Sugar.	Woody Fibre.	Mineral Matter or Ash.	Date of Collection.
Trifolium pratense—Red clover	81·01	4·27	·69	8·45	3·76	1·82	June 7
,, pratense perenne—Purple clover	81·05	3·64	·78	8·04	4·91	1·58	,, 4
,, incarnatum—Crimson clover . .	82·14	2·96	·67	6·70	5·78	1·75	,, 4
,, medium—Cow-grass	74·10	6·30	·92	9·42	6·25	3·01	,, 7
Ditto, second specimen	77·57	4·22	1·07	11·14	4·23	1·77	,, 21
Trifolium procumbens—Hop trefoil . .	83·48	3·39	·77	7·25	3·74	1·37	,, 13
,, repens—White trefoil	79·71	3·80	·89	8·14	5·38	2·08	,, 18
Vicia sativa—Common vetch	82·90	4·04	·52	6·75	4·68	1·11	,, 13
,, sepium—Bush vetch	79·90	4·64	·58	6·66	6·24	1·98	,, 9
Onobrychis sativa—Sainfoin	76·64	4·32	·70	10·73	5·77	1·84	,, 8
Medicago lupulina—Black medich . . .	76·80	5·70	·94	7·73	6·32	2·51	,, 6
,, sativa—Lucerne	69·95	3·83	·82	13·62	8·74	3·04	..
Plantago lanceolata—Rib-grass	84·75	2·18	·56	6·06	5·10	1·35	May 28
Poterium sanguisorba—Burnet	85·56	2·42	·58	6·85	3·44	1·15	,,
Achillea millefolium—Millefoil	..	10·34	2·51	45·46	32·69	9·00	,,
	79·68	3·98	0·75	8·39	5·31	1·88	

The following analyses of various kinds of clover were made by Dr. Anderson. The clovers were grown in the garden of Messrs. Lawson, of Edinburgh. The specimens submitted to analysis were collected when the plants had come into full flower, which was, in the case of crimson clover, in the middle of August, and in the case of the rest, in the middle of September:—

Composition of different kinds of Clover. By Dr. Anderson.

	Percentage in the Fresh Clover.				Percentage in Dry Clover.	
	Water.	Dry Substances.	Ash.	Nitrogenized Substances.	Ash.	Nitrogenized Matters.
Red clover—Trifolium pratense:						
1. From English seed	85·30	14·70	1·30	2·31	8·90	15·87
2. From German seed (from the Rhine) .	81·68	18·32	1·49	2·81	8·15	15·50
3. From French seed	83·51	16·49	1·95	2·25	11·82	13·56
4. From American seed	79·98	21·02	1·58	2·87	8·05	..
5. From Dutch seed	..	..	..	..	8·82	12·43
Cow-grass—Trifolium medium:						
Variety, Duke of Norfolk	77·39	22·61	2·73	2·25	12·09	10·19
,, common	81·76	18·24	1·92	3·19	10·53	14·37
Crimson clover—Trifolium incarnatum:						
From French seed	82·56	17·44	1·88	3·25	10·81	18·56
Yellow clover—Medicago lupulina:						
From English seed	77·38	22·62	2·02	3·50	8·95	15·44
From French seed	78·60	21·40	1·75	2·94	8·18	13·69
Lucerne—Medicago sativa	80·13	19·87	2·49	3·06	11·77	15·50

The artificial grasses analysed by myself were all grown in small beds of the same unmanured field at Cirencester, and the specimens were collected in August and September, just at the time when they began to enter into flower. The following table contains the results of this investigation:—

a. Composition of Artificial Grasses in Natural State. By Dr. Voelcker.

	I. Red Clover.	II. White Clover.	III. Yellow Clover.	IV. Alsike Clover.	V. Bokhara Clover.	VI. Lucerne.	VII. Sainfoin.	VIII. Vetch.	IX Plantain
Water	80·64	83·65	77 57	76·67	81·30	73·41	77·32	82·16	80·79
Soluble in water—									
a. Organic substances	6·35	4·98	8·26	4·91	6·80	9·43	8·00	6·07	8·38
b. Inorganic substances	1·55	1·13	1·40	1·33	1·54	2·33	1·20	1·07	1·26
Insoluble in water—									
a. Impure vegetable fibre	11·04	9·80	12·17	16·36	10·01	14·08	12·95	10·23	9·00
b. Inorganic matters (ash)	·42	0·44	0·60	0·73	·35	0·75	0·53	0·47	0·57
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

b. Constituents arranged in Groups.

Water	80·640	83·65	77·570	76·670	81·300	73·41	77·320	82·16	80·790
Flesh-forming matters	3·606	4·52	4·481	4·825	3·281	4·40	3·512	3·56	2·481
Heat and fat producing substances	13·784	10·26	15·949	16·445	13·529	19·11	17·438	12·74	14·899
Inorganic matters (ash)	1·970	1·57	2·000	2·060	1·890	3·08	1·730	1·54	1·830
	100·000	100·00	100·000	100·000	100·000	100·00	100·000	100·00	100·000

a. Composition of Artificial Grasses in Dry State.

Soluble in water—									
a. Organic substances.	32·79	30·46	36·83	21·05	36·36	35·47	35·28	34·02	43·64
b. Inorganic substances	8·01	6·91	6·24	5·70	8·23	8·76	5·29	5·99	6·55
Insoluble in water—									
a. Impure vegetable fibre	57·02	59·94	54·26	70·13	53·53	52·95	57·09	57·35	46·85
b. Inorganic matters (ash)	2·18	2·69	2·67	3·12	1·88	2·82	2·34	2·64	2·96
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

b. Constituents arranged in Groups.

Flesh-forming substances	18·64	28·31	20·00	20·69	17·56	16·56	15·50	20·00	12·94
Heat and fat producing matters	71·17	62·09	71·09	70·49	72·33	71·86	76·87	71·37	77·55
Inorganic substances (ash)	10·19	9·60	8·91	8·82	10·11	11·58	7·63	8·63	9·51
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

In explanation of these results it is to be observed that the crude woody fibre constitutes the part insoluble in water. It cannot, therefore, be compared with the woody fibre obtained in Professor Way's analyses.

A comparison of the artificial with the preceding natural grasses shows that the former, on the whole, contain more water, but at the same time a larger amount of flesh-forming constituents, than the latter. It will be observed that the proportions of water and dry nutritive matter, as well as that of flesh-forming constituents, in different species of artificial grasses, vary in some instances considerably. Similar differences are observed in some of the analyses of one and the same kind of clover, as recorded by Professor Way, Dr. Anderson, and myself. Thus, for instance, we meet with the following differences in one and the same species of clover:—

	Percentage of Water in Fresh State.		Percentage of Flesh-forming Substances in Dry State.	
	Highest.	Lowest.	Highest.	Lowest.
Red clover—Trifolium pratense ..	85·30 (Anderson.)	79·98 (Anderson.)	22·194 (Way.)	12·46 (Anderson.)
Cow-grass—Trifolium medium ..	81·76 (Anderson.)	74·10 (Way.)	20·968 (Way.)	10·19 (Anderson.)
White clover—Trifolium repens ..	83·65 (Voelcker.)	79·71 (Way.)	27·31 (Voelcker.)	18·45 (Way.)
Lucerne—Medicago sativa	80·13 (Anderson.)	69·95 (Way.)	16·56 (Voelcker.)	12·56 (Way.)
Sainfoin—Onobrychis sativa	77·32 (Voelcker.)	76·64 (Way.)	18·17 (Way.)	15·50 (Voelcker.)

The percentage of water in the various clovers on an average amounts to:—

	Per Cent.
According to Anderson	80·83
„ Voelcker	78·65
„ Way	78·24

The amount of flesh-forming substances in the dry clovers on an average is—

According to Anderson	14·40
„ Voelcker	19·44
„ Way	19·31

I purposely abstain from drawing any practical deductions from these analyses; for although they show that some species of clover are more nutritious than others, it does not follow that this will be the case under all circumstances. It indeed appears to me that the quality of the clover depends not so much upon the species cultivated as upon the time when it is cut down, and on the nature of the land on which it is grown. On one kind of soil, it is more than probable that a particular species of clover will delight more than another, and that consequently a great difference in the nutritive value of the same kind of clover will be observed when cultivated on land naturally suited for it or otherwise. The period at which clover is cut down especially affects its value. It has been observed already that young clover is always richer in flesh-forming substances, and contains less woody fibre than old clover, for which reasons it is more nutritious. Under the head of clover-hay, I shall mention the details of some direct experiments made in 1851 by Stöckhard and Hellriegel, which show how great is the influence of the time of cutting clover for hay on its nutritive qualities.

Green Rye and Rape.—The following table represents the proximate composition of green rye and rape in a fresh and in a dried state. Both the rye and rape were grown on a calcareous soil near Cirencester, and analysed by myself:—

Composition of Green Rape and Rye. By Dr. A. Voelcker.

	Green Rye.		Green Rape.	
	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	75·423	..	87·050	..
Solid substance, consisting of:	24·577	100·00	(12·950)	..
Woody fibre	10·488	42·674	3·560	27·490
Ash united with fibre	·418	1·701	·432	3·335
Insoluble albuminous compounds ..	·894	3·638	1·493	11·529
Soluble albumen	1·811	7·369	1·640	12·664
Gum and pectin	4·449	18·102	1·729	13·351
Salts insoluble in alcohol	·572	2·327	·990	7·645
Sugar	4·685	19·062	2·218	17·622
Salts soluble in alcohol	·368	1·499	·186	1·435
Fatty matters, with a little chlorophyll	·892	3·628	·649	5·016
	100·000	100·000	99·947	99·587

Rape-leaves, like cabbage, contain moreover a considerable quantity of sulphur and phosphorus, in a peculiar state of organic combination.

In two different samples of rape the percentage of sulphur and phosphorus was found, for the dry substance—

	I.	II.	Average.
Phosphorus	·79	·87	·83
Sulphur	·84	·73	·78

The dry leaves thus contained nearly one per cent. of sulphur, and an equal amount of phosphorus in organic combination. Arranged into groups according to the chief classes of alimentary principles, the composition of green rye and rape may be represented as follows:—

	Green Rye.		Green Rape.	
	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	75·423	..	87·050	..
Nitrogenized substances (flesh-forming constituents)	2·705	11·007	3·133	24·193
Non-nitrogenized matters—				
a. Woody fibre	10·488	42·674	3·560	27·490
b. Fatty matters	·892	3·628	·649	5·016
c. Respiratory substances	9·134	37·164	4·000	30·886
Inorganic matters (ash)	1·358	5·527	1·608	12·415
	100·000	100·000	100·000	100·000

These analytical results give rise to several observations:—

1. It will be seen that rape is much more nutritious than green rye, and contains as large a proportion of flesh-forming constituents as the best kinds of food which are used in a green state.

2. But not only is rape rich in flesh-forming matters, but it contains also a considerable quantity of oily or fatty matters. It will be observed that the fresh leaves contain of these fatty matters more than a half per cent., and the perfectly dry substance about five per cent. So large a proportion of fatty matters, as far as I know, does not occur in any other green food.

The occurrence of so considerable a quantity of fatty matters explains at once, in an intelligible manner, the high fattening properties which distinguish rape as a sheep-feed.

Rape requires to be grown on good land. In poor soils it never comes to anything, and it is not worth the trouble of cultivating. On land of moderate fertility, or on good rich land, an occasional crop of rape, I am inclined to believe, would supply the farmer with a larger amount of feeding material than is afforded in a crop of turnips grown under the same circumstances. Weight for weight, rape is richer in flesh-forming matters, and especially in fatty substances, than turnips; and as a crop of rape per acre is often heavier than a turnip crop, the more extended cultivation of rape appears to be desirable wherever it is admissible to introduce it.

With respect to the feeding value of green rye, it appears, according to the above analyses, that it is inferior to the better sorts of clover.

White Mustard (*Sinapis alba*), *and Prickly Comfrey* (*Symphytum asperrimum*).—The general composition of these two kinds of green food has been ascertained by me to be as follows:—

a. Composition in 100 parts.

	White Mustard.		Prickly Comfrey.			
			Leaves.		Stem.	
	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	87·40	..	88·40	..	94·74	..
Soluble in water—						
a. Organic matters	6·70	53·18	1·61	13·89	5·26	100·00
b. Inorganic matters (ash)	1·81	14·36	·87	7·50		
Insoluble in water—						
a. Impure vegetable fibre	3·86	30·63	8·00	68·97		
b. Inorganic matters (ash)	·23	1·83	1·12	9·64		
	100·00	100·00	100·00	100·00	100·00	100·00

b. Constituents arranged in Groups.

	White Mustard.		Prickly Comfrey.			
			Leaves.		Stem.	
	In Natural State.	Calculated Dry	In Natural State.	Calculated Dry.	In Natural State.	Calculated Dry.
Water	87·400	..	88·400	..	94·74	..
Flesh-forming substances	3·287	26·12	2·712	23·37	·69	13·06
Non-nitrogenized substances—						
Heat and fat producing matters . .	7·273	57·69	6·898	59·49	3·81	72·49
Inorganic matters (ash)	2·040	16·19	1·990	17·14	·76	14·45
	100·000	100·00	100·000	100·00	100·00	100·00

The white mustard is an excellent green fodder, which is given with much advantage to sheep. It grows very rapidly, and may therefore be sown, when circumstances allow, as a catch-crop. In the fresh state mustard contains a large amount of water, and in comparison with the fibre, a much greater proportion of soluble substances than most kinds of green food. Notwithstanding the large proportion of water, white mustard is rich in flesh-producing substances, which fully explains its value as a feeding material.

The prickly comfrey (Symphytum asperrimum) is a native of the Caucasus, from whence it was introduced into England in 1811, as an ornamental plant, by Messrs. Loddige of Hackney. More recently, the cultivation of comfrey has been recommended as affording a cheap and nutritious green food for cattle. The prickly comfrey is a beautiful perennial plant, with reddish-blue flowers. It grows to a great size, and may be cut down several times in one season, as it throws out new leaves again, and shoots very rapidly when cut down a few inches above the ground.

At first cattle do not like it much, on account of the prickly nature of its leaves; but by and by they get accustomed to this food, and then do pretty well upon it.

In its fresh state, comfrey contains still more water than white mustard; but notwithstanding this large proportion of water, the amount of flesh-forming substances is considerable. The juice of this plant contains much gum and mucilage, and but little sugar.

Cabbage (*Brassica oleracea*); *Cauliflower* (*Brassica botrytis*); *Mangold Leaves*; *Turnip Tops.*—The following tables give the general composition, as ascertained by myself, of these substances in a fresh and in a dried state:—

a. Composition in Natural state.

	Cabbage.	Cauliflower.		Mangold.	Tops of Swedes.	Tops of Norfolk-bell Turnips.
		leaves.	flower.	leaves.		
Water	86·28	89·01	88·600	91·960	88·367	91·284
Soluble in water—						
a. Organic substances	6·26	5·57	5·786	8·040	3·699	3·104
b. Inorganic substances (ash)	1·61	·69	·740		1·984	1·225
Insoluble in water—						
a. Impure vegetable fibre	5·59	4·57	4·760		5·638	4·092
b. Inorganic matters (ash)	·26	·16	·114		·312	·295
	100·00	100·00	100·000	100·000	100·000	100·000

b. Constituents arranged in Groups.

Water	86·28	89·01	88·600	91·960	88·367	91·284
Flesh-forming substances	4·75	3·61	3·844	1·764	2·087	2 456
Heat and fat producing substances	7·10	6·53	6·702	4·984	7·250	4·740
Inorganic matters (ash)	1·87	·85	·854	1·292	2·296	1·520
	100·00	100·00	100·000	100·000	100·000	100·000

a. Composition of Dry Substances.

Soluble in water—						
a. Organic substances	45·62	50·53	50·700	100·	31·794	35·613
b. Inorganic substances (ash)	11·74	6·40	6·600		17·054	14·055
Insoluble in water—						
a. Impure vegetable fibre	40·74	41·57	41·700		48·470	46·948
b. Inorganic matters (ash)	1·90	1·50	1·000		2·682	3·384
	100·00	100·00	100·000	100·	100·000	100·000

b. Constituents arranged in Groups.

Flesh-forming substances	34·68	32·43	33·80	22·019	17·944	28·175
Heat and fat producing substances	51·68	59·67	58·60	61·912	62·320	54·386
Inorganic matters (ash)	13·64	7·90	7·60	16·069	19·736	17·439
	100·00	100·00	100·00	100·000	100·000	100·000

It appears from these analyses that cabbages, and the leaves and flowers of cauliflower, are very rich in flesh-forming substances. Indeed no kind of green food, cultivated on a large scale in the field, contains so much nutritious matter as cabbage. Being much more nutritious, weight for weight, than turnips, and at the same time very succulent, cabbages form a valuable food for milk cows. Cattle are very fond of cabbage, and dairy cows fed upon it and some hay produce much and rich milk; and the butter made from the latter is free from the disagreeable flavour which it always has when cows are fed upon turnips. Cabbages, for this reason, are a valuable substitute for turnips, and deserve to be more extensively cultivated in England than they are at present.

Mangold leaves and turnip tops, it will be observed, also contain a large amount of nitrogenized matters. Chemically considered, they ought therefore to possess considerable feeding properties; but experience has shown that their value as articles of food does not range very high. Mangold-wurtzel leaves, moreover, are very apt to scour animals, and ought therefore to be given to them only in moderate quantities.

Mangold leaves and turnip tops thus present us with instances which illustrate that the actual value of an article of food cannot always be determined by the same analytical process which in many cases affords good indications of the value of food. Mangold leaves and turnip tops, it will be seen by a glance at the above tabulated analytical results, contain a very large proportion of inorganic matters, or ash. This ash chiefly consists of alkaline phosphates, which are known to produce a relaxation of the bowels when taken internally, even in moderate quantities. The presence of much phosphate of potash and soda in the leaves of mangolds or turnip tops may thus be the reason why the nutritive substances which they contain are not assimilated by the animal organism, and why cattle do not get on well upon such food.

9. HAY AND STRAW (Clover-Hay and Hay of Artificial Grasses).—The composition of clover-hay, and the hay of artificial grasses, necessarily is regulated by that of the fresh plants which are grown for hay, and which we have seen differ often considerably in composition. Moreover, the composition of hay, and with it its nutritive qualities, depend very much upon the time at which the plants are cut down, on the state of the weather at haymaking time, and the care bestowed upon the haymaking process. For these reasons, it is not practicable to attach a precise nutritive value to clover-hay.

Composition of Clover-hay and Hay of Artificial Grasses.
(According to Professor Way's data.)

	Flesh-forming Substances.	Fatty Matters.	Respiratory Substances.	Woody Fibre.	Ash.	Water.
Trifolium pratense—Red clover . . .	18·79	3·06	37·06	16·46	7·97	16·6
Trifolium pratense perenne—Purple clover	15·98	3·41	35·35	21·63	6·96	,,
Trifolium incarnatum—Crimson clover.	13·83	3·11	31·25	26·99	8·15	,,
Trifolium medium—Cow grass . . .	20·27	2·97	30·30	20·12	9·67	,,
Ditto, second specimen . . .	15·64	3·98	41·38	15·70	6·64	,,
Trifolium procumbens—Hop trefoil. .	17·07	3·89	36·55	18·88	6·94	,,
Trifolium repens—White trefoil . . .	15·63	3·65	33·37	22·11	8·57	,,
Vicia sativa—Common vetch	19·68	2·55	32·87	22·82	5·42	,,
Vicia sepium—Bush vetch.	19·23	2·40	27·62	25·87	8·21	,,
Onobrychis sativa—Sainfoin	15·38	2·51	38·30	20·59	6·56	,,
Medicago sativa—Lucerne.	10·63	2·30	33·47	28·51	8·42	,,
Medicago lupulina—Yellow clover . .	20·50	3·38	27·76	22·66	9·03	,,
Plantago lanceolata—Rib grass . . .	11·91	3·06	33·58	27·56	7·23	,,
Poterium sanguisorba—Burnet . . .	13·96	3·34	39·50	19·89	6·64	,,
Achillea millefolium—Millefoil . . .	8·62	2·09	37·88	27·24	7·50	,,
Mean . . .	15·81	3·18	34·42	22·47	7·59	16·6

As it may be useful to know what would be the composition of hay produced by the various kinds of clover and artificial grasses, the analyses of which are stated above, the preceding table has been compounded.

In an air-dry state, clover-hay contains on an average 16·6 per cent. of moisture. Calculating thus for 16·6 per cent. of moisture in every case, the composition of the hay of the subjoined clovers and artificial grasses will be as in the table (p. 44).

Dr. Anderson states the composition of clover-hay of the second cutting, and grown in the field, as follows:—

Moisture	16·84
Flesh-forming substances	13·52
Non-nitrogenised matters	64·43
Mineral matters (ash)	5·51
	100·00

The influence of the period at which clover is cut for hay on the composition of the latter is shown in the following experiments of Stöckhard and Hellriegel:—

	Stem.			Leaves.		
	Water in Fresh Plant.	Hay.		Water in Fresh Plant.	Hay.	
		Flesh-forming Matters.	Ash.		Flesh-forming Matters.	Ash.
Clover cut on the 4th June, quite young . . .	82·80	13·61	9·71	83·50	27·17	9·42
,, 23rd ,, ready for cutting .	81·72	12·72	9·00	82·68	27·69	9·00
,, 9th July, beginning to flower.	82·41	12·40	6·12	77·77	15·83	10·46
,, 29th ,, full flower . . .	78·30	9·28	4·63	70·80	19·20	9·58
,, 21st August, ripe	69·40	6·75	4·82	65·70	18·94	12·33

It will be observed that the leaves are much more nutritious than the stems, which decrease rapidly in value at the period of maturity.

Still more strikingly the deterioration of clover-hay by not cutting down the clover at the proper time appears in the following experiments by Dr. Wolff, made in 1853:—

	Red Clover.				Alsike Clover.			
	Beginning to flower, 11th June.		Full flower, 25th June.		Beginning to flower, 23rd June.		Full flower, 29th June.	
	Fresh.	Hay.	Fresh.	Hay.	Fresh.	Hay.	Fresh.	Hay.
	pr. cent	pr. cent	pr. cent	pr. cent	pr. cent	pr. cent	pr. cent	p. cent
Water	83·07	16·60	76·41	16·60	86·98	16·60	82·60	16·60
Ash	1·43	7·04	1·67	5·90	1·12	7·17	1·45	6·94
Woody fibre	4·24	20·87	8·88	31·37	3·79	24·26	5·11	24·47
Nutritive substances	11·26	55·43	13·04	46·07	8·11	51·91	10·84	51·93

It will be observed that, whilst alsike clover cut on the 23rd of June, and six days later, produced an equally nutritious hay, a fortnight difference in the time of cutting down the red clover was attended with a considerable deterioration of the hay. For whilst the clover cut on the 11th June gave hay containing 20·87 of woody fibre, cut on the 25th, or a fortnight later, it produced 31·37 of indigestible fibre. It is the experience of practical men that the same weight of clover, when made into hay, is not so nutritious as it is in a fresh state. This no doubt is due partly to the changes which clover undergoes in the drying process, but also it is accounted for by the fact that, during the turning and drying in the field, and the subsequent carting of the clover, its more delicate and nutritious smaller leaves are wasted. Unpropitious weather, accompanied with frequent heavy rains, still more diminishes the nutritive qualities of the clover-hay, inasmuch as heavy rains wash out a portion of the nutritive juices, and clover which is kept in a wet state for a long time on the field is apt to enter into fermentation, during which a considerable portion of the albuminous compounds is destroyed.

Meadow Hay and Aftermath.—Like clover hay, ordinary meadow hay and aftermath are liable to considerable variations in composition. The same circumstances which affect the nutritive value of the hay of artificial grasses determine the value of the hay of natural grasses. Taking the mean of 25 analyses of common meadow hay, the composition of the latter may be stated as follows:—

Water	14·61
Flesh-forming constituents	8·44
Respiratory and fatty matters	43·63
Woody fibre	27·16
Mineral matters (ash)	6·16

The composition of the hay produced by the several natural grasses analysed by Professor Way has been stated already under the head of natural grasses. It will be observed that the average composition of hay from 23 different natural grasses agrees well with the average composition of meadow hay, which has just been stated. Well-made hay made of grass, cut rather earlier than is done usually, is richer in flesh-forming matters than ordinary meadow hay. The following analyses by Dr. Wolff may represent the composition of meadow hay of superior quality:—

Water	16·94
Flesh-forming matters	10·69
Respiratory and fatty matters	40·17
Woody fibre	27·16
Mineral matters (ash)	5·04
	100·00

On the other hand, the two subjoined analyses by Dr. Anderson may express the composition of inferior meadow hay:—

	Fresh Hay.	Hay One Year old.
Water	16·54	13·13
Flesh-forming matters (nitrogenised matters)	6·16	4·00
Non-nitrogenised substances	69·89	77·61
Mineral matters (ash)	7·41	5·26

It is generally believed that aftermath is less nutritious than hay. This may, indeed, be the case, for the aftermath, which is made at a later period of the year, when rainy days are more abundant, often remains a long time in the field before it can be stacked, and thus is deteriorated in value by unpropitious weather. When, however, aftermath is cut not too late in the season, and fair and warm weather allows its being made rapidly into hay, it is quite as valuable as the hay of the first cut. That it may be even more nutritious than the first hay, appears from the following comparative experiments by Dr. Keyser:—

	Hay.	Aftermath.
Water	13·38	13·06
Flesh-forming matters	9·06	10·75
Respiratory and fatty matters	42·74	49·74
Woody fibre	27·15	19·02
Mineral matters (ash)	7·76	7·46
	100·00	100·00

These results show that the preparation of flesh-forming matters is greater, and that of woody fibre smaller, in aftermath than in the hay of the same meadow, and that consequently the former is the more valuable of the two. It ought to be mentioned that the hay was repeatedly washed by heavy rains, whereas the aftermath was harvested in very favourable weather, in consequence of which the former had a bleached appearance, whilst in the latter the green colour and aromatic taste were preserved; the aftermath, moreover, was softer and finer than the hay.

Straw.—The following table represents the average composition of the straw of cereals:—

	Wheat-straw.	Rye-straw.	Barley-straw.	Oat-straw.
Water	14·23	14·30	14·30	12·06
Flesh-forming matters	1·79	2·29	1·68	1·63
Respiratory and fatty matters	31·06	37·15	39·98	37·86
Woody fibre	45·45	43·18	39·80	43·60
Mineral matters (ash)	7·47	3·08	4·24	4·85
	100·00	100·00	100·00	100·00

The differences in the composition of the straw of our cereals are trifling. There is but a small amount of flesh-forming matters and a large amount of indigestible woody fibre in straw, which fully explains its low feeding value. Oat-straw, however, when still somewhat green at the top, is much more nutritious than the sample the composition of which is here stated.

Pea and Bean Straw.—The composition of two varieties of bean-straw is stated by Dr. Anderson as follows:—

	Common Scotch Bean-straw.	Straw of Winter-beans.
Water	19·23	20·90
Flesh-forming matters	8·25	6·79
Non-nitrogenized substances	65·85	65·96
Mineral matters (ash)	6·67	6·35
	100·00	100·00

The mean of the analyses by Boussingault, Hertwig, and Sprengel, gives for the composition of pea-straw the following results:—

	Natural State.	Calculated Dry.
Water	12·00	..
Flesh-forming matters	12·55	14·26
Respiratory and fatty matters	21·93	24·92
Woody fibre	47·52	54·00
Mineral matters (ash)	6·00	6·82
	100·00	100·00

Bean and pea straw thus are rich in flesh-forming constituents, and differ in this respect materially from the straw of all our cereals, which are far less valuable as feeding materials.

Having stated the composition of most articles of food which are employed by the British farmer for feeding or fattening of stock, some considerations may find here an appropriate place, which ought to be well weighed in estimating the nutritive value of food and its adaptation to particular purposes.

It having been shown by analysis that all the richer kinds of food contain a large amount of flesh-forming constituents, and that no article of food entirely deficient in these principles can support the healthy existence or growth of animals, great importance is necessarily attached to this class of substances in food. We have seen, however, that though essential to the very existence of animals, food must contain a number of other constituents in addition to the flesh-forming substances, if it is to meet all the wants of the animal body. It follows from this that the endeavour to determine the relative nutritive value of different articles of food, by merely taking into account the proportion of flesh-forming constituents contained in them, must lead to erroneous conclusions, and that consequently the tables of nutrition, which have been constructed by some who have over-estimated the practical importance of the nitrogenized compounds in food, have not that practical value which it was believed at one time they possessed. The amount of flesh-forming matters in food does afford useful indications as to its fitness for particular purposes; but it can never become the rule whereby we can measure the comparative nutritive value of the various feeding materials. Food best adapted for producing muscle, when supplied to animals in large quantities, does not sustain their healthy condition, because it is ill suited to feed respiration. Other food, again, is peculiarly well adapted for the laying on of fat, but does not supply in sufficient quantity the daily waste to which the muscles of animals are exposed, nor does it contain the materials from which the bones are formed, and for these reasons does not meet the wants of the growing nor even the fattening beast. In short, a mixed food, containing both flesh-forming and respiratory substances, as well as fat-producing and saline constituents, and bone-materials, is necessary to preserve the health of an animal, and the nitrogenised or flesh-forming principles alone cannot determine the practical feeding value of food. The *total* nutritive effect which an article of food is capable of producing thus depends, in the first place, on the presence of all these substances, and second, on a variety of circumstances, to which I beg now to direct the attention of the reader.

In estimating the practical value of an article of food, we must take into consideration—

1. *The Age of the Animal.*—Young and growing animals require a more concentrated and more readily digestible food than full-grown or store beasts, *i. e.* food being, comparatively speaking, rich in nitrogenized matters and poor in indigestible woody fibre.

The food upon which growing stock is fed not only has to supply the daily waste of muscle, but must also increase the weight of the animals; and as the process of renewal in young animals moreover proceeds more rapidly than in full-grown stock, the food of the former should contain a larger supply of flesh-forming substances and of bone-materials. Hence the great value of linseed-cake and of linseed-jelly for young stock, and the poor condition of young beasts fed upon too much chaff. The yet tender organs of digestion necessitate a more digestible food than that upon which store beasts may be fed with economy, and thus the same food which may be valuable for store beasts will often be found totally unfit for young stock.

2. *The various Kinds of Animals.*—We know by experience that the best food for horses is by no means the best for cows or sheep, and hence the nutritive value of an article of food will be different in relation to horses from what it is in relation to cattle. The organization of the digestive organs of our domestic animals fully accounts for the different effects which are often produced by the same article of food when given to different kinds of animals. Thus whilst beans are highly nutritious when given to horses, their value for fattening cattle is far less striking; and whilst cut straw, given by itself, may support store cattle, it cannot sustain for any length of time the life of sheep or horses. The nutritive value of food thus varies with the description of the animals to which it is given.

3. *The Natural Disposition or Temper of the Animals.*—Whilst some animals, like the Herefordshire cows and shorthorns, are naturally good fatteners, Welsh cattle and Kerry cows, to mention only a few instances, never will become very fat, even if they are kept for a long time on abundant supplies of the choicest food. The practical value of food thus is likewise influenced by the natural disposition of the animal which is kept upon it.

4. *The Purposes for which Animals are kept.*—The effect which food is capable of producing is also influenced by the purposes for which animals are kept on the farm. The value of food necessarily will be a different one, if we speak in relation to working animals, or fattening beasts, or cows kept for dairy purposes. Thus, for instance, the same amount and kind of food which in summer is hardly capable of keeping working horses in good condition, is more than sufficient to render them plump and fat in a short time in winter, when they are retained for days and weeks together in the stable. The nutritive value of food thus is influenced by the work done by the animal. The harder it is kept at work, the greater the waste in muscle, and consequently the richer the food ought to be in flesh-forming matters which is given to working horses or bullocks.

Highly nitrogenized food, however, though of great value when given to working animals, does little good, and may even do harm when given in too large a proportion to fattening beasts. Valuable food for fattening stock is food rich in starch, and still more so, food rich in ready-made fat; or, to speak generally, food not so well adapted for working animals, because it does not contain a sufficient quantity of muscle material.

These few examples will show that the opinion which is entertained respecting the nutritive value of food cannot be invariably the same, but is regulated, amongst other circumstances, by the purpose for which the animals are kept on the farm.

The fitness of the same kind of food thus varies with the age, natural disposition, and kind of the animals to which it is given, as well as with the purposes for which they are kept on the farm; and it is therefore quite impossible to classify the various articles of food in an order which will indicate their relative feeding values in all cases.

But supposing the composition of food to be known, and the wants of the animals are well considered, it is still impossible in all cases to estimate beforehand what practical effect a feeding substance will produce, for it may be rich in flesh-forming substances, and contain fat and heat producing compounds, as well as saline and earthy matters; and yet it may be, comparatively speaking, poor food, inasmuch as its constituents are not assimilated by the animal organism. The digestibility of food consequently is a point which ought to be well kept in view in estimating its nutritive value. Our knowledge of this process of digestion, unfortunately, is so limited, that we cannot speak definitely of all the conditions which regulate the digestibility of food. Still, however, a few circumstances may be pointed out, by way of example, which influence the assimilation of food by the animal system.

Amongst other conditions the digestibility of food depends—

1. *On the Kinds of Animals.*—The same description of food which is assimilated in a great measure by one kind of animal remains almost wholly undigested when given to another. Thus it has been proved by direct experiments that cows will extract a great deal of nourishment from cut straw, whilst horses do not possess the power in the same degree of appropriating nourishment from cut straw, and sheep likewise do not appear to digest chaff so readily as cattle.

2. *On the amount and character of the Woody Fibre contained in Food.*—Feeding materials, containing but a small amount of woody fibre, are generally more readily digested than those articles of food which, like straw, principally consist of woody fibre. Hence barley-meal, oats, and grain in general, substances rich in starchy compounds, are so well adapted to the rapid fattening of animals.

The condition of the woody fibre further affects the nutritive value of food in no mean degree. Whilst the woody fibre in roots left too long in a growing state on the land, or the fibre of grass and clover left standing until it become dead ripe, is not readily digested, there can be no doubt that the soft fibre of young grass, clover, and roots, is readily assimilated in the animal organism and transformed into starch, sugar, and finally into fat. It is for this reason that grain crops, more especially oats, when harvested before the plants have become dead-ripe, produce straw which is greatly more nutritious than the straw of dead-ripe grain crops. In some parts of Scotland the custom prevails to cut the oat when the top of the haulm is still somewhat green; and it is upon straw of that description that store cattle are kept during the winter almost entirely.

3. *On the amount of Flesh-forming Substances.*—Food too rich in these constituents is not readily digested by cattle, whilst working horses are greatly benefited by food of that description. Thus, bean-meal or peas ought to be given sparingly to cattle, because beans and peas contain a very large amount of flesh-forming substances, which renders them indigestible when given to cattle.

4. *On the Bulk of the Food.*—The normal functions of the digestive organs not only depend on the composition of the food, but also on the volume. The volume or bulk of food contributes to the healthy activity of the digestive organs, by exercising a stimulating effect on the nerves which govern them. The whole organization of ruminating animals necessitates the supply of bulky food to keep the animal in good condition. Experience shows that horses require a less bulky and more concentrated food than cattle; but if we reverse the case, and feed cattle with too concentrated a food and horses with too bulky a feeding substance, much of the food will remain undigested.

5. *On the form in which Food is presented to the Animal.*—It sometimes happens that an article of food is said to possess little value, which, properly prepared, may be given to cattle with much advantage. Thus, straw cut into chaff—and, better still, steamed afterwards when mixed with sliced roots—constitutes a very acceptable food for cattle. The bruising of oats, barley, cake, &c., the making of linseed into jelly, the steaming of hay and cooking of food, are illustrations, showing how, by an alteration in the form of a feeding material, its digestibility, and with it its nutritive value, becomes enhanced.

The benefit of steaming or cooking of food is principally due to this circumstance. It does not add anything new to the food; it does not call into existence any fresh nutritious matter; but brings the nourishment present in the food in an unfit condition into a state in which it is more readily assimilated by the animal. Steaming, moreover, reduces the bulk of the food, and masticates, so to speak, the food for the animal. The animal, therefore, is enabled to consume in a given time a larger quantity of food, and so saved to some extent the work of mastication, which, like every movement of the muscle, is attended with a certain loss of the substance of the beast. The quieter and warmer we keep the animal, and the more we facilitate the assimilation of food, the more rapidly it will become fat. By steaming, likewise, the disagreeable smell of musty hay or cake is destroyed, and on the whole, steamed food becomes more palatable.

6. *On small Proportions of Substances with which we may not even be acquainted.*—Professor Liebig's researches on the juices of flesh have made us acquainted with a remarkable crystallized substance, to which he has given the name Kreatine. This substance appears to exercise a remarkable function in the digestion of food. Liebig also showed the presence of phosphate of potash and lactic acid in the juice of flesh, and considers these constituents indispensable for the digestion of meat. He has indeed proved that flesh, from which all juice is perfectly extracted by water, is so indigestible, that even dogs will refuse to eat it.

The total amount of the compounds which appear to play so important a function in the digestion of meat is but very small. Now, if the digestibility of flesh is determined in a great measure by small quantities of substances, the importance of which remained unnoticed until the master researches of a Liebig on the juices of flesh made us acquainted with the influence the above-mentioned substances play in the process of digestion—is it not likely that vegetable food may contain small quantities of compounds which exercise a similar influence?

In conclusion it may be observed, that the economical value of food is further influenced—

1. *By prejudicial substances which food may contain.*—Thus, for instance, mustard cake cannot be used as a feeding material, notwithstanding its containing a large amount of flesh-forming and fat-producing substances, because in the stomach of the animal fed upon it, it gives rise to the production of the poisonous irritating essential oil of mustard: or, the refuse cake, produced in the manufacture of castor oil, cannot be used for feeding purposes on account of the drastic effects which the oil, still remaining in the cake, will produce in the animal system.

2. *By the mechanical effect the food exercises.*—An illustration in point is offered in bran, which, on account of its sharp edges, stimulates the nerves of the digestive canals to such an extent that much of it passes through the system undigested. Otherwise bran ought to be very nutritious, for it contains even more flesh-forming matters, as well as more fatty matter, than wheaten flour. Could not these relaxing effects of bran which, I believe, are principally due to its mechanical condition, be overcome by the cooking or steaming of the bran?

3. *By the physical condition of the food.*—It is so self-evident that mouldy, fusty food cannot be so good as it is in a fresh state, that I need not dwell on this point. Every one knows that the

fresher cake and food in general—(there are some exceptions, as for instance, mangolds, which become better on keeping),—the better it is adapted for feeding-purposes.

4. *By the flavour which it imparts to the meat or the milk.*—The economical value of an article of food is also regulated by the flavour which it imparts either to the meat or the milk. An article of food may be excellent for producing flesh or milk, and yet, on account of the disagreeable flavour which it imparts to either the one or the other, it may not be desirable to employ it as a feeding material. The case of fenugreek seed, to which reference is made above, fully proves this.

These remarks, and others which will suggest themselves to practical men, show that the chemical composition of food alone cannot determine its economic value, but that a variety of circumstances have to be taken into account before we can arrive at anything like a correct view of the nutritive value of a feeding material.

Agricultural Chemistry.

FOUR LECTURES

ON

FARMYARD MANURE, ARTIFICIAL MANURES, BARREN AND FERTILE SOILS, OIL-CAKES, &c.

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CONTENTS.

FOUR LECTURES, &c.

1.—FARMYARD MANURE.

FARMYARD MANURE differs from all artificial manures in several important particulars. I have purposely selected a general title for the lecture inasmuch as the subject is a wide one, and presents to the chemist and the practical man so many points of interest that it is a great difficulty to make a proper selection. I do not propose to give a complete lecture on farmyard manure, but to make some observations of interest, which are the result, not of speculation, but of a number of experiments—analytical ones in the laboratory, and practical ones on the farm. I shall first make some remarks on the composition of fresh farmyard manure; and need not tell any one practically acquainted with the matter, that nothing can be more varying. Manure produced from young growing stock is not so good as that from old or fattening animals. Then again that which is produced from underfed animals is of a very inferior description; and indeed it is very bad policy to keep animals underfed, for it occasions a waste of food and manure as well. Then the composition of the excrements of the domestic animals is different. The excrements of horses, which are fed with a more nitrogenised food, are of a very fertilising character; and perhaps the animal excrements may be placed in the following order: horse-dung and sheep-dung are about equal, then cow-dung, and last pig-dung. But not only the different excrements influence the composition of farmyard manure, but also the quantity of litter employed. Then the way in which the manure is prepared—whether made in boxes which retain everything valuable, or in an open yard; also in the manner in which it is kept—whether placed on a slope, allowing the best part of the manure to trickle away to the nearest drain, or whether it is kept on level ground, or covered up so as to keep off the rain, must affect the quality of manure. I wish to impress upon your mind that it is the complexity of the composition which renders farmyard manure so valuable and indispensable to the farmer. It is a perfect manure, because it contains all the elements necessary for supporting a healthy and vigorous growth of the plant; and it is a universal one, because it universally produces those effects, and upon a great variety of agricultural products. Another reason why it is so valuable is, that it produces mechanical effects which no artificial manure that I am acquainted with can produce. The important mechanical effects, especially of long dung on clay soils, are not to be underrated. These mechanical effects are attended with highly beneficial results, which cannot be attained by any artificial manure.

Composition of fresh Farmyard Manure.—By way of illustration, the subjoined Tables, embodying the results of a careful recent examination of farmyard manure, may be given:—

Composition of Fresh Farmyard Manure (composed of Horse, Pig, and Cow Dung).

Water		66·17
*Soluble organic matter		2·48
Soluble inorganic matter (ash):—		
Soluble silica	·237	
Phosphate of lime	·299	
Lime	·066	
Magnesia	·011	
Potash	·573	
Soda	·051	
Chloride of Sodium	·030	
Sulphuric acid	·055	
Carbonic acid and loss	·218	
		1·54
†Insoluble organic matter		25·76
Insoluble inorganic matter (ash):—		
Soluble silica	·967	
Insoluble silica	·561	
Oxide of iron, alumina, with phosphates	·596	
Containing phosphoric acid	(·178)	
Equal to bone earth	(·386)	
Lime	1·120	
Magnesia	·143	
Potash	·099	
Soda	·019	
Sulphuric acid	·061	
Carbonic acid and loss	·484	
		4·05
		100·00

* Containing nitrogen	·149
Equal to ammonia	·181
† Containing nitrogen	·494
Equal to ammonia	·599
Whole manure contains ammonia in free state	·034
„ „ in form of salts	·088

According to these results, the same manure in a perfectly dry condition will have the following composition :—

Detailed Composition of Fresh Farmyard Manure in Dry State.

*Soluble organic matter		7·33
Soluble inorganic matter (ash) :—		
Soluble silica	·703	
Phosphate of lime	·884	
Lime	·185	
Magnesia	·033	
Potash	1·695	
Soda	·153	
Chloride of sodium	·089	
Sulphuric acid	·035	
Carbonic acid and loss	·772	
		4·55
†Insoluble organic matter		76·15
Insoluble inorganic matter :—		
Soluble silica	2·865	
Insoluble silica	1·659	
Oxide of iron and alumina, with phosphates	1·404	
Containing phosphoric acid	(·528)	
Equal to bone earth	(·822)	
Lime	3·335	
Magnesia	·424	
Potash	·294	
Soda	·077	
Sulphuric acid	·210	
Carbonic acid and loss	1·722	
		11·97
		100·00

* Containing nitrogen	·44
Equal to ammonia	·53
† Containing nitrogen	1·46
Equal to ammonia	1·77
Whole manure contains ammonia in free state	·10
,, ,, in form of salts	·26

Fresh farmyard manure being composed of the droppings of horses, cows, and pigs, and the straw used for litter, according to the above determination, in round numbers consists of two-thirds of water, and one-third of dry matters. Since this fresh manure was not more than fourteen days old, and no rain had fallen during the time it had lain in the dung-pit, all the water is due to the urine and the moisture of the droppings and litter. The quantity of straw employed as litter must necessarily affect the general composition of fresh dung, and more especially the amount of moisture which it contains; but, I believe, we are not far wrong by saying that fresh mixed dung, in the production of which litter has been liberally supplied to the animals, when free from rain, consists of one-third of dry matters and two-thirds of moisture.

An inspection of the analytical results just mentioned will further bring to view several interesting particulars :—

1. *In fresh dung the proportion of soluble organic and mineral substances is small.* This circumstance fully explains the slow action of fresh dung when compared with the effect which well-rotten manure is capable of producing.

2. The proportion of insoluble matters, more especially of insoluble organic matters, in fresh dung, on the contrary, is very large. By far the larger proportion of the insoluble organic matters consists of straw, changed but little in its physical character and chemical composition.

In the sample of manure analysed the amount of insoluble organic matters is ten times as great as that of soluble organic matters, and the proportion of insoluble mineral substances nearly three times as large as the amount of soluble mineral matters.

3. Fresh dung contains a mere trace of ammonia in a volatile state of combination, and but a trifling quantity of ammonia in the form of ammoniacal salts.

4. The total amount of nitrogen contained in the *soluble portion* of fresh manure likewise is inconsiderable. Most of the nitrogen which, as we shall see by-and-by, is gradually liberated as the fermentation of dung progresses, is contained in the portion of the manure which is insoluble in water. In other words, comparatively speaking, little nitrogen exists in fresh dung in a state in which it can be assimilated by the growing plants. Thus, in the sample analysed, the readily available amount of nitrogen in 100 lbs. of fresh dung is only ·149 of a lb., whilst about four times as much nitrogen, or, in exact numbers, ·494 lb., occurs in the insoluble portion of 100 lbs. of fresh dung.

5. A comparison of the composition of the organic soluble matters with the composition of the organic insoluble matters of fresh dung, however, shows that the former are far more valuable than the latter, inasmuch as the soluble organic matters contain a very much larger percentage of nitrogen, and in a state of combination in which nitrogen is available to the immediate use of plants.

This will appear from the following numbers :—

100 parts of organic soluble matters in fresh dung contain 6·04 of nitrogen.
100 ,, insoluble matters ,, ,, 1·92 ,,

In the same weight of each there is thus more than three times as much nitrogen in the soluble organic matters as in the insoluble organic matters.

6. With respect to the inorganic or mineral constituents of fresh dung, it will be seen that it contains all those mineral matters which are found in the ashes of all our cultivated plants.

7. Comparing the composition of the soluble inorganic matters with that presented by the insoluble, no essential *qualitative* difference is perceived between both, for the same constituents which occur in the soluble ash are found also in the insoluble ash. But there exists a striking difference in the quantitative composition of the soluble and the insoluble mineral matters of fresh dung.

8. The principal constituent of the soluble ash of fresh dung, so far as quantity is concerned, is *potash;* 100 parts of soluble ash, it will be seen, contain no less than 37·26 parts of real potash, or a quantity which is equivalent to 54·7 of pure carbonate of potash. The analysis of the soluble portion of ash of fresh dung gave only 14 per cent. of carbonic acid, including the loss in analysis; and as 37·26 of potash take up 17·5 of carbonic acid in becoming carbonate of potash, and moreover much of the soluble lime existed in the water-solution as bicarbonate of lime, it is evident that a considerable quantity of potash is united with silicic acid in the soluble ash. The large percentage of soluble silica confirms this view; fresh farmyard manure thus contains much soluble silicate of potash.

9. The large amount of soluble silica, both in the soluble and in the insoluble ash, is deserving notice. In the soluble ash this silica is united principally with potash, and probably also with some soda; in the insoluble ash it is combined chiefly with lime, or exists in a finely divided state, in which it is readily soluble in dilute caustic potash.

10. The most prominent constituent of the soluble ash of fresh dung is silicate of potash.

11. The most prominent constituent of the insoluble ash is lime.

12. It is particularly worthy of notice that the soluble ash of even *perfectly fresh* dung contains a very *high percentage* of *phosphate* of *lime.*

The proportion of phosphate of lime in the soluble portion of ash was in fact found to amount to no less than 19½ per cent. of the whole soluble ash, whilst the percentage of phosphate of lime in the insoluble ash was found to be only 9½.

I must confess that I was not prepared to find so large an amount of a compound which is generally considered insoluble in water, and for this reason is not enumerated in the published analyses of farmyard manure amongst the soluble constituents of dung. Repeated experiments, however, executed, with all care to avoid any possible source of error, have shown me that water dissolves phosphate of lime or bone-earth much more rapidly and to a much greater extent than it has hitherto been supposed. This observation gains much in interest, if it be remembered that the late Mr. Pusey suggested many years ago a method of rendering bone-dust more efficacious as a manure for root-crops. His plan was to place bone-dust moistened with water and mixed with ashes, sand, or other porous matters in a heap, and to keep this heap moist by pouring occasionally water upon it, or, better still, stale urine or liquid manure. The suggestion has been followed by many with much success. But few may have known that by adopting Mr. Pusey's plan of reducing bone-dust still further they have been instrumental in generating that combination which gives peculiar value to superphosphate of lime, namely, soluble phosphate of lime.

In one of the latest numbers of the 'Annalen der Chemie und Pharmacie,' edited by Liebig, Wöhler, and Kopp, Professor Wöhler, of the University of Göttingen, makes the important observation that bone-dust moistened with a little water, in the course of a few days yields a considerable quantity of phosphate of lime to water, and that this solubility rapidly increases with the putrefaction of the gelatine of bones. My analysis of farmyard manure, made a year before the recent notice, which Professor Wöhler gave in the 'Annalen der Chemie,' respecting the solubility of phosphate of lime in water, may be regarded as a confirmation of Wöhler's direct experiments upon bone-dust, as well as an interesting scientific commentary on Mr. Pusey's practical suggestion of rendering bone-dust more efficacious as a manure for root-crops.

13. The insoluble part of the ash of fresh farmyard manure includes the sand, earth, and other mineral impurities, which mechanically get mixed with the dung. Most of these impurities are mentioned in the ash-analyses as insoluble silicious matter; another portion is comprehended under oxides of iron and alumina with phosphates; and a third part, probably a considerable portion of the mechanical impurities, is included under lime, for the gravel and soil at Cirencester abounds in carbonate of lime.

Due allowance must be made for these mechanical impurities in all considerations respecting farmyard manure, otherwise conclusions will be drawn which the facts of the case do not warrant.

14. *Chemically considered Farmyard Manure must be regarded as a perfect and universal Manure.*—It is a universal manure, because it contains *all* the constituents which our cultivated crops require to come to perfection, and is suited for almost every description of agricultural produce.

As far as the inorganic fertilising substances are concerned, we find in farmyard manure: potash, soda, lime, magnesia, oxide of iron, silica, phosphoric acid, sulphuric acid, hydrochloric and carbonic acid—in short, all the minerals, not one excepted, that are found in the ashes of agricultural crops.

Of organic fertilising substances we find in farmyard manure some which are readily soluble in water and contain a large proportion of nitrogen, and others insoluble in water and containing, comparatively speaking, a small proportion of nitrogen. The former readily yield ammonia, the latter principally give rise to the formation of humic acids and similar organic compounds. These organic acids constitute the mass of the brown vegetable substance, or rather mixture of substances, which, practically speaking, pass under the name of humus.

Farmyard manure is a perfect manure, because experience as well as chemical analysis shows that the fertilising constituents are present in dung in states of combination, which appear to be especially favourable to the luxuriant growth of our crops. Since the number of the various chemical compounds in farmyard manure is exceedingly great, and many no doubt exist in a different state of combination from that in which they are obtained on analysing farmyard manure, in our present state of knowledge it is impossible artificially to produce a concentrated, universal, and perfect manure, which might entirely supersede home-made dung.

I do not refer to the mechanical effect which farmyard manure is capable of producing. This mechanical effect, especially important in reference to heavy clay soils, ought to be duly regarded in estimating the value of common dung, but for the present it may suffice to draw attention to the fact, that even fresh dung contains a great variety of both organic and inorganic compounds of various degrees of solubility. Thus, for instance, we find in fresh manure volatile and ammoniacal compounds, salts of ammonia, soluble nitrogenized organic matters, and insoluble nitrogenized organic substances, or no less than four different states in which the one element, nitrogen, occurs in fresh manure. In well-rotten dung the same element, nitrogen, probably is found in several other forms. This complexity of composition—difficult, if not impossible, to imitate by art—is one of the reasons which render farmyard manure a perfect as well as a universal manure.

On the Changes which Fresh Farmyard Manure undergoes in Ripening.—The peculiar character of these changes becomes apparent if the composition of fresh dung is compared with that of well rotten dung. I would therefore in the next place direct attention to the subjoined Table, representing the detailed composition of rotten dung:

Composition of well-rotten Dung.

Water		75·42
*Soluble organic matter		3·71
Soluble inorganic matter (ash):—		
Soluble silica	·254	
Phosphate of lime	·382	
Lime	·117	
Magnesia	·047	
Potash	·446	
Soda	·023	
Chloride of sodium	·037	
Sulphuric acid	·058	
Carbonic acid and loss	·106	
		1·47
†Insoluble organic matter		12·82
Insoluble inorganic matter (ash):—		
Soluble silica	1·424	
Insoluble silica	1·010	
Oxides of iron and alumina, with phosphates	·947	
Containing phosphoric acid	(·274)	
Equal to bone earth	(·573)	
Lime	1·667	
Magnesia	·091	
Potash	·045	
Soda	·038	
Sulphuric acid	·063	
Carbonic acid and loss	1·295	
		6·58
		100·00

* Containing nitrogen	·297
Equal to ammonia	·36
† Containing nitrogen	·309
Equal to ammonia	·375
Whole manure contains ammonia in free state	·046
" " form of salts	·057

Dried at 212° F. the composition of this manure is as follows:—

Composition of the same Manure in dry state.

*Soluble organic matter		15·09
Soluble inorganic matter:—		
Soluble silica	1·035	
Phosphate of lime	1·554	
Lime	·476	
Magnesia	·193	
Potash	1·816	
Soda	·140	
Chloride of sodium	·151	
Sulphuric acid	·235	
Carbonic acid and loss	·380	
		5·98
Insoluble organic matter		52·15
Carried forward		73·22

Brought forward		73·22
Insoluble inorganic matter :—		
Soluble silica	5·79	
Insoluble silica	4·11	
Oxides of iron and alumina, with phosphates	3·85	
Containing phosphoric acid	(1·11)	
Equal to bone earth	(2·41)	
Lime	6·78	
Magnesia	·37	
Potash	·18	
Soda	·15	
Sulphuric acid	·29	
Carbonic acid and loss	5·26	
		26·78
		100·00

* Containing nitrogen	1·21
Equal to ammonia	1·47
† Containing nitrogen	1·26
Equal to ammonia	1·53
Whole manure contains ammonia in free state	·189
„ „ form of salts	·232

The comparison of these analytical results with the numbers obtained in the analysis of the fresh manure exhibits several striking differences, to some of which I beg to direct attention.

1. The well-rotten dung contains nearly 10 per cent. more water than the fresh. The larger percentage of water, it is true, may be purely accidental; but, considering the tendency of the liquid excrements to sink to the lower part of the manure pit in which the rotten dung accumulates, I believe rotten dung will always be found moister than fresh dung upon which no rain has fallen.

2. Notwithstanding the much larger percentage of moisture in the well-rotten dung, it contains in its natural state, with 75½ per cent. of water, almost as much nitrogen as the fresh dung, with only 66 per cent. of moisture. Supposing both to be equally moist, there would thus be considerably more nitrogen in rotten dung than in an equal weight of fresh. This is clearly observed by comparing the total amount of nitrogen in the perfectly dry fresh and rotten dung. In the former it amounts to 1·90 per cent. of nitrogen, in the latter to 2·47. As far as this most valuable element is concerned, farmyard manure becomes much richer, weight for weight, in becoming changed from fresh into rotten dung.

3. During the fermentation of the dung the proportion of insoluble organic matters greatly diminishes; thus the dry fresh manure contained 76 per cent. of insoluble organic matters, whilst there were only 52 per cent. in the dry rotten dung.

4. It is especially worthy of observation that, whilst the insoluble organic matter is much reduced in quantity during the fermentation, the insoluble organic matter which remains behind

in rotten dung is richer in nitrogen than an equal quantity of insoluble organic matter from fresh dung. Thus 76 per cent. of insoluble organic matter of fresh dung contain 1·46 per cent., whilst 52 per cent. of it from rotten dung very nearly contain the same quantity, namely, 1·26. Or,—

100 parts of insoluble organic matter from fresh dung contain	1·92 per cent. of nitrogen.
100 parts of insoluble organic matter from rotten dung contain	2·41 ,, ,,

5. On the other hand, the relative proportion of insoluble inorganic matter increases much during the fermentation of the dung, since dry fresh dung contains about 12 per cent. of insoluble mineral matters, and dry well-rotten dungs 26·8 per cent., or more than double the amount which is found in fresh dung.

6. But perhaps the most striking difference in the composition of fresh and rotten dung is exhibited in the relative proportions of soluble organic matter. Well-rotten dung, it will be observed, contains rather more than twice as much soluble organic matters as the fresh; with this increase the amount of nitrogen present in a soluble state rises from ·44 per cent. to 1·21 per cent.

7. Not only does the absolute amount of soluble nitrogenised matters increase during the fermentation of dung, but the soluble organic matters relatively get richer in nitrogen also. Thus,—

100 parts of dry organic soluble matter from fresh dung contain	6·14 per cent. of nitrogen.
100 parts of dry organic soluble matter from rotten dung contain	8·02 ,, ,,

8. Lastly, it will be seen that the proportion of soluble mineral matters in rotten dung is more considerable than in fresh.

9. On the whole, weight for weight, well-rotten farmyard manure is richer in soluble fertilizing constituents than fresh dung, and contains especially more readily available nitrogen, and therefore produces a more immediate and powerful effect on vegetation.

Bearing in mind the differences observable in the composition of fresh and rotten dung, we can in a general manner trace the changes which take place in the fermentation of dung. Farmyard manure, like most organic matters, or mixtures in which the latter enter largely, is subject to the process of spontaneous decomposition, which generally is called fermentation, but more appropriately putrefaction. The nature of this process consists in the gradual alteration of the original organic matters, and in the formation of new chemical compounds. All organic matters, separated from the living organism, are affected by putrefaction, some more readily, others more slowly. Those organic substances which, like straw, contain but little nitrogen, on exposure to air and moisture at a somewhat elevated temperature decompose spontaneously and slowly, without disengaging any noxious smell. On the other hand, the droppings of animals, and especially their urine, which is rich in nitrogenous compounds, rapidly enter into decomposition, producing disagreeable-smelling gases. In a mixture of nitrogenous substances and organic matters free from nitrogen, the former are always first affected by putrefaction; the putrefying nitrogenised matters then act as a ferment on the other organic substances, which by themselves would resist the process of spontaneous decomposition much longer. Without air, moisture, and a certain amount of heat, organic matters cannot enter into putrefaction. These conditions exist in the droppings of cattle and the litter of the stables, hence putrefaction soon affects fresh dung. Like many chemical processes, putrefaction is accompanied with evolution of heat. Air and water exercise an important influence on the manner in which the decomposition of organic matters proceeds. Both are absolutely requisite in order that putrefaction may take place. Perfectly dry organic substances remain unaltered for an indefinite period, as long as they are kept perfectly dry. But too large an amount of water, again, retards the spontaneous decomposition of organic substances, as it excludes the access of air and prevents the elevation of temperature, both of which conditions greatly increase the rapidity with which organic matters are decomposed. Although air is an essential element in the putrefaction of organic matters the unlimited access is unfavourable to this process of spontaneous decomposition, and is productive of new changes. In farmyard manure the unlimited access of air is prevented by the compact nature of dung-heaps, consequently only a limited quantity of air can find its way into the interior of the mass. During the fermentation of fresh dung, disagreeable smelling gases are given off. These arise principally from the sulphur, and from the phosphorus of the nitrogenized compounds present in dung. A considerable proportion of this sulphur and the phosphorus combine with hydrogen, and form sulphuretted and phosphoretted hydrogen—two extremely nauseous gases, which both escape from fermenting dung-heaps. Another portion of the sulphur and the phosphorus unites with atmospheric oxygen, and in the presence of porous substances becomes changed into sulphuric and phosphoric acid, two non-volatile compounds, which are left behind.

We have seen the relative proportion of inorganic matters in well-rotten dung is much greater than in fresh. This increase in mineral matters can have only been produced at the expense of organic substances, the quantity of which during the process of fermentation must decrease in a corresponding relative degree. Thus the total amount of organic and inorganic matters in fresh dung, dried at 212° Fahr., is,—

Organic matters	83·48
Inorganic matters	16·52
	100·00

Whilst in rotten dung there are in 100—

Organic substances	68·24
Mineral substances	31·76
	100·00

It is clear therefore that, during the fermentation of dung, much of the organic substances must become changed into compounds, which are either readily soluble in water, and easily washed out by heavy rains, or into gaseous products, which are readily volatilized. In point of fact, both volatile gases and readily soluble organic compounds are formed. Amongst the former, carbonic acid and ammonia deserve especial mention; amongst the latter, soluble humates and ulmates may be named. These ulmates and humates are dark-brown-coloured compounds of humic and ulmic acids, with the alkalies, potash, soda, and ammonia. Ulmic and humic acids in a free state are scarcely soluble in water, and for this reason colour it only a light brown. These organic acids have a very powerful affinity for ammonia, in consequence of which they lay hold of any free ammonia, which is generated in the fermentation of dung, and fix it perfectly, as long as no other compound is present or produced in fermenting dung, which at an *elevated temperature* again destroys the union of ammonia with humic, ulmic, and similarly constituted acids. Now, ammonia is generated during the putrefaction of the nitrogenized constituents of dung in large quantities, and would be dissipated into the air much more rapidly than is the case in reality, if there were not formed in the dung itself a group of organic compounds, which act as most excellent fixers of the volatile ammonia. I refer to the humus substances which are gradually produced from the non-nitrogenized constituents of dung. In other words, the straw employed as litter during the putrefaction of dung is to a great extent converted into humic and ulmic acids, which fix to a certain extent the ammonia produced from the more nitrogenous excrementitious matters. The pungent smell of fermenting dung, however, shows that the volatile ammonia cannot be fixed entirely by these means. In the course of this inquiry I shall point out the reason of this, and content myself in this place by saying that the proportion of ammonia which passes into the atmosphere from fermenting dung-heaps, and the loss which hereby is occasioned, is much less considerable than it is generally assumed to be. In fermenting dung-heaps the carbonaceous constituents at first are changed into humus substances, but these are rapidly oxidized by atmospheric oxygen, and partly changed into carbonic acid, a gaseous substance which, in conjunction with oxide of carbon and carburetted hydrogen, is given off abundantly from all putrefying organic matters.

I have endeavoured to describe briefly the principal changes which take place in the fermentation of farmyard manure. It has been shown:—

1. That during the fermentation of dung the proportion of both soluble organic and soluble mineral matters rapidly increases.
2. That peculiar organic acids, not existing—at least, not in considerable quantities—are generated, during the ripening of dung from the litter and other non-nitrogenized organic constituents of manure.
3. That these acids (humic, ulmic, and similar acids) form, with potash, soda, and ammonia, dark-coloured, very soluble compounds. Hence the dark colour of the drainings of dung-heaps.
4. That ammonia is produced from the nitrogenous constituents of dung, and that this ammonia is fixed, for the greater part, by the humus substances produced at the same time.
5. That a portion of the sulphur and phosphorus of the excrementitious matters of dung is dissipated, in the form of sulphuretted and phosphoretted hydrogen.
6. That volatile ammoniacal compounds, apparently in inconsiderable quantities, escape into the air.
7. That the proportion of organic substances in fresh dung rapidly decreases during the fermentation of dung, whilst the mineral substances increase in a corresponding degree.
8. That this loss of organic substances is accounted for by the formation of carbonic acid, oxide of carbon, and light-carburetted hydrogen, or marsh-gas.
9. That the proportion of nitrogen is larger in rotten than in fresh dung.

The practical result of these changes is, that fresh manure, in ripening, becomes more concentrated, more easily available to plants, and, consequently, more energetic and beneficial in its action. It may be questioned, with much propriety,—Is this apparently desirable result attained without any appreciable loss? or is it realised at too great an expense? In other words, Is the fermentation of dung, or is it not, attended with considerable loss of really valuable fertilizing substances?

In putting this question we have to bear in mind that the loss in valuable mineral matters, under proper management, practically speaking, can be avoided, since they are non-volatile, and, therefore, must remain incorporated with the dung, if care be taken to prevent their being washed away by heavy falls of rain. We have likewise to bear in mind that, in an agricultural point of view, the carbonaceous, non-nitrogenized manure constituents do not possess a very high intrinsic value; and that we therefore need not trouble ourselves about their diminution, if it can be shown that it is accompanied with other beneficial changes. The only other constituents which can come into consideration are the nitrogenized matters. The question may therefore be thus simplified: Is the fermentation of farmyard manure necessarily attended with any appreciable loss in nitrogen?

Any one may ascertain that fermenting dung gives off ammonia, by holding over a dungheap, in active fermentation, a moistened reddened litmus-paper. The change of the red colour into blue sufficiently shows that there is an escape of ammonia. However, this experiment does not prove as much as is sometimes believed; for inasmuch as the most minute traces of ammonia produce this change of colour, the escape of this volatile fertilizing matter may be so small that it is practically altogether insignificant. The comparison of fresh with rotten dung, we have seen already, does not decide whether or not fresh farmyard manure sustains a loss in nitrogen in becoming changed into rotten manure. Apparently there is a gain in nitrogen, for we have seen that rotten dung contains more nitrogen than fresh. This gain in nitrogen, however, is explained by the simultaneous disappearance of, relatively, a much larger quantity of carbonaceous organic matter. Still the accumulation of nitrogen in rotten dung is important, and hardly to be expected; for, since a considerable portion of the nitrogenized organic matters is changed into volatile ammonia during fermentation, a loss, instead of a gain, in nitrogen naturally might be expected. A much greater loss in nitrogen than is actually experienced would, indeed, take place during the fermentation of dung, if this process were not attended with the simultaneous formation within the manure-heap of excellent fixers of ammonia.

However, the mere analysis of farmyard manure cannot decide the question which has just been raised, and I therefore at once determined to make the analyses in conjunction with direct weighings of dung in various stages of decomposition. To this end I weighed out carefully two cartloads-full of the same well-mixed sample of fresh farmyard manure, the full analysis of which has been given before. The manure was placed in a heap set against a stone wall, but otherwise exposed to the influence of the weather. The entire crude loss which this experimental heap sustained in the course of time was ascertained by periodical weighings on the weighbridge. Simultaneously with these weighings the manure was submitted to analysis, and thus I was enabled not only to determine from time to time the loss in weight which the experimental heap sustained in keeping, but also to ascertain which constituents were affected by this loss, and in which relative proportions. The results of these periodical weighings and analyses are incorporated in the following table.

TABLE showing Composition of the Whole Heap: Fresh Farmyard Manure. Expressed in lbs.

	When put up. Nov. 3rd, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Weight of manure in lbs.	2838	2026	1994	1974
Amount of water in the manure	1877·9	1336·1	1505·3	1466·5
Amount of dry matter in the manure ..	960·1	689·9	488·7	507·5
Consisting of—				
*Soluble organic matter	70·38	86·51	58·83	54·04
Soluble mineral matter	43·71	57·88	39·16	36·89
†Insoluble organic matters	731·07	389·74	243·22	214·92
Insoluble mineral matter..	114·94	155·77	147·49	201·65
	969·1	689·9	488·7	507·5
*Containing nitrogen	4·22	6·07	3·76	3·65
Equal to ammonia	5·12	7·37	4·56	4·36
†Containing nitrogen	14·01	12·07	9·38	9·38
Equal to ammonia	17·02	14·65	11·40	11·39
Total amount of nitrogen in manure ..	18·23	18·14	13·14	13 03
Equal to ammonia	22·14	22·02	15·96	15·75
The manure contains ammonia in free state	·96	·15	·20	·11
,, ,, ammonia in form of salts, easily decomposed by quicklime	2·49	1·71	·75	·80
Total amount of organic matters	801·45	476·25	302·05	268·96
Total amount of mineral matters	158·15	213·65	186·65	238·54

It will be remarked that in the first experimental period the fermentation of the dung, as might have been expected, proceeded most rapidly, but that, notwithstanding, very little nitrogen was dissipated in the form of volatile ammonia; and that on the whole the loss which the manure sustained was inconsiderable when compared with the enormous waste to which it was subject in the subsequent warmer and more rainy seasons of the year. Thus we find at the end of April very nearly the same amount of nitrogen which is contained in the fresh; whereas, at the end of August, 27·9 per cent. of the total amount of nitrogen, or nearly one-third of the nitrogen in the manure, has been wasted in one way or the other.

It is worthy of observation that, during a well-regulated fermentation of dung, the loss in intrinsically valuable constituents is inconsiderable, and that in such a preparatory process the efficacy of the manure becomes greatly enhanced. For certain purposes fresh dung can never take the place of well-rotten dung. The farmer will, therefore, always be compelled to submit a portion of home-made dung to fermentation, and will find satisfaction in knowing that this process, when well regulated, is not attended with any serious depreciation of the value of the manure. In the foregoing analyses he will find the direct proof that, as long as heavy showers of rain are excluded from manure heaps, or the manure is kept in waterproof pits, the most valuable fertilising matters are preserved. But let us now see how matters stand when manure heaps, the component parts of which have become much more soluble than they were originally, are exposed to heavy showers of rain.

In the first experimental period little rain fell, and this never in large quantities at a time, whilst in the interval of April and August rain was more abundant, and fell several times in continuous heavy showers. In consequence of this soluble matters in the heap were washed out, and with them a considerable portion of available nitrogen, and the more valuable mineral constituents of dung were wasted.

The above analytical data, if I am not mistaken, afford likewise a proof that even in active fermentation of dung but little nitrogen escapes in the form of volatile ammonia, but that this most valuable of all fertilising materials, along with others of much agricultural importance, is washed out in considerable quantities by the rain which falls on the heaps, and is wasted chiefly in the drainings of the dungheaps.

A single fact, it has been truly said, is worth more than a dozen vague speculations. We hear frequently people talk of the loss in ammonia which farmyard manure undergoes on keeping, and this loss is referred by them to the volatilization of the ammonia which is produced in the putrefaction of the nitrogenized constituents of dung. I have, however, already mentioned that simultaneously with the ammonia, ulmic, humic, and other organic acids are generated from the non-nitrogenized constituents of manure, and that these acids possess the power of fixing the ammonia in an excellent manner. If this were not the case, it would be difficult, if not impossible to explain the circumstance that the proportion of soluble nitrogenized matters increased considerably in the manure on keeping for a period of six months, and that during this period the total amount of nitrogen scarcely suffered any diminution. In April the amount of nitrogen in the soluble matters of the entire heap is 6·07 lbs., and by the 23rd of August it is reduced to 3·76 lbs. Why, it it may be asked, is it not likely that most of this nitrogen has passed into the air in the form of volatile ammoniacal compounds? In reply to this question, I would answer that a loss taking place in this way would be felt much more sensibly in the period of active fermentation, in which, however, we have seen that scarcely any nitrogen is dissipated. In the August and November analyses, moreover, it will be observed that not only the amount of soluble organic matters, and with it that of the nitrogen, decreases, but that the soluble mineral matters, which in April amount to 57·88 lbs. in the entire heap, became reduced to 39·16 lbs. by the 23rd of August. Now, this decrease in soluble mineral substances can only be ascribed to the rain which fell in this period, and it is plain that the deteriorating influence of heavy showers of rain must equally affect the soluble nitrogenized constituents of dung.

It may perhaps appear strange that the total amount of dry matter in the manure is greater in November, 1855, than in August, and likewise that there is a good deal more insoluble mineral matter at the end of the experimental year than at the beginning. In explanation of these apparent inconsistencies, I would observe that the increase in insoluble mineral matters is accounted for in the difficulty of shovelling the manure into the dung-cart without mixing with it each time the weighing is made a certain portion of the soil on which the heap is placed. It must likewise be borne in mind that it is almost next to impossible to incorporate mechanical impurities so thoroughly with the dung that differences amounting to 2 or 3 per cent. in the amount of insoluble matters may not occur in the analyses of 2 samples taken from the same heap. In the percentic composition of farmyard manure such differences appear inconsiderable, but when applied to the whole heap they strike us as being great. In short, it is impossible to determine accurately the total amount of insoluble mineral matters in the whole heap. The general deductions, however, which may legitimately be made from the foregoing analyses are not in any perceptible degree affected by this unavoidable source of inaccuracy; but it is well to remember not to dwell too much on minor differences which perhaps may strike the reader; some such differences may be due to purely accidental causes.

On the Methods of Producing and Keeping Farmyard Manure.

With reference to the modes of making manure, allow me to observe at once that I am a strong advocate for the box system, and have every reason to consider manure made in boxes incalculably superior to that made in open yards, and considerably better than manure made in stables and covered yards. In the preparation of box manure abundance of litter is employed; and being cut up, the urine of animals is much more perfectly absorbed than in stables, where much of it passes away. This will explain why box-manure is richer in nitrogen and soluble matters, and consequently much more efficacious than common yard-manure. I have heard it stated that the dung made in fattening-boxes remained as fresh after six months as at first; but this is a mistake. The fact is, the solid and liquid excrements of animals become thoroughly incorporated with the cut straw used as litter, and by the treading of the animals the whole becomes consolidated to an extent that comparatively little air can find access. Still sufficient air comes in contact with the manure, and it undergoes a steady, slow, but uniform fermentation. The dung gradually ripens in the boxes; and this mode of producing manure possesses the great advantage that, during its stay in the boxes, no ammonia nor any soluble organic and inorganic matters are wasted.

In many places there exist, it is true, no facilities of making manure in boxes, and other methods of making manure have to be followed. If the manure cannot be made in boxes, it should at least be produced in covered places, and not be kept longer than it can be helped. The sooner it is carted to the field the better.

Manure made in open yards is always of a very inferior description. Generally the animals kept in open yards are store cattle, which are principally fed upon cut straw, and only now and then get a root. It would be a waste to construct a pit with a watertight tank for such manure; but I cannot help thinking that it is a mistake to expect the straw in open yards much improved in manuring qualities by treading it down by underfed store cattle. The man who keeps lean stock may not experience much loss by keeping the manure exposed to the weather in open yards, for the animals get out of the food all that is good, and hardly find enough to support their own frame. We cannot therefore expect much bone materials or nitrogenised matters in the excrements, and it is not likely that the manure will be very efficacious. But to keep dairy-cows or fattening stock in open yards is a bad practice which should never be tolerated.

I have always thought that a great loss was experienced by keeping farmyard manure exposed to the rain and wind in open yards; but I had no idea of the extent to which manure is diminished in weight and deteriorated in fertilising properties until I had tried a series of very conclusive experiments on this point. With a view of ascertaining the amount of loss farmyard manure sustains, on exposure to the weather in an open yard, I spread 1652 lbs. of fresh dung in an open yard to about the usual thickness, and ascertained from time to time the weight of the manure, and, at the same time, its composition. The results of these weighings and examinations are contained in the following Table:—

Table showing Composition of entire mass of Experimental fresh Farmyard Manure, spread. In Natural State. Expressed in lbs. and fractions of lbs.

	When put up. Nov. 3rd, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Weight of manure in lbs.	1652·	1429·	1012·	950·
Amount of water in the manure	1093·	1143·	709·3	622·8
Amount of dry matter	559·	285·5	302·7	327·2
Consisting of—				
*Soluble organic matter	40·97	16·55	4·96	3·95
Soluble mineral matter	25·43	14·41	6·47	5·52
†Insoluble organic matter	425·67	163·79	106·81	94·45
Insoluble mineral matter	66·93	90·75	184·46	223·28
	559·00	285·50	302·70	327·20
*Containing nitrogen	3·28	1·19	·60	·32
Equal to ammonia	3·98	1·44	·73	·39
†Containing nitrogen	6·21	6·51	3·54	3·56
Equal to ammonia	7·54	7·90	4·29	4·25
Total amount of nitrogen in manure ..	9·49	7·70	4·14	3·88
Equal to ammonia	11·52	9·34	5·02	4·64
The manure contains ammonia in free state	·55	·14	·13	·0055
,, ,, ammonia in form of salts, easily decomposed by quicklime	1·45	·62	·55	·28
Total amount of organic matters	466·64	180·34	111·77	98·40
Total amount of mineral matters	92·36	105·16	190·93	228·80

This Table requires an explanatory notice. It will be observed that the amount of insoluble mineral matters in the manure increases greatly in every succeeding experimental period. Especially it is great in November, 1855. This increase is due entirely to accidental admixtures of earthy matters, which could not be excluded without losing some of the manure. It was found, namely, impossible to collect the manure properly without mixing with it some of the soil over which it was spread. On the 23rd of August, 1855, the manure had shrunk to a very small bulk, and on the 15th of November, 1855, the greater portion of the manure appeared to have gone either into the air or to have been washed into the soil. It was necessary therefore to scrape the soil as close as possible in order not to lose any of the manure; and it is due to this circumstance that at the conclusion of the experiment a very much larger proportion of insoluble mineral substances was found than in the perfectly fresh manure. I may mention, however, that the whole mass of the spread manure has been most carefully mixed before a sample was taken for analysis. The earthy matters I have every reason to believe were intimately mixed with the manure; and since the composition of the entire mass has been calculated from the data already furnished, the general deductions which may be derived from my experiments are not affected by this circumstance. In speaking of the loss which this manure sustained in keeping, I will select the more important fertilising constituents for illustration, and in reference to them beg to make the following observations:—

1. The weight of the whole manure, when spread out in an enclosed yard, amounted to 1652 lbs. In this quantity were present 40·97, or nearly 41 lbs. of soluble organic matters. After the lapse of six months only 16½ lbs. were left in the manure; in nine months barely 5 lbs., and after twelve months merely 4 lbs.

Thus only about 1-10th part of the original quantity of soluble organic matters was left over by keeping fresh farmyard manure spread out in an open yard.

2. The nitrogen contained in the 41 lbs. of soluble organic matters amounted to 3·28 lbs. After six months only 1·19 lbs. of nitrogen, in the state of soluble compounds, was left; after nine months little more than ½ lb., and after twelve months only ⅓ of a lb. In other words, the nitrogen in the state of soluble compounds has disappeared almost entirely in the course of a year.

3. In an equally considerable degree the soluble mineral matters were dissipated in the manure. Originally the manure contained 25·43 lbs. of soluble mineral matters. After six months this quantity became reduced to 14·41 lbs; after nine months to 6·47 lbs., and after a lapse of twelve months to 5·52 lbs.

On the whole the manure thus lost 78·2 per cent. of the original quantity of soluble mineral matters.

4. Still more striking is the loss in insoluble organic matters. In the fresh manure were present 425·67 lbs. of insoluble organic substances. In the course of six months these became reduced to 163·79 lbs.; a further exposure of rather more than three months to the weather reduced this quantity to 106·81 lbs., and after twelve months merely 94·45 lbs. were left over. The manure

lost thus no less than 77·7 per cent. of the original quantity of insoluble organic matters.

5. If we look to the total amount of nitrogen, we shall find that the original proportion of nitrogen in the manure, amounting to 9·49 lbs., was reduced in the course of six months to 7·70 lbs., after nine months to 4·14 lbs., and after twelve months to 3·88 lbs.

At the conclusion of the experiment more than half the quantity, or, in exact numbers, 59·1 per cent. of the nitrogen contained in the fresh manure, was wasted.

6. If we replace, in the analysis made on the 15th November, 1855, the number which expresses the amount of insoluble mineral matters by the number 66·93, expressing the proportion of insoluble mineral matters which the manure contained at the commencement of the experiment, and which it would have also contained had no earthy matters been mixed up with the manure, and add to it the other constituents, we obtain for the corrected composition of the whole manure in November, 1855, the following numbers, which for comparison's sake are contrasted with the analysis of the fresh manure of November, 1854:—

	When put up, Nov. 3, 1854. lbs.	At conclusion of experiment, Nov. 15, 1855. lbs.
Weight of the manure	1652	950
Amount of water in the manure	1093	622·8
„ dry substances	559	170·85
Consisting of:—		
Soluble organic matters	40·97	3·95
*Soluble mineral matters	25·43	5·52
†Insoluble organic matters	425·67	94·45
Insoluble mineral matters	66·93	66·93
	559·00	170·85
* Containing nitrogen	3·28	·32
Equal to ammonia	3·98	·39
† Containing nitrogen	6·21	3·56
Equal to ammonia	7·54	4·25
Total amount of nitrogen in manure	9·49	3·88
Equal to ammonia	11·52	4·64
The whole manure contained:—		
Ammonia in free state	·55	·0055
Ammonia in form of salts readily decomposed by quicklime	1·45	·28
Total amount of organic matters	466·64	98·40
„ mineral matters	92·36	72·45

It will hence appear from these results that the experiment was begun with 559 lbs. of dry manure; after the lapse of twelve months, only 170·85 lbs. were left behind. Kept for this length of time spread in an open yard, the manure thus lost no less than

69·8 per cent. in fertilising matters; or, in round numbers, *two-thirds of the manure were wasted, and only one-third was left behind.* This fact teaches a most important lesson, and speaks for itself so forcibly that any further comment appears to me useless.

I have already observed that there is no advantage in keeping manure for too long a period before carting it on the fields, and again beg to urge you to adopt this last-named plan in preference to setting up a manure-heap in a corner of the field and exposing it to the deteriorating influence of rain. You need not be afraid that it will lose any of its essential fertilizing constituents by spreading it out, even if you cannot plough in the manure for a long time to come. By spreading out the manure, the fermentation is stopped immediately, and no ammonia can possibly escape into the air. The rain which falls on the manure will wash its valuable constituents into the soil, the very place where they are wanted to be. By spreading the manure over the land and allowing it to be washed in gradually by the falling rain, it becomes much more uniformly incorporated with the soil than by any other method, and this unquestionably is a great advantage; in proof of which I beg to remind you of the superior effect of superphosphate when sown with the liquid manure drill, or guano mixed with salt, sand, or anything which tends to secure a more uniform distribution of this fertilizer.

Some farmers are afraid that heavy rain might wash into the subsoil the best fertilizing constituents of manure, especially when it is carted on the land in autumn; but this fear is unfounded, for the beautiful researches of Professor Way have shown that most soils of average quality possess the power of absorbing manuring matters and retaining them so firmly, that they cannot be sensibly removed by the heaviest showers or long-continued rain. The only exception to this general absorbing property of soils we find in very light sandy soils. On such soils the manure should be used just before the crop is sown which is intended to be cultivated.

I am aware, however, that the manure cannot always be carted at once on the land, and for the root-crops has to be kept until it is thoroughly decomposed. Where the manure cannot be made in boxes, it is very desirable that it should be kept in covered pits. However there is no rule without exception, for where litter is abundant, as in the neighbourhood of Cirencester, all the rain which falls in the year is required to make the straw into manure, and it would entail additional cost to place a dung-pit under cover. Under such circumstances, I think the expense for erecting a roof over a dung-pit may be avoided with propriety.

With reference to the time of applying farmyard manure, I would observe that much depends on the kind of land which is to be manured. On the whole, I think autumn manuring greatly preferable to spring manuring, even in the case of moderately strong land. On stiff clay soils farmyard manure should always be used in autumn, and, if possible, be ploughed in before the frost sets in. By this means the full advantage of manure is secured, for, in addition to the chemical effects which manure is capable of producing, it will exercise upon stiff clays a most beneficial mechanical effect by keeping the land more porous and open. On the other hand it is not desirable, for obvious reasons, to apply manure in autumn to very light sandy land.

As in the beginning of this lecture I have treated many interesting points with reference to farmyard manure in a very cursory manner, I beg to refer those who wish to study more fully the chemistry of farmyard manure to a paper of mine, published in the 'Journal of the Royal Agricultural Society of England,' July, 1856. Before concluding, however, I may be permitted to state the following general conclusions, to which a series of similar experiments to those referred to in this lecture have led me :—

Conclusions.

1. Perfectly fresh farmyard manure contains but a small proportion of free ammonia.

2. The nitrogen in fresh dung exists principally in the state of insoluble nitrogenized matters.

3. The soluble organic and mineral constituents of dung are much more valuable fertilizers than the insoluble. Particular care, therefore, should be bestowed upon the preservation of the liquid excrements of animals, and for the same reason the manure should be kept in perfectly waterproof pits, of sufficient capacity to render the setting up of dungheaps in the corner of fields, as much as possible, unnecessary.

4. Farmyard manure, even in quite a fresh state, contains phosphate of lime, which is much more soluble than has hitherto been suspected.

5. The urine of the horse, cow, and pig, does not contain any appreciable quantity of phosphate of lime, whilst the drainings of dungheaps contain considerable quantities of this valuable fertilizer. The drainings of dungheaps, partly for this reason, are more valuable than the urine of our domestic animals, and therefore ought to be prevented by all available means from running to waste.

6. The most effectual means of preventing loss in fertilizing matters is to cart the manure directly on the field whenever circumstances allow this to be done.

7. On all soils with a moderate proportion of clay no fear need to be entertained of valuable fertilizing substances becoming wasted if the manure cannot be ploughed in at once. Fresh, and even

well-rotten dung, contains very little free ammonia; and since active fermentation, and with it the further evolution of free ammonia, is stopped by spreading out the manure on the field, valuable volatile manuring matters cannot escape into the air by adopting this plan.

As all soils with a moderate proportion of clay possess in a remarkable degree the power of absorbing and retaining manuring matters, none of the saline and soluble organic constituents are wasted even by a heavy fall of rain. It may, indeed, be questioned whether it is more advisable to plough-in the manure at once, or to let it lie for some time on the surface, and to give the rain full opportunity to wash it into the soil.

It appears to me a matter of the greatest importance to regulate the application of manure to our fields so that its constituents may become properly diluted and uniformly distributed amongst a large mass of soil. By ploughing in the manure at once, it appears to me this desirable end cannot be reached so perfectly as by allowing the rain to wash in gradually the manure evenly spread on the surface of the field.

By adopting such a course, in case practical experience should confirm my theoretical reasoning, the objection could no longer be maintained that the land is not ready for carting manure upon it. I am much inclined to recommend as a general rule: cart the manure on the field, spread it at once, and wait for a favourable opportunity to plough it in. In the case of clay soils, I have no hesitation to say the manure may be spread even six months before it is ploughed in, without losing any appreciable quantity of manuring matters. I am perfectly aware that, on stiff clay-land, farmyard manure, more especially long dung, when ploughed in before the frost sets in, exercises a most beneficial action by keeping the soil loose and admitting the free access of frost, which pulverizes the land, and would therefore by no means recommend to leave the manure spread on the surface without ploughing it in. All I wish to enforce is, that when no other choice is left but either to set up the manure in a heap in a corner of the field, or to spread it on the field, without ploughing it in directly, to adopt the latter plan. In the case of very light sandy soils it may perhaps not be advisable to spread out the manure a long time before it is ploughed in, since such soils do not possess the power of retaining manuring matters in any marked degree. On light sandy soils I would suggest to manure with well-fermented dung shortly before the crop intended to be grown is sown.

8. Well-rotten dung contains likewise little free ammonia, but a very much larger proportion of soluble organic and saline mineral matters than fresh manure.

9. Rotten dung is richer in nitrogen than fresh.

10. Weight for weight, rotten dung is more valuable than fresh.

11. In the fermentation of dung a very considerable proportion of the organic matters in fresh manure is dissipated into the air in the form of carbonic acid and other gases.

12. Properly regulated, however, the fermentation of dung is not attended with any great loss of nitrogen nor of saline mineral matters.

13. During the fermentation of dung, ulmic, humic, and other organic acids are formed, as well as gypsum, which fix the ammonia generated in the decomposition of the nitrogenized constituents of dung.

14. During the fermentation of dung the phosphate of lime which it contains is rendered more soluble than in fresh manure.

15. In the interior and heated portions of manure-heaps ammonia is given off; but, on passing into the external and cold layers of dungheaps, the free ammonia is retained in the heap.

16. Ammonia is not given off from the surface of well-compressed dungheaps, but on turning manure-heaps it is wasted in appreciable quantities. Dungheaps for this reason should not be turned more frequently than absolutely necessary.

17. No advantage appears to result from carrying on the fermentation of dung too far, but every disadvantage.

18. Farmyard manure becomes deteriorated in value when kept in heaps exposed to the weather—the more the longer it is kept.

19. The loss in manuring matters, which is incurred in keeping manure-heaps exposed to the weather, is not so much due to the volatilization of ammonia as to the removal of ammoniacal salts, soluble nitrogenized organic matters, and valuable mineral matters, by the rain which falls in the period during which the manure is kept.

20. If rain is excluded from dungheaps, or little rain falls at a time, the loss in ammonia is trifling, and no saline matters of course are removed; but if much rain falls, especially if it descends in heavy showers upon the dungheap, a serious loss in ammonia, soluble organic matters, phosphate of lime, and salts of potash is incurred, and the manure becomes rapidly deteriorated in value, whilst at the same time it is diminished in weight.

21. Well-rotten dung is more readily affected by the deteriorating influence of rain than fresh manure.

22. Practically speaking, all the essentially valuable manuring constituents are preserved by keeping farmyard manure under cover.

23. If the animals have been supplied with plenty of litter, fresh dung contains an insufficient quantity of water to induce an active fermentation. In this case fresh dung cannot be properly fermented under cover, except water or liquid manure is pumped over the heap from time to time.

Where much straw is used in the manufacture of dung, and no provision is made to supply the manure in the pit at any time with the requisite amount of moisture, it may not be advisable to put up a roof over the dung-pit. On the other hand, on farms where there is deficiency of straw, so that the moisture of the excrements of our domestic animals is barely absorbed by the litter, the advantage of erecting a roof over the dung-pit will be found very great.

24. The worst method of making manure is to produce it by animals kept in open yards, since a large proportion of valuable fertilizing matters is wasted in a short time; and after a lapse of twelve months at least two-thirds of the substance of the manure is wasted, and only one-third, inferior in quality to an equal weight of fresh dung, is left behind.

25. The most rational plan of keeping manure in heaps appears to me that adopted by Mr. Lawrence, of Cirencester, and described by him at length in Morton's 'Cyclopædia of Agriculture,' under the head of 'Manure.'

2.—THE COMMERCIAL AND AGRICULTURAL VALUE OF ARTIFICIAL MANURES.

[Delivered at Barnstaple, January, 1857.]

Any one who has seen the astonishing effects which guano produces when applied to corn crops, or superphosphate when applied to root crops, can doubt no longer the very great importance which the introduction of artificial manures has acquired with respect to practical agriculture. It is from the introduction of artificial manures that we have to look forward for still greater success in agricultural improvements. When artificial manures were first brought under the notice of farmers they were offered for sale in a very crude and inefficient state; and it is really marvellous to see the vast improvements which have taken place in their manufacture. Year after year are improvements introduced by intelligent manufacturers possessed of sufficient capital to carry out the suggestions of scientific chemists in an efficient manner, and scarcely has one improvement met with practical success before another is brought under the notice of practical farmers. It is really surprising that, notwithstanding the great improvements which intelligent manufacturers of artificial manures have introduced into their manures, there should be manures of a very low standard still offered in the market, and purchased by practical farmers. I have been thinking a good deal about the causes which would account for the curious anomaly, that, while there are in the manure market artificial manures of the highest degree of fertility—manures which are really worth the money which is asked for them, there are others, scarcely worthy the name of artificial manures, offered for sale and finding ready purchasers; and I have come to the conclusion that, in the first instance, the proper use to which artificial manures should be applied by farmers is not so well understood as it is desirable it should be; and, secondly, that there are in the case of the small farmer, peculiar circumstances which account for the anomaly that the best manures often do not find so ready a sale as manures altogether of an inferior character.

With respect to the first point I would observe that it is quite an erroneous view to think that an artificial manure should answer the same purposes for which common farmyard manure is usually applied. Farmyard manure is a perfect and universal manure, and, if you have plenty of it, it would be foolish buying artificial manures; but the question is, can you always make farmyard manure with a profit? can you always feed animals with a profit so as to produce sufficient home-made manure to answer your purpose? Supposing you can feed with profit only a limited quantity of stock, would you not make that quantity of home-made manure which you produce by the judicious selection of artificial manures go once or twice as far as you would without the use of artificial manures? I answer that question by a decided "Yes." I think the judicious selection of artificial manure will not supersede farmyard manure, but will enable the intelligent agriculturist to make one ton go twice as far as it would without the simultaneous use of artificial manures.

Some manufacturers recommend as a peculiar feature of their articles which they offer for sale, that they are equal to the best home-made manure; that they are, in fact, universal manures, answering to every description of crops; but I think the very recommendation is a condemnation of their manures: for it must not be the aim of the manure manufacturer to produce a manure similar in character to farmyard manure, but rather to produce manure not partaking of the characters peculiar to farmyard manure. You must well remember that farmyard manure exercises a mechanical as well as a chemical effect upon the soil and the crops which are intended to be raised. The mechanical effect produced by farmyard manure tends to lighten the soil, and admit freely air and atmospheric food for plants, and indirectly to offer for the plants the food of the soil, which is present in it in an insoluble state, and which, by the introduction of farmyard manure, is rendered soluble. These mechanical effects, which are intimately connected with the chemical effects which farmyard manure produces in soils, cannot well be imitated by any artificial manure. It is irrational to expect artificial manures to produce these mechanical effects; you ought rather to look to the direct food which artificial manure supplies to plants, and which is supplied by home-made manure to only an inconsiderable extent.

COMPOSITION OF FRESH AND WELL-ROTTEN FARM-YARD MANURE
(COMPOSED OF HORSE, PIG, AND COW DUNG).

	Fresh.		Well-Rotten.	
	In Natural State.	Dry.	In Natural State.	Dry.
Water	66·17		75·42	
Soluble Organic Matter	2·48	7·33	3·71	15·09
Soluble Inorganic Matter (Ash):—				
Soluble Silica ..	·237	·703	·254	1·035
Phosphate of Lime	·299	·884	·382	1·554
Lime	·006	·185	·117	·476
Magnesia	·011	·033	·047	·193
Potash	·573	1·695	·446	1·816
Soda	·051	·153	·023	·140
Chloride of Sodium	·030	·089	·037	·151
Sulphuric Acid ..	·055	·035	·058	·235
Carbonic Acid and Loss	·218	·773	·106	·380
	1·54	4·55	·47	5·98
Insoluble Organic Matter	25·76	76·15	12·82	52·15
Insoluble Inorganic Matter (Ash):—				
Soluble Silica ..	·964	2·865	1·424	·570
Insoluble Silica ..	·561	1·659	1·010	4·11
Oxide of Iron Alumina Phosphates ..	·596	1·404	·947	3.85
Containing Phosphoric Acid	(·178)	(·528)	(·274)	(1·11)
Equal to Bone Earth	(·386)	(·822)	(·573)	(2·41)
Lime	1·120	3·335	1·667	6·78
Magnesia	·143	·424	·091	·37
Potash	·099	·294	·045	·18
Soda	·019	·677	·038	·15
Sulphuric Acid ..	·061	·210	·063	·29
Carbonic Acid and Loss	·484	1·722	1·295	5·26
	4·05	11·97	6·58	26·78
	100·00	100·00	100·00	100·00
Containing Nitrogen	·149	·44	·297	1·21
Equal to Ammonia	·181	·53	·36	1·47
Containing Nitrogen	·494	1·46	·309	1·26
Equal to Ammonia	·599	1·77	·375	1·53
Whole Manure, containing Ammonia in free state	0·34	·10	·046	·189
,, in form of Salt	0·88	·26	·057	·052

If you look at the composition of farmyard manure, you will observe entering into it, a large amount of substances which are present in the soil in abundance, or which—in the form of straw or litter—can be easily incorporated with the soil, and which are cheap and readily procurable in the market. Now these cheap materials—amongst which I would mention lime, magnesia, silica (which is but another name for sand), oxide of iron, alumina, and a few other substances—are abundantly in the soil. When supplied in the manure, they do not produce any striking effect, but there are other constituents entering into the composition of farmyard manure, which, when supplied to the soil, produce the most striking effects. The amount of nitrogen in fresh farmyard manure, or in rotten dung, is exceedingly small; but, notwithstanding this, it exercises a most remarkable effect upon wheat, barley, oats, and grass crops.

All substances containing nitrogen may be regarded as special manures for cereals and grass crops. Their especial function is to promote the luxurious growth of cereals; and hence you need not feel astonished to see a remarkable effect following the use of guano, for this is a manure rich in nitrogen, and, in consequence of the large amount of ammonia which it contains, produces an extremely beneficial effect on the wheat crop. Another constituent present in farmyard manure, only in small quantities, is phosphate of lime—the principal constituent of bones. Bones, as most of you know, consist, as far as their bulk is concerned, principally of phosphate of lime. Now phosphate is extremely useful for root crops. It is required by all agricultural produce; but experience has shown that it is most beneficially applied to root crops. My time will not permit me to assign the reasons why phosphate of lime, when supplied to the soil in a proper state, is especially useful to root crops; but I appeal to the general experience of practical farmers, and content myself by saying, rather dogmatically, that phosphate of lime is a special manure for root crops. At all events, it is one of the most important fertilising materials which is found in farmyard manure; but you will observe that the proportion of bone material, or phosphate of lime, in farmyard manure is but small. There is a class of substances of the name of potash and soda, two substances comprised under the general name of alkalis. These alkalis—potash and soda—are largely required by all agricultural plants. They are found in the ashes of all agricultural produce, and are absolutely necessary for their existence. Now the great value of artificial manures depends just on this, that they concentrate these important fertilising materials—important because all soils contain them only in small quantities, and all agricultural produce requires them in larger quantities than any of the other constituents which are found in farmyard manure. The great value of artificial manures depends upon the circumstance that they present these important constituents in a concentrated state. Perhaps some of you may say, "It's all very well for you to tell us this; and to lecture to practical men about phosphate and ammonia, but how far does your theoretical reasoning agree with the experience of farmers?" I would refer you in answer to this, to the acknowledged advantages which the use of guano and superphosphate produces; and any one who has seen the striking results of these two descriptions of manure will see at once that their value does not depend upon anything mysterious, but upon real chemical substances. It must always be our aim to be guided by practical experience, and to explain matters of fact which are the results, not only of the limited experience of a farmer in one district, but also of the general experience of farmers throughout the country. I would impress upon my audience the important fact that the value of artificial manures cannot be simply ascertained by practical experiments, unless these experiments are various in their character, and extend over a long series of years. An analysis of manure will give you useful hints as to the money which you ought to pay for it, but it does not tell you which is the best manure which, under existing circumstances, ought to be used; and it is not the office of the scientific chemist or the manure dealer to recommend to his clients particular manures. The fact of the case is that the farmer must use his own judgment; at the same time I would remind you that artificial manures are not intended to save labour.

Those who think that good crops can be secured by merely using guano, or superphosphate, or nitrate of soda, or any other artificial manure, without adopting other means, will find themselves grievously disappointed. The fact is, the use of artificial manures requires superior intelligence, I might almost say a special training, which can hardly be expected from men who all their life have been accustomed to follow farming as a livelihood. I would say to all those who are not in a position to use artificial manures with advantage, Better follow your own approved system of farming, without using artificial manures at all, than simply depend upon the use of artificial manures for success. No success will follow unless you introduce into your farming practice improvements of another character. The best manures are frequently condemned for want of not using mechanical means of cultivation, which so greatly improve the condition of the soil. I cannot too strongly impress upon your minds the fact, that it is not merely by using artificial manures that profitable results are obtained in farming matters. It is of the greatest importance that you look first to the mechanical improvement of the soil. I have seen in many cases superphosphate entirely fail, for want of a proper pulverisation of the soil. A very striking case was very recently brought under my notice. On the farm attached to the Agricultural College of Cirencester, with which I am connected, I have lately made some experience with different manuring matters. On one portion of the soil I used superphosphate: the result was that on this portion I did not get a single hundredweight more produce than on another portion in close proximity where no superphosphate was used at all. Fortunately I tried the same experiment on another portion of the farm, and got a very large result. Now, if I had been content with making only one experiment, to what conclusion should I have arrived? To the following: that on clay soils—for it was a clay soil on which I tried the experiment—superphosphate was of no use; and that it was the worst manure I could use, for it hardly gave me any increase. But I should have drawn a wrong conclusion, and you will observe how difficult it is to form a satisfactory conclusion from a single experiment: for, having tried the same experiment on a similar soil,—but upon a soil which was taken in hand for several years before the experiment was tried, and which, when the manure was applied, was in a high state of mechanical subdivision—I obtained three times as much as upon the portion of land where nothing was applied. You will observe, then, how the mechanical condition of the soil influences the efficacy of artificial manures. Some manufacturers of artificial manures are so well aware of the importance of introducing into farming improved agricultural implements, that they sell those implements without any profit, for they know that they can only then expect a large sale of their manures, when the farmer does the best on his part, and that good manures have no chance of any success, if no care is taken to bring the soil in such a mechanical condition that the artificial manures can exercise any beneficial effect.

In the next place, allow me to observe, that the chemical composition of the land greatly influences the efficacy of manure. There are some soils in which phosphatic manures—manures containing bone material, or phosphate of lime—have no effect. Some soils resting on the greensand formation contain sufficient phosphate of lime to meet all the requirements of the growing crops; hence you cannot feel surprised that bones or superphosphate produce no effect upon such soils. The fact is, the soil already contains more than sufficient phosphate of lime to meet all the requirements of the plant; and hence it is that dealers in superphosphate, containing frequently a very small proportion of of bones, can dispose of their inferior description of superphosphate in localities where bone materials exist in large quantities in the soil; in other words, when they can carry on their trade in a very rich part of the country, they will meet with quite as much success as manufacturers selling superphosphate containing a high percentage of phosphate.

The first questions for the farmer to ask himself are, what will answer my purpose best? what will give me a good crop? and what manure gives me the best return? and, having settled these questions, I think he should then ask, what ought I to pay for the manure which has answered my purpose? I beg to direct your attention, in the next place, to a few more conditions which influence the efficacy of manure. If you use a top dressing of guano, or nitrate of soda, too late in the season, upon wheat or oats, it hardly produces any effect. I would not use a top dressing for wheat later than February. On clay soils it may be advisable to use it in autumn. When used late in spring, guano, nitrate of soda, and similar manures, do not produce any great effect; while, when the same manures are used at the proper time, they produce a most beneficial result. The time of application then greatly influences the efficacy of manure; but not only the time, but also the mode in which the manure is applied. If you use a concentrated manure like guano, in an imperfectly powdered state—perhaps with all the hard lumps in it you find in the bags which you get from the manure merchant—it does not produce that effect which is realised by crushing and sifting it, and perhaps mixing it with salt or sand. You have no doubt seen it recommended to mix salt with guano. Some persons think salt has the effect of "fixing" the ammonia, but the "fixing" of ammonia by salt is all nonsense, for the simple reason that guano contains scarcely any free ammonia. The result of a number of experiments gave me as the amount of carbonate of ammonia in guano hardly three quarters per cent., a very small quantity indeed. Allow me to suggest to you to mix guano with oil of vitriol. You will find that the peculiar smell is by no means destroyed by sulphuric acid, which would be the case if it were due to ammonia. People run wild with the idea that everything which smells is ammonia. They talk of ammonia and carbonic acid, and then think they have done a great service by introducing chemistry to the notice of the practical farmers; but such men do a great deal towards bringing that science into disrepute. Well, now, why does guano act so well when mixed with salt? Chiefly, I believe, because you cannot mix it without breaking down the hard lumps, and thus distribute it more equally upon the land, and everything in farming depends upon the equal distribution of manuring substances. I would say, mix the guano with earth (if dry), burnt clay, sand, or salt; but this is a dangerous thing to say, for some people have taken a strong fancy for salt, and if they are told to mix guano with sand, it will sound far too homely. They are much more likely to follow your advice if you tell them to mix it with salt. Therefore it is sometimes advisable not to say the exact thing: a little mystery might be, perhaps, under existing circumstances the best; but, for my own part, I have a great horror for anything like humbugging the practical man. It is not by blind experiments that any great success can well be realised in farming matters. Nor is it by mere theoretical speculations that agriculture will be greatly advanced; but it is by the joint labours of the practical man in the field, and the researches of the man of science, that great and important results may be confidently expected.

In the next place I would observe that there are circumstances over which the farmers frequently have no control which greatly influence the efficacy of manures. For instance, you cannot always make certain of good seasons; and in a bad season the worst manures frequently have as good a chance as the very best. Then, again, you cannot control diseases in plants. You will often find that diseases in a mysterious way attack the wheat crop; and the fly carries off the turnip plant. All these matters have to be well weighed before you can really come to a just conclusion respecting the practical value of artificial manures.

Now, I do not mean to say that in the long run the real value of any description of manure will not be clearly defined. Practical experience has shown that only those manures which contain a large amount of ammonia, or a large amount of phosphate, or both, are really efficient manures. But, supposing you have ascertained that a certain description of manure is efficacious for a particular purpose, say the raising of turnips, how is the farmer to decide what he is to pay for it? In other words, how can he estimate the money value of the artificial manures which he buys? Now, as hinted already, I would say, the practical value of a manure does not necessarily coincide with its money value. Lime on soils deficient in that substance produces a very powerful effect; on some clay soils it is the manure which ought to be used; but what will you say of a farmer if he gives for lime the same amount of money which he pays for guano? With great propriety you will say he is a fool. Supposing such a person should say, "I don't care for the value of lime; I want a good crop, and I am satisfied with the result;" the man who sold him lime will have a good laugh at him. You may think that I am using exaggerated language, for nobody in his proper senses would reason thus; but allow me to observe that there is no exaggeration if you replace the word lime by artificial manures. There are manures sold in the market which are not worth one quarter the money which is actually paid for them; and it is the duty of chemists to point out the rascality of parties, for it is nothing else, of those who sell such manures. But with reference to the money value of a manure, and the benefits a farmer may derive from it, I beg to say, that to a hard-working labouring man a crust of bread and cheese is certainly as valuable, and it does him a great deal more good, than lobster salad; but would he be right to pay as much for the bread and cheese as for lobster salad? Certainly not. Supposing then, that two samples of superphosphate are sold at the same price, and in a certain place they produce the same results, would the farmer be justified in paying as much for the inferior description of superphosphate as he pays for the superior description? Certainly not. It is his business to determine what is wanted on his land, and if he finds that it requires dissolved bones let him pay according to the amount of bones which have been used in preparing the manure.

In common life you do not estimate entirely the value of a thing by the benefit you derive from its possession. If you want a good plough horse you will ask what such a horse fetches in the market. Now why do you not ask in the same way what good superphosphate of lime fetches in the market? If you want a good turnip manure you ought to inquire what is the lowest price at which you can produce turnips; for I have no hesitation in saying that turnips are often produced at too high a price. No fixed rules can be laid down in farming. Every man must use his own judgment, and inquire what is the best produce for him to raise under the circumstances in which he finds himself situated.

For my own part I would not condescend to recommend any manure, even if I could do so with propriety; for it is not the part of any chemist to say, "This manure is a good one," or, "that manure is a better one." It is the chemist's business to ascertain the composition of a manure, and to estimate its value accordingly. Chemists, however, ought not merely to take into account the value of the constituents, but ought also to make a fair allowance for the skill and trouble which is incurred on the part of the manufacturer in the preparation of the manure; for the mode of preparation often very greatly enhances the practical efficacy, as well as the commercial value, of the manure. Materials in a raw state are much cheaper than they are in a prepared state. Take, for instance, a sack of flour. In the form of bread it is much dearer, because it has undergone preparation. The baker cannot be expected to bake for nothing, nor can the manure manufacturer be expected to dissolve his bones for nothing. It is fortunate for the farmers that there are men of the highest degree of integrity and principle engaged in the manure trade, who make their living principally by the profit they gain in the purchase of the raw material; but I am grieved to say there is another class of men engaged in the manure trade who know the weak sides of the farmers; who know that a man who takes a reasonable percentage in the employment of his capital, will not condescend to have a long talk in his dealings; indeed he cannot afford to have a talk of a couple of hours in length before he effects a sale. There are dealers who go into the market, and lay hold of the small farmer and talk him over over a glass of grog, and they will often say, "You need not trouble yourself about the composition of the manure, if you don't get a good crop of turnips I won't take any money for my manure." Another perhaps will say, "Never mind about the money now, I'll take it in six or twelve months, or when it is convenient to you." The man who employs a large capital cannot wait so long for a return.

In conclusion, allow me to illustrate the above remarks on artificial manures by a reference to a few fraudulent manures, and to impress upon you the necessity of paying much attention to the composition of artificial manures, which are offered for sale in the market.

In the first place I beg to direct your attention to the subjoined diagram, which represents the composition of two samples of the British Economical Manure, which have been referred to me for analysis.

British Economical Manure.

Water	36·52	13·43
Organic Matter	..	3·04
Oxide of Iron and Alumina	..	2·30
Sulphate of Iron	23·75	25·84
,, Lime (Gypsum)	·86	32·42
,, Magnesia	·20	..
,, Soda	15·14	18·40
Bi-sulphate of Potash	4·67	..
,, Soda	10·92	..
Insoluble Silicious Matter (Sand)	5·85	3·36
	100·05	100·00
Containing Ammonia	·68	·30

Many people have been sadly deceived in buying the British Economical manure, a manure which is sold at 12*l.* per ton, and consists almost altogether of materials possessing very little value.

It will be observed that the first sample contains not quite three-quarters per cent. of ammonia, and the second sample not even one-half per cent., whilst phosphate of lime is altogether wanting in both samples. Instead of these valuable compounds, green vitriol or sulphate of iron, crude sulphate of soda, or as it is technically called, salt-cake, gypsum, and sand constitute the chief ingredients of this manure, which professes to be superior in efficacy to the best Peruvian guano.

It will strike you that the second sample contains a very much larger amount of gypsum, and is much drier than the first sample. When first brought out the manure was found too wet, and therefore was objected to by many farmers, who in general like a manure that runs easily through the drill. To remedy this defect the ingenious proprietor of the economical manure introduced into its composition a large quantity of gypsum, a cheap material, which answers exceedingly well the purpose of drying up moist substances.

In this dry condition the economical manure is now generally sold, but its composition is by no means constant, for the proprietor has no manufactory of his own, and gets his manure made as best he can. It is made in various parts of the kingdom, generally in localities where chemical manufactories abound, as in the neighbourhood of Liverpool, Bristol, Glasgow, Newcastle, and London.

By paying a handsome profit to the chemical manufacturers, who in many instances are but too glad to dispose of their refuse materials, the proprietor of the British Economical Manure engages the interests of the manufacturers, and by giving a commission of 1*l.* to 2*l.* for the sale of every ton of this manure he secures agents in all parts of England to dispose of the all but worthless stuff.

In the next place, let me point out to you in the subjoined diagram the composition of two manures, one of which is called Mexican guano, and the other professes to be the very essence of Peruvian guano :—

GUANO (*so called*).

	Mexican.	Essence of.
Water	5·33	8·28
Organic Matter	3·52	13·11
Oxide of Iron and Alumina	..	3·59
Phosphate of Lime	18·10	2·35
Sulphate of Lime (Gypsum)	..	15·17
Carbonate (Chalk)	69·75	8·00
Chloride of Sodium (common Salt)	1·75	15·80
Insoluble Silicious Matter (Sand, &c.)	..	34·29
Magnesia	1·35	..
Loss	20	
	100·00	100·50
Containing Nitrogen	19	52
Equal to Ammonia	23	64

Large quantities of this so-called Mexican guano were sold not long ago at a high price, notwithstanding its inferior composition.

It is true the Mexican guano is not quite as bad as the "Economical manure," for it contains 18 per cent. of phosphate of lime, which you well know is a valuable fertilizing constituent; but it is a farce to call a manure, which contains nearly 70 per cent. of carbonate of lime or chalk, and a mere trace of ammonia, by the name of guano. The analysis shows plainly the true character of the so-called Mexican guano, which in reality is nothing more or less than sea-sand, containing a certain amount of fragments of fish-bones.

With respect to the second manure given in the above diagram, I would observe that a more fraudulent case, excepting the British Economical, has never been brought under my notice. Instead of 16 per cent. of ammonia, which good Peruvian guano contains, this essence has only six-tenths per cent., and instead of 20 to 25 per cent. of phosphate of lime or bone-earth, only two to three-tenths per cent. The examination, indeed, has shown that this "essence of guano" contained a mere trace of Peruvian guano, a large quantity of gypsum, lime, sand, brick-dust, common salt, and sheep's dung. So clumsily was the mixture made, that the last-mentioned ingredient could be readily identified by its characteristic form.

How is it, it may well be asked, that such and similar manures can find purchasers in an enlightened country like England? The answer to this question is to be found in the credulity of many, who, strange to say, place more reliance upon printed testimonials, than upon the only trustworthy means of ascertaining the value of manures, *i.e.* chemical analysis. Let me guard you against being deceived by enticing testimonials, for, generally speaking, the worse the manure the more favourable the testimonials. Gas-lime, road-scrapings, peat-ashes, and similar refuse matters, in a more or less disorganised state, can be sold, as shown by actual experience, at high prices, and the most favourable testimonials respecting their efficacy can be obtained, if an originator of a fraudulent manure makes up his mind to spend a couple of thousand pounds in advertisements, getting up testimonials, and otherwise pushing his manures.

I feel much tempted to bring under your notice other fraudulent manures, which are at the present time largely advertised in agricultural periodicals, but the cases just mentioned I trust will suffice to put the unsuspecting farmer on his guard.

It must not be supposed, however, that fertilisers of recognised merit, such as guano or superphosphate, offer no temptation to the unprincipled dealers to fleece the unwary. Indeed, guano and superphosphate are as much adulterated as any other description of artificial manure, and it may not therefore be amiss to allude briefly to the composition of good and inferior guanos, and the circumstances which principally determine the value of superphosphate of lime. In the following Table is stated the composition of four different samples of guano, all professedly Peruvian guano:—

COMPOSITION OF GUANO.

	1.	2.	3.	4.
Water..	12·42	12·00	11·32	11·54
Organic Matter and Ammonical Salts ..	52·98	59·11	36·58	19·79
Phosphates of Lime and Magnesia (Bone Earth)	25·06	19·31	30·98	42·93
Alkaline Salts, chiefly Chlorides of Potassium and Sodium	8·26	8·13	6·62	4·78
Gypsum	..	..	..	1·70
Insoluble Siliceous Matter	1·50	1·45	14·50	9·36
	100·23	100·00	100·36	100·00
Yielding Ammonia	17·21	19·30	11·80	4·35

The two first-mentioned samples are genuine Peruvian guanos of excellent quality. The third is Peruvian guano of an inferior description; the large amount of siliceous matter arises no doubt from the rock having been too closely scraped in collecting it. The fourth, though sold as Peruvian, appears to be in reality a Saldanha-bay guano of medium quality.

Considerable differences thus occur in the composition of different samples of guano, sold as the above four samples, at the same prices.

It is well to remember that the chief value of guano depends upon the amount of ammonia which it is capable of furnishing, and not upon that of phosphates and alkaline salts. A good Peruvian guano should contain from 50 to 60 per cent. of organic matter, yielding at least 16 per cent. of ammonia, 20 to 25 per cent. of bone-earth, 6 to 8 per cent. of alkaline salts, and no more than 2 per cent. of insoluble siliceous matter (sand).

On burning genuine Peruvian guano it loses about two-thirds in weight, and leaves one-third of its weight of a perfectly white ash, which does not effervesce with an acid; whilst adulterated guano generally produces on burning a much larger quantity of a reddish coloured ash, or a white ash, which either does not readily dissolve in dilute acid (showing the adulteration with gypsum), or strongly effervesces with an acid (proving the adulteration with chalk).

Genuine Peruvian guano, moreover, weighs from 68 to 72 lbs. per bushel; whilst adulterated guano weighs considerably more, no cheap material having been discovered with which guano can be readily adulterated without increasing its specific gravity.

In purchasing Peruvian guano it is by no means necessary to incur the expense of an analysis, for the composition of genuine Peruvian guano varies so inconsiderably, that a written guarantee of a dealer, stating to furnish Peruvian guano first quality as imported by Messrs. Gibbs, affords quite a sufficient safeguard. Unless a dealer is willing to give such a general guarantee, I would advise to have no transaction with him.

There are men who guarantee Peruvian guano as imported by Gibbs, but sell you an inferior article, and yet give you no ground to lodge an action for damages. The fact is, every year cargoes of guano, damaged by sea-water, are imported by Messrs. Gibbs, and sold by auction as D. or D. D. guano, *i.e.* damaged or double damaged. A party, therefore, who merely guarantees Peruvian guano as imported by Gibbs may sell you a damaged guano, and it is necessary, therefore, that you should get a written guarantee, in which the guano is warranted genuine Peruvian *first quality,* as imported by Messrs. Gibbs.

Such a general guarantee, however, is of no use whatever in buying superphosphate of lime, for there is no standard whereby the genuineness of superphosphate can be tested. The fact is superphosphate can be manufactured at any price—from 4*l.* to 12*l.* and upwards. The manufacturer, by meeting the tastes of his customers and the prices they are willing to give for this manure, can readily make any quality of superphosphate. If a cheap article is wanted he has only to dilute a certain quantity of dissolved bones with gypsum or ashes, or use coprolites for dissolving in acid instead of bone-dust.

In buying superphosphate of lime you should therefore demand of the maker or dealer a guarantee, which will enable you to ascertain whether or not the maker of this manure is making a reasonable or an exorbitant profit. Such a guarantee is afforded solely in an analysis, or at least in a general statement, that the bulk of superphosphate shall contain a certain amount of soluble and insoluble phosphate of lime and of ammonia. For these three different fertilizing ingredients determine principally the agricultural and commercial value of superphosphate of lime.

It is well to bear in mind that it is the soluble phosphate which renders superphosphate peculiarly valuable as a manure for root-crops, and that this soluble phosphate is worth at least three times as much as insoluble or bone phosphates. All really valuable samples of superphosphate, therefore, should be rich in soluble phosphate. A manufacturer who merely guarantees genuine superphosphate gives in reality no guarantee whatever. The following diagram gives the composition of five samples of commercial superphosphates, all sold at about the same price, *i.e.* from 6*l.* to 7*l.* per ton:—

COMPOSITION OF SUPERPHOSPHATE OF LIME.

	1.	2.	3.	4.	5.
Water	19·26	20·53	14·40	22·03	20·39
Organic Matter	16·12	14·76	8·93	trace	27·79
Soluble Phosphate of Lime ..	6·38	10·31	3·60	8·55	5·02
Equal to Bone Earth	(9·94)	(16·09)	(5·61)	(13·33)	(7·37)
Insoluble Bone Phosphate ..	22·16	17·72	6·83	none	1·56
Hydrated Sulphate of Lime (Gypsum)	25·10	28·39	44·23	24·42	40·16
Burned Gypsum	..	..	..	40·46	..
Alkaline Salts	5·16	1·56	2·52	2·41	2·93
Sand	5·82	6·73	19·50	2·16	4·23
	100·00	100·00	100·00	100.00	100·00
Per-centage of Nitrogen ..	1·66	·853	1·44	17	1·11
Equal to Ammonia	2·01	1·065	1·75	20	1·42

It will be observed how greatly these samples differ in composition, and, consequently, also in relative value.

Nos. 1 and 2 are both good superphosphates.

No. 3, on the other hand, is much adulterated with sand and gypsum, and contains only 5·61 per cent. of soluble and 6·8 per cent. of insoluble phosphate of lime.

No. 4 is richer in soluble phosphate, but mixed with a great deal of gypsum, and scarcely worth half the money at which it was sold.

No. 5 is a superphosphate manufactured by a maker, of Wellington, who calls this poor manure, containing only 7·37 per cent. of soluble and 1·56 of insoluble phosphate of lime, with 1·42 per cent. of ammonia, an ammonia phosphate, although it contains less ammonia than many samples of ordinary superphosphates.

It cannot be surprising that men who have the impudence to ask 6*l.* per ton for such a superphosphate as that mentioned under No. 5 can have the impertinence to tell agriculturists that of all crops turnips require least phosphate in a manure, and that therefore a superphosphate containing much soluble and insoluble phosphate is not a valuable manure for *root-crops.*

The MAYOR (who occupied the chair at the lecture delivered at Barnstaple) announced that discussion was invited on the subject of the lecture, and that the Professor would have much pleasure in answering any questions which might be put to him.

Mr. R. GREGORY (guano merchant) expressed his pleasure in listening to the excellent lecture. The lecturer had admitted that guano was most congenial to the wheat plant, and superphosphate for the turnip crop. That doctrine he had of late heard disputed; but whether those who entertained a contrary opinion had been labouring under a delusion or not it was difficult to say. Many gentlemen present contended that guano was more congenial and more productive to the root crop than superphosphate. He was, therefore, anxious to have that question decided.

Professor Voelcker thought there could be no question about the efficacy of guano both in the cultivation of the turnip and wheat crops. Experience had, however, shown that phosphates were peculiarly valuable in the root crops. It mattered little whether they were in bone-dust or guano; but the question was in what form could we get them cheapest, and he thought that if they bought a good superphosphate, they must necessarily get phosphate cheaper than they could get it in guano. Now he had come to this conclusion from experiments which he had prosecuted, that a small quantity of ammonia was extremely useful for the turnip crops. As a manure, they would find 3 cwt. of superphosphate and 1 cwt. of guano very good; but if they depended entirely on their guano as a manure for their turnips, they would throw away the greater part of the most valuable—commercially speaking—constituent, namely, ammonia.

Mr. How asked what percentage of soluble and insoluble phosphate should a superphosphate contain to be a good and genuine article?

Professor Voelcker said it must be the object of the manufacturer to produce soluble phosphate, which was a material the farmer could not produce conveniently. It might answer in certain cases to mix bone-dust with it; but this the farmer could do himself. The value of phosphate depended principally upon the amount of soluble phosphate it contained; and the more soluble it contained the more the manufacturer had a right to expect for it.

Mr. How repeated his question, upon which

Professor Voelcker said he ought to frame his question in this manner—What ought a manufacturer to charge for a quantity of soluble phosphate?

Mr. How did not understand what amount of soluble and insoluble phosphate a ton of superphosphate should contain.

Professor Voelcker said it would depend upon the price.

Mr. How.—Say 8*l*. a ton.

Professor Voelcker said perhaps the gentleman who had put the question would forgive him if he declined answering it, because it would be injudicious to interfere with the trader in his competition with others of his class. The more soluble phosphate superphosphate contained the better; and let those who could supply the larger quantity of soluble phosphate get the best sale for it. It was not the business of the chemist to fix prices, but to guard farmers against being grossly taken in.

Mr. Gregory could not help bringing to his recollection the fact that when the London Economical manure, which had been referred to by the learned lecturer, first came out, the books which were published in its favour contained copies of testimonials from persons who had tested it and who alleged that it answered; but when it appeared it was almost useless. He made these remarks to assure the meeting that testimonials were often a perfect humbug.

Mr. Young (manure-merchant) had been exceedingly gratified with the lecture, and he believed every one present could similarly express himself; but he would mention that they in that part of the kingdom had but very few opportunities of meeting with a gentleman so well acquainted with agricultural subjects to afford the information they required. He believed that bones contained, besides phosphate of lime, another matter known by the name of gelatine, which he understood was considered of some value. There were manufacturers, however, who extracted from bones this gelatine, which they sold for the purposes of sizing. He asked if it was not advisable to make one-half of the phosphate of lime soluble and the other half insoluble?

Professor Voelcker would leave that question entirely to the judgment of the manufacturer and the farmer to find out which answered them best.

Mr. G. H. Cotton said that it had been stated that it was desirable to mix guano with common salt or burnt clay. As common salt was a cheap article, it occurred to him that farmers would be glad to know in what proportions the lecturer would recommend it to be mixed.

Professor VOELCKER said that in his district they used one part of guano with two of salt.

The MAYOR said there was one part of the lecture he did not understand—perhaps it was from his ignorance of agriculture. It had been said that the value of superphosphate depended upon the quantity of soluble and insoluble phosphate which it contained. What appeared to him material for agriculturists to know was, how they could ascertain that quantity.

Professor VOELCKER said that was a very important question. He would answer that it was perfectly impossible for any one to estimate the value of a sample of superphosphate merely by inspection. There were hundreds of samples brought to his notice throughout the year. It was no use smelling or tasting the superphosphate, for by this means they were unable to decide which was the best. There was only one means of ascertaining it, and that was by ascertaining what it contained. It was unreasonable on the part of dealers to ask the farmers to have their manures analysed, for a careful analysis could not be made under a guinea, and that was a heavy charge for a purchaser to pay. He advised all purchasers to procure a guarantee when they bought a manure. Somehow or other the dealer of an adulterated article would slip out of the obligation. Many of them would advise their purchasers to have their manures analysed, and would tell them that if they were not up to the standard they would "take something off;" and the purchasers after all might get deceived by an analysis. He had before him analyses of a manure, called "Binn's Patent Manure." In the prospectus it was said that the manure was sold at a very low price, and that the analyses had been made by Professors Way and Campbell. [Dr. Voelcker here read the results of the analyses, which showed that a portion of the constituents of the manure consisted of mere rubbish, and only 4 per cent. of phosphate of lime.] The analyses were honest, and even offered a condemnation of the manure; but this only showed them that they could not form any idea of the superiority or inferiority of manures from the name attached to an analyses; and if upon any occasion they found his signature attached to an analysis, he advised them not to come to the conclusion, from that circumstance alone, that the manure was a good one. He had proposed to a meeting of the Bath and West of England Society that if any of the members of that society sent him a copy of an analysis, he would tell them in round numbers what it was worth.

Mr. LANGDON, in behalf of the agriculturists present, begged to offer their sincere thanks to the lecturer for his able lecture, and to say they were highly pleased at the lucid manner in which he had answered the questions put to him.

The motion was seconded by Mr. COTTON, and carried unanimously, after which three hearty cheers were given for the lecturer.

3.—THE COMPOSITION OF FERTILE AND BARREN SOILS.

[Delivered at Newton, January, 1857.]

IN passing through a country of even limited extent, every intelligent man must become aware of the great diversity of soils which he meets in his journey, and on inquiry he will find that the agricultural products of these varied soils are likewise subject to very great changes. It is evident there must be a cause, or various causes in operation to account for the different aspects and agricultural capabilities of the various soils which we meet with in such a journey; and, without accounting fully for those differences, I will observe that one of the principal causes in operation is the varied composition of the soils. No one who has paid any attention to the subject can doubt that the composition of soils must materially influence their properties, and consequently also their productiveness. I propose to point out to you to-day some of the chemical characters of fertile and of barren soils; but before entering into detail I would observe that the chemical composition of soils alone does not account for the high fertility of some soils, or the sterility of others; there are indeed many circumstances to be taken into account if we wish to form an accurate opinion respecting the fertility of land. The chemical composition of the soil is but one element, although an important one, to be considered in forming that opinion. Therefore, prior to pointing out the chemical properties of land, I will remind you of a few circumstances that influence its fertility.

Circumstances influencing Fertility.

It is well known that the mechanical condition of soils greatly influences their productiveness; often land which under proper cultivation would produce good crops, for want of proper tillage, yields but indifferent ones; and the introduction of improved agricultural implements, with greater attention to the mechanical working of land—especially heavy land—will no doubt be attended with great advantage. I attach great importance to the mechanical working of the land, having seen its value illustrated in various parts of England, for besides improving the mechanical condition of the land it conduces to chemical changes of the greatest consequence to the growth of luxuriant crops. Indeed it is impossible to follow some of the recommendations of Mr. Smith of Lois Weedon, Mr. Mechi, and other advocates for deep culture or repeated ploughing, harrowing, and other processes for working the soil, without augmenting the amount of available food for plants.

Next, the *depth of soil* is to be taken into consideration in forming a just estimate of its capabilities, and of the means of improving it. It is very well to suggest deep ploughing, but I could show you land which would be ruined by deep ploughing; and therefore we should be careful how we condemn any practice prevailing in any particular place. We should never say this is bad farming, or that is good farming, simply because the former does not tally with our preconceived notions of farming, or because the latter agrees with them; for in farming there is no general rule to be laid down; you cannot say you must plough 6 or 8 inches deep, you must subsoil, or you must adopt one sort of tillage invariably, on all sorts of lands. It is impossible to do this; and the farmer who would blindly follow recommendations, even if they proceed from high authorities in agricultural matters, would possibly find, to his loss, that he had much better have obeyed his own judgment, and acted on his own discretion. But the question is, how is he to form a correct opinion? How can he be assured he is right in introducing improved methods of tillage? Certainly, if he only blindly follows the practices of his forefathers, it is impossible for him to take advantage of the suggestions that are made from time to time by men well qualified to give an opinion; it is impossible for him to apply with advantage artificial manures, for the true use of those manures requires a mind trained in, at least, the first principles of chemistry. Apply artificial manures simply because you are recommended to do so, and in nine cases out of ten you will be disappointed. Hence it is that we frequently find the good farmers of the old school, and who hitherto have secured a fair return for their money, setting their faces against all modern improvements, and decrying superphosphates and all other artificial manures. And in their position perhaps they are right; for it is not the introduction of artificial manures alone that will enable a farmer to get a large crop of turnips or grain; he requires to exercise his judgment in the purchase of a manure, and when he has it, he must again exercise judgment in applying it to the land. Without this judgment, it is safer to continue to use the farmyard manure; for it is a universal manure, containing all the elements of fertility, all the substances which plants thriving luxuriantly require. In a word, if he is not acquainted with the first principles of chemistry, he had much better follow his own approved practice of farming than rush heedlessly into modern improvements, and apply artificial manures without ascertaining whether those manures are suitable to his particular soil or crop.

Practice and Theory.

Indeed, as we advance in agriculture it becomes more and more a rational Practice, and assumes more and more the form of an Art. Agriculture, in my belief, will never become thoroughly a science. The very nature of its object precludes this. Agriculture bears in this respect a close analogy to the practice of medicine: in both cases it is well to lay down principles—or rather, to elucidate principles; but in a very great measure we should depend on experiences (hear hear). In one farm we may produce one year only 20 bushels of wheat, and in another 30 bushels, though in both instances we follow exactly the same mode of tillage and use the same manure; for we have not all the modifying influences affecting the result under control, and therefore we cannot shape, so to speak, agriculture into a science, or establish any invariable scientific rules for our guidance. We are dependent on the test of experience, and thus many results may be stated to the chemist which it would be irrational in him to dismiss, even if they should appear to be inconsistent with recognised chemical principles: he should rather suspect himself than find fault with the universal practice followed hy intelligent farmers. We may rest assured, that as a rule, a practice established throughout a large tract of country, and followed with success by acknowledged good farmers, has something to recommend it, and that it is based on sound scientific principles—principles of which we are perhaps altogether ignorant. It is indeed remarkable that the researches of the chemist in the laboratory, when they are carefully and honestly made, always confirm practice of the character just announced. I am rather deviating from my subject, but perhaps that deviation will not be altogether unprofitable. I am anxious to impress on the minds of the farmers that sound practice always tallies with theory, if it is based on a true foundation. There may be much which in the mind of the farmer is set down as theory, in which there is no theory at all; which passes with him for science, but which is no science at all. What, after all, is science? It is the systematic arrangement of a number of experiences. Those experiences can only be attained by constant attention to practical matters. Such experiences are not attained merely by reasoning, but by experimenting—used in its right sense. A farmer who cultivates his land well is continually experimenting; he introduces a new plough, he cuts the soil a little deeper, or buys another manure, and thus he acquires experience; but frequently the experience would be of much greater value to him if he could give the reasons for the good results that follow. Now, it is the object of the scientific man to account for the benefits that result from agricultural practice; he does so by instituting experiments different in one respect although similar in another, to the farmer's experiments on his soil. The two stand on a level; you experiment in the farm, and the chemist, who has any claim to be heard by the farmers, experiments in the laboratory.

Mock Science.

If one merely looks into works on agriculture, and then writes worthless articles for agricultural papers; or rushes from one town to another, dashing through the country in an express train, just to satisfy his conscience by visiting such and such a county famed for its agriculture, and if he gets laughed at by practical farmers, it serves him right. There are people of this kind. They will rise from reading a work, perhaps by Professor Liebig, or any other celebrated agricultural writer, and being inflated with their newly-acquired knowledge, think there is nothing better to do than to tell some practical farmer who has been cultivating his land successfully, what he had best do to double its productiveness, call him a fool and an ignorant fellow if he does not follow their recommendation, use such and such a manure, and, in short, adopt that practice which they have picked up in a day or two from some book. You will generally find a man of this class is as ignorant of chemistry as the man he would advise. Put him into a laboratory, and he would not be able to distinguish a bottle containing soda from one containing potash. Men of this character deserve to be laughed at, for they do a great deal of mischief by their lecturing on farming and chemistry. It is by their means that chemical science especially is brought into discredit among the farmers.

Trustworthy Science.

Returning to the subject of science and its agreement with good practice, you will find that its results are based on experience just as are those of agriculture, and not merely on reasoning. Reasoning is very useful both to the farmer and chemist, but it is by painstaking experiments that the object is attained. I sometimes think that the instances in which the practice of the farmer finds explanation and confirmation in the recent researches of the chemist, would afford a good subject for an illustrative lecture. Whether you take the chemistry of soils, plants, or manures, you will meet with numerous points of contact, showing the intimate connection of chemical science with practical agriculture; but I am passing away from my subject—that of soils. Let me point out in the first place the

Chemical Character of Soils.

ANALYSES OF LOAMY SOILS.

	DR. ANDERSON.			
	No. 1.		No. 2.	
	Soil.	Subsoil.	Soil.	Subsoil.
Silica	63·1954	61·6358	74·3927	73·6416
Peroxide of Iron	4·8700	6·2303	4·7130	4·9230
Alumina	14·0400	14·2470	5·5440	9·3830
Lime	·8300	1·2756	1·3913	·7189
Magnesia	1·0200	1·3938	·7468	·8489
Potash	2·8001	2·1761	1·7142	·1540
Soda	1·4392	1·0450	·6788	·0367
Sulphuric Acid	·0911	·0396	·1006	·2060
Phosphoric Acid	·2400	·2680	·1460	·1640
Carbonic Acid	·0500	..	..	..
Chlorine	·0098	·0200	·0068	·0060
Organic Matter..	8.5508	6·8270	6·3271	5·8554
Water..	2·7000	4.5750	4·4260	4·2510
Loss	..	..	..	..
	99·8364	99·7342	100·1873	100·1885

ANALYSES OF CLAY SOILS, BY DR. VOELCKER.

	No. 1.	No. 2.	No. 3.
Water driven off at 212° Fahr.	5.539	..	..
Organic Matter and Water of Combination	3·621	3·38	6·11
Oxides of Iron	3·070	8·82	8·34
Alumina		6·67	
Carbonate of Lime	·740	..	..
Lime	..	1·44	·41
Magnesia	.605	·92	1·49
Potash	·269	1·48	·65
Soda	·220	1·08	..
Phosphoric Acid	·386	1·51	·04
Soluble Silica	1·450	72·83	80·69
Insoluble Silicates (fine Clay)	84·100		
Chlorine and Sulphuric Acid	traces	traces	traces
Carbonic Acid and Loss	..	2·87	2·27
	100·000	100·00	100·00

A fertile soil is one that contains all the substances which our cultivated plants require for coming to perfection—which contains them in abundance, and in such a state that they are readily assimilated by the growing plants. I am speaking chemically, not forgetting that the physical condition of the soil greatly influences its agricultural capabilities; but, not having time now to discuss the physical properties, I pass them by, observing that, although I am a chemist, I attach very great importance to the physical condition of soils.

To ascertain the character of good soils, we cannot do better than examine those remarkable for their fertility. Such soils have been carefully analysed, and I will direct your attention to the above diagrams, which may illustrate the subject. On the diagram headed "loamy soils," you have two soils from the Lothians, remarkable for producing large crops of wheat. Then you have, under the head "clay soils," the analyses of three different soils, one from the valley of Evesham, in Gloucestershire, likewise remarkable for their fertility. You observe that a great number of substances enter into the composition of these soils. You find silica, which is the chief constituent of all soils. We don't always find it in an uncombined state, in which it is familiar to you under the name of "sand"—this being a form of silica; but we find the same substance in combination with alumina, constituting the chief ingredient in clay soils, and in this form it is called a silicate of alumina: or, in ordinary language, sand and clay are two chief component parts of soils. You will also find lime amongst the component parts of those (fertile) soils—not in very large quantities, still in quantities sufficient to meet the needs of agricultural crops. Few soils are without lime; all must contain it if they can be in a condition to produce good crops, for not one of our cultivated crops is destitute of lime; without it they cannot grow; hence it is that in some soils a small dressing of lime produces a great effect. Lime is the third principal constituent of soils. The fourth and last principal constituent is organic matter arising from the remains of former crops—decaying roots and leaves. It is invariably present in fertile soils; but I would observe that the proportion of organic matter does not determine the fertility of land. It was assumed at one time that the fertility of soils was regulated by the quantity of organic matter which they contained. If you take up an agricultural work published as late as 1800, or even 1850—for I have found works of the kind as late as that—you will find a theory advocated that the more "humus" the soil contains, the more fertile it is. But this theory is not correct.

Vegetable Moulds.

ANALYSES OF FERTILE AND INFERTILE VEGETABLE MOULDS.

	MULDER.		DR. SPRENGEL.			
	No. 1.	**No. 2.**	**No. 3.**	**No. 4.**	**No. 5.**	**No. 6.**
Organic Matter and combined Water (humus)	12·000	12·502	10·90	16·70	37·00	90·44
Potash	1·026	1·430	·01	·06	trace	·01
Soda	1·972	2·069				
Ammonia	·060	·078	..	..	do.	trace
Lime	4·092	5·096	1·00	·13	·32	·55
Magnesia	·130	·140	·20	·03	·31	·08
Peroxide of Iron ..	9·039	10·305	6·30	·64	·52	·12
Protoxide of Iron ..	·350	·563				
Protoxide of Manganese	·288	·354	..	..	..	..
Alumina	1·364	2·576	9·30	·78	·45	·63
Phosphoric Acid ..	·466	·324	·13	·11	trace	·02
Sulphuric Acid ..	·896	1·104	·17	·02	do.	·19
Carbonic Acid ..	6·085	6·940	..	..	..	..
Chlorine	1·240	1·382	trace	·01	trace	trace
Soluble Silica ..	2·340	2·496	71·80	81·50	61·57	7·96
Insoluble Silicates (Clay)	57·646	51·706				
Loss	1·006	·935	·19	·02	..	..
	100·000	100·000	100·00	100·00	100·17	100·00

No. 1 and 2 are fertile soils of a tract of land in North Holland, gained by embankment from the sea.
No. 3. Rich vegetable mould.
No. 4. Poor sandy mould.
No. 5. Very fertile peaty mould.
No. 6. Boggy; very sterile land.

"Humus" is another term for decaying organic matter; you will find it in any soil that has been in cultivation for some time. The relative proportion of humus in soils varies exceedingly; and you find very fertile soils on the one hand with, comparatively speaking, a small proportion of organic matter, and fertile soils on the other hand, with a large proportion of such matter. This will appear when you glance at the diagram headed "Vegetable Moulds."

We call soils containing a considerable proportion of organic matter, vegetable moulds. The first on the table is a soil from Holland, which has been reclaimed from the sea, and is extremely fertile; it contains a large quantity of organic matter; but you would be wrong to estimate the fertility of the soil by the abundance of the organic matter. Other circumstances are to be taken into account, for you observe the No. 6 soil contains 90 per cent. of humus; there is very little else in the soil but organic matter and some sand; it is simply a peat soil, and the very appearance of a peat soil shows that the organic matter cannot ensure its fertility—indeed, in some instances, it is desirable to destroy the organic matters. You will find that farmers of the old style stick up for the presence of organic matters, and advocate the fertility of those matters, while putting lime to them, which has the effect of destroying them—for it is one of the beneficial effects of lime, that it does destroy organic matter when in that state most commonly known as sour humus, although it is not more sour than other organic matters undergoing decomposition. It is one of the actions of lime to convert sour humus into useful matter; the farmers then call it sweet. But the very terms of sweet and sour show there is something wrong in their theory of the fertility of humus. Assuming there is a land which is suffering from excess of organic matter in a certain condition, the farmers would say—"Your humus is sour; you want sweet humus; lime neutralises the acid and makes it sweet." But it is altogether a theoretical speculation; and it is astonishing to see how men, who are not accustomed to the modern way of chemical and scientific research, are led continually into theorising. There seems no man so apt to theorise as the imperfectly instructed. Here we have a soil (peat) with a vast proportion of organic matter, and it is worth nothing until it has undergone radical improvement; and we perceive that what characterises fertile soils is not the mere prevalence of one constituent, but the presence of a number of substances all necessary for the life of our plants.

Sandy Soils.

ANALYSES OF SANDY SOILS BY DR. SPRENGEL.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica and Quartz Sand..	96·000	92·014	90·221	98·8	96·7	94·7
Alumina	·500	2·652	2·106	·6	·4	1·6
Oxides of Iron	2·000	3·192	3·951	·3	·5	2·0
Oxide of Manganese ..	trace	·480	·960	..	..	..
Lime	·001	·243	·539	·1	trace	1·0
Magnesia	trace	·700	·730	·1	·1	trace
Potash	do.	·125	·066	..	trace	1·0
Soda	do.	·026	·010	..	do.	
Phosphoric Acid	do.	·078	·367	..	do.	trace
Sulphuric Acid	do.	trace	trace	..	do.	..
Chlorine	..	do.	·010	..	·1	..
Organic Matter (humus)	1·499	·490	1·040	..	2·2	·5
	100·000	100·000	100·000	99·9	100·0	100·0

No. 1. Barren sandy soil.
No. 2. Poor sandy soil.
No. 3. Good sandy soil.
No. 4. Very barren drift; sand.
No. 5. Barren sandy soil.
No. 6. Fertile sandy loam.

Sandy soils are always loose, friable, porous soils. Most of them require constant manuring in order to produce remunerative crops, and therefore are called hungry soils. It is upon these soils that liquid manure is used with great advantage; and on the whole all soluble manures, used in small quantities at a time, and applied in renewed doses, produce capital crops on the better descriptions of sandy soils, and even on the poorer sands. The chief constituent of sandy soils is silica. In some soils belonging to this class the proportion of silica or sand rises as high as 95·98 per cent.; such soils are always very sterile. Others contain less sand and appreciable quantities of organic matters, lime, potash, soda, phosphoric and sulphuric acids; and such soils are naturally more productive.

Calcareous and Marly Soils.

ANALYSIS of a MARLY SOIL from the neighbourhood of Cirencester.
By Dr. A. VOELCKER.

Organic matter and water of combination ..	10·50
Oxide of iron and alumina	11·92
Carbonate of lime	19·92
Carbonate of magnesia	·25
Potash	·62
Soda	·09
Phosphoric acid	·38
Sulphuric acid	·04
Soluble silica	13·45
Insoluble silicates and sand	42·07
Loss	·76
	100·00

In marly soils we have a class of soils which resemble on the one hand clay soils, and on the other hand calcareous soils. According to the proportion of lime and clay which they contain, they are more or less stiff, and, on the whole, belong to the better kinds of soils. Many marly soils produce naturally heavy crops of pulse, peas, and clover, and, when properly pulverised, also good root-crops.

All marly soils contain more than 5 per cent., and not more than 20 per cent., of lime. When there is much sand mixed with the clay and lime in the soil, it is called a sandy marl; on the other hand, if a marly soil contains much clay, it is termed a clay marl. Clay marls are often used with much benefit for improving light sandy soils.

ANALYSIS of a CALCAREOUS SOIL from the Farm of the Royal Agricultural College, Cirencester. By Dr. VOELCKER.

Organic matter and water of combination	6·339
Oxides of iron and alumina, with a trace of phosphoric acid	9·311
Carbonate of lime	54·566
Magnesia	trace
Sulphuric acid	ditto
Chlorine	ditto
Potash and soda	1·032
Insoluble silicious matter	28·947
	100·195

The preponderating constituent in calcareous soils is lime. In chalky soils, as some of the calcareous soils resting on the great oolite, the proportion of carbonate of lime rises often as high as 70 to 80 per cent. Calcareous soils, in which lime preponderates so largely, are, generally speaking, not very productive; but they are well adapted for the growth of leguminous plants, especially sainfoin, which tribe of plants appears to delight in calcareous soils. The physical characters, as well as the chemical composition of soils belonging to this class, vary exceedingly, and also the agricultural capabilities and value of different calcareous soils.

Those calcareous soils which contain a considerable proportion of clay are cold and difficult to work, whilst others containing more sand are lighter and more easily cultivated.

Before proceeding further, I may be allowed to observe, that of all systems of classifying soils, the one in which soils are arranged in groups according to the preponderance of one of its four chief component parts—namely, lime, clay, sand, and organic matters—appears to me the most simple and practically useful. Accordingly soils may be conveniently classified as follows:—

1. Sandy soils, or soils containing above 80 per cent. of silicious sand.
2. Calcareous soils ,, ,, 20 per cent. of lime.
3. Clay soils ,, ,, 50 per cent. of clay.
4. Vegetable moulds (humus soils) ,, 8 per cent. of organic matter, or humus.
5. Marly soils, or soils in which the proportion of lime amounts to more than 5 per cent., but does not exceed 20 per cent. of the whole weight of the dry soil, and that of clay is more than 20, but less than 50 per cent.
6. Loamy soils, or soils in which the proportion of clay likewise varies from 20 to 50 per cent., but which contain less than 5 per cent. of lime, and all the different constituents in a finely pulverized state.

Mineral Constituents of Plants.

We owe a debt of gratitude to Professor Liebig for showing that those mineral constituents which we find on burning the grain of wheat, oats, barley, or grass, and on burning root-crops, are not merely accidental, but that they are essential ingredients; that unless the plants you intend to grow find those materials in the soil you cannot grow them with success. Indeed, if they are altogether deficient, or if one of them is so—if phosphoric acid, for instance, is deficient altogether—its deficiency prevents wheat setting its seed. Experiments have been tried repeatedly in artificial soils composed of all the constituents that we find in the ashes of plants, with the exception of one which, like phosphoric acid, is of great importance to the formation of the grain of wheat; the result was that the plant would grow to a certain point, and even flower, but it formed no grains, or only one or two imperfect ones. We must lay it down then as an established principle in agricultural chemistry, that, unless those mineral constituents that we find in the ashes of plants are present in the soil, or are supplied to it, the plants cannot be grown. It is also be remembered that soils remarkable for a high state of fertility contain some necessary constituents in inexhaustible supplies.

The soils that we find here are in many instances clays, and contain a considerable quantity of the mineral matters that we find in the ashes of plants; and we may draw on the resources of those mineral riches without fear of exhausting them—whilst in other instances, where the more important articles of mineral food are deficient in soils, the constituents withdrawn must be restored, if we do not wish permanently to detract from the character of the land. In clay and loamy soils it must be an object to the farmer to inquire how he can best get out of the land the substances needed in plants. He need not scruple in working his land well, or in taking from it without always giving back the same constituent that he has taken. Truly, theoretically considered, nothing is clearer than that what you take out of the land must be restored; and you may lay down rules for making a restoration of this kind—and in leases it is common to require the tenant to return to the land a certain quantity of a certain manure periodically—but these rules are not always wise. If I had to deal with my own land, I would let it to an intelligent farmer, and tell him to farm in the best way he could, for I am convinced that what would be for his profit would also be for mine. It is a short-sighted policy on the part of landlords that leads them to think the tenants would get too much out of the land, for they bind men down to established rules which prevent agricultural improvement. The theory no doubt is—give back to the land what you take from it; but in cultivating rich loamy soils, or such clays as are found in the neighbourhood of Torquay, where the soil is formed from the decomposition of trap-rock, what is the use of putting back a little lime or phosphoric acid when you have in the soil itself inexhaustible stores? If you have a good balance in the agricultural bank, never mind using it abundantly—employ capital in making it useful by working the soil, and by the judicious purchase of artificial manures containing those constituents that are not abundant in the soil. Clay soils admitting of this treatment are, therefore, very fertile, because they contain most of the chemical substances that enter into the composition of plants; and the question is, how can they best be got at?

How to make Minerals in the Soil available.

With respect to many soils, it becomes a delicate question to decide whether their elements are best rendered educible by means of improved agricultural implements and machinery, or by the introduction of some artificial manure, such as ammonia, nitrate of soda; for I would not trouble to put any mineral back in a rich clay soil. Theoretically, by this means the land would grow poorer in mineral constituents; but, practically, having an immense store of mineral food, and every year taking out but very little, you will never exhaust it—not at least for centuries; and your sole question is, how can you get at it? Is the best means the use of improved agricultural implements, admitting air to every part of the soil, and facilitating chemical decomposition of the rock substance, or the introduction of ammoniacal matters, which render certain constituents soluble and available for the use of the plant? It is a delicate question to decide, and it can only be decided by the accumulated experience of the farmer and the chemist. Here, let me say, we could decide on many important points if we only had the cordial co-operation of practical farmers. We have a heap of matters to work upon, and we cannot arrive at results in them because they have to be brought to the test of experience. There are many things and conditions quite true theoretically which are affected by considerations of £. *s. d.* They may or may not be profitable. "Will they pay?" is the question the farmer puts to the chemist; but if the latter is a sensible man he will not give an answer to that question.

How the Chemist assists the Farmer.

"It is the business of my life," says the agricultural chemist, "to instruct you in the right principles of science as applied to agriculture; I can assist you to understand those principles; but your making of money is your business, not mine, and I give you hints which you may apply if you please; on their proper use success depends in a great measure; if you do not choose to apply them you may be left behind, and others, sharper or more determined, will use them in the right way, and make them profitable." It is, in fact, altogether necessary that the farmer should use his own discretion as to the application of manures, &c. I will make this plain by reference to the composition of sandy soils. These soils are generally naturally sterile, or are capable of producing very little—they are called hungry soils, because they swallow up manure; observe the difference between these soils and clay. Phosphoric acid is only just traceable in them; lime is greatly deficient; indeed, they are made up almost entirely of silica, and remembering that plants do not live alone by silica, but by lime and phosphoric-acid and other things as well, we see why sandy soils require much good manure. Farmyard manure would do; it is a perfect manure, containing all the constituents of the fertile soils; whilst in most artificial manures we have only two or three of the most fertilising constituents present; hence, there is danger in using, on bad land, special manures; I do not think that special manures can be used extensively on very barren soils, constituted chiefly of silica, because in artificial manures we have special constituents—some of them, doubtless, the most important to fertility, and I would guard against being supposed to speak disparagingly of those manures, only they must be used with great judgment, when they will answer well; but in sandy soils it is extremely hazardous to use artificial manures alone. Soils of that kind require a different process of cultivation, because they are deficient in requisite mineral substances.

Absorbent Powers of Soils.

But there is another point which has to be taken into consideration in speaking of the composition of soils. I refer to the atmospheric food which soils absorb, some in small and others in large quantities. Clay, which is of the class of fertile soils, has in a very high degree the power of absorbing ammonia, and other fertilising gases, from the atmosphere, while barren sandy soils do not possess the power. Moreover, all soils characterised by great fertility retain manurial substances for a much longer time than others which are what are called "hungry" soils. It is important to bear this in mind, because it will influence our practice of applying manure to the land. We frequently hear a discussion about the use of long and short dung, or winter and spring manuring, and I find in agricultural discussions each man closes his opinion with the words, "I know I am right," and thinks his opponent is wrong; the discussion concludes, and each goes away exactly in the same mind as when it began—simply through not understanding that the advocates of long dung are right in one case, and the advocates of short dung in another particular case; but the reason why they are right is unknown to one or the other, because each doggedly adheres to his opinion, and will not give the other credit for being a good farmer. It has often struck me, in attending agricultural meetings, that if you ask one farmer about another, Is so and so a good farmer? the reply is, "He may be, but he knows nothing about stock," and so on. Now this does not come of a disparaging or jealous spirit, but it is the result of a conviction that the person spoken of must be quite wrong. Yet inquiry may show that one is as right as the other, but that they have to deal with two different cases. On one of the farms at Cirencester some of the fields differ from each other greatly in composition—some only contain 2 per cent. of lime, while others come under the denomination calcareous soils, and contain as much as 54 per cent. Suppose the farm were divided into several small farms, one of the occupiers might say, "I find lime of the greatest benefit," and another might try it and say, "I find lime of no use at all," and both be right, though wrong in condemning each other's practice. I could point out soils where guano would be useful, and others where it would be useless. Therefore, criticisms on farming must not be based on particular cases.

Manuring depends on the kind of Crop.

We must take into account the crops we intend to cultivate. What is good for turnips is not always so for wheat, and this is not dependent on a chemical difference between the ashes of the wheat and the turnip, but on the mode of growth of plants. We have to calculate how long we keep a plant in the soil before we reap it. It is not a question of the composition of plants, but of the time they may have for assimilating food from the soil. If, like wheat, it is long in growth, often the food present in the soil is sufficient to supply what it wants: perhaps a little top dressing might be desirable to give it a start at first, but after that the root has time to penetrate the soil in search of food; but we cannot reason so with regard to turnips, which have a short period—from three to four months—of vegetation. One might say the soil contains as much as is sufficient for its growth; very possibly it contains six or twenty times the quantity required; but the practical question is—can you get it into the plant in the time? You will find the food may be abundant in the soil, yet it may not be present in that digested form to meet the peculiar wants of the special crop you want to grow. You may imagine it strange that the soil should retain sufficient phosphoric acid to meet the wants of twenty crops of wheat, and yet not supply a sufficient quantity for one crop of turnips, and the analysis shows that a crop of turnips contains less phosphoric acid than a crop of wheat. When these statements are made they seem contradictory of theory, and they require much explanation to the uninitiated. It must be remembered that the period during which plants assimilate food from the soil should be taken into account in considering the manure we should give to a plant. There may be sufficient phosphate in a soil to grow wheat because it is sufficient time in the soil to collect it, but the turnip, which requires less phosphoric acid, has only half the time for assimilating the food; moreover, a turnip cannot throw its roots so far in search of food as the wheat plant, which throws out its rootlets through a great mass of soil; therefore we must give it food in a more prepared state than it is in the soil, and hence the great use which superphosphates, or soluble phosphates of lime, are to the growth of turnips and all root crops. Those facts show that it is not merely by analysing soils that the chemist can be of much advantage in agriculture. It requires, indeed, peculiar insight into peculiar manures, and considerable acquaintance with physiology as well as chemistry, in order to enable a man to give correct opinions on any particular subject in agricultural chemistry that may be referred to him: and inasmuch as in many matters, and with respect to many practices, we are totally ignorant of the true cause in operation, it is unwise to speak too positively on any particular subject, if we have not the extended experience of farmers with relation to it, not only in one district but throughout the country at large. In the cases I have cited, theoretically considered, the addition of superphosphate would be of no service to the turnip; but practical experience has shown that it is of great use to the grower of turnips, and it remains for the chemist to find out the cause, and not to say there is something wrong on the part of the farmer in using superphosphate when he finds it answers his purpose. There must be some cause for this divergence from theory, and I believe it to lie in the shorter period of vegetation, which makes superphosphates valuable to roots. From this you will observe how the composition of soils influences the practice of the farm, and the administration of artificial as well as natural manure. I will take an instance. It may be asked should the systems of liquid or solid manuring be followed? I have no hesitation in saying that liquid manure is the worst form of manure you can use on some land, while on others it is the best. If you have a soil that contains little else but sand, and you apply liquid manure, not merely water, but the constituents of farmyard manure in a liquid state, you gain advantage from it, because by using solid manure you cannot prevent the rain washing a great portion of the fertilising matter, which is lost, but which might be saved by using liquid manure from time to time. Instead of doing it once for all, it should be applied in small quantities three or four times, for it gets to the plant in the most prepared state, which in poor sandy soils is attended with no inconvenience, but it would be very inconvenient to apply liquid manure on a stiff retentive soil where excess of water ought to be drained off. A sandy soil drains itself; therefore you can administer to its wants by liquid manure, but the liquid is not useful on clay soils, because in districts which are visited by much rain, it is a great object to drain off the excess of rain, and by applying food in the form of liquid manure to heavy land you injure it in a mechanical way. At any rate, liquid manuring does not answer on clay soils. Other descriptions of soils might be mentioned; but enough has been said, I hope, to show how important it is to consider the composition of soils, and how important it is that the chemist should gain the confidence of the practical man. Finally, the important advantages that have been secured to the farmer during the last few years will be increased if he heartily joins the man of science, and gives practical testimony of his belief in the truth announced in the motto adopted by the Royal Agricultural Society of England—which intimates the secret of progress—Practice and Science—a term often used without a consciousness of all it implies.

The Analysis of Soils.

The Rev. Mr. Wolston thanked the Professor for his lecture, and asked whether there was any test whereby a farmer could ascertain the composition of soils.

Professor Voelcker.—I would caution my audience against expecting too much from the analysis of soils: it has been made far too much of by men imperfectly acquainted with the subject; for it must be remembered that it is not merely the presence of certain substances in the plants that must regulate our course of cultivation, for other circumstances should be taken into account. The minute analysis of soils is not attended with so much benefit as it was once believed it would confer on the agricultural community; but an analysis which gives us the amount of the chief ingredients, clay, organic matter, lime and sand, will in many instances enable the agriculturist and chemist to give valuable hints to the practical farmer. For instance, it would enable him to determine whether a piece of land wants lime, and if you submit the land to minute analysis, he could not give any valuable information beyond that; or it would enable him to say whether there is an excess of organic matter in the soil, whether it requires draining, whether it is fit for burning. These are the great points to be desired; but to ascertain them we do not want a minute analysis. I would further say that in referring to the chemist for an analysis, the farmer would often derive greater information from the analysis if he were to put the chemist in possession of some facts relating to the soil, which he might have observed, but cannot correctly account for. For otherwise the chemist must submit the soil to a strict analysis, and on beholding the relative proportions, he might be led to attach an undue value to some ingredients, without its being attended with any practical effect; but by your mentioning one particular fact it may set him on the right direction; and frequently in such cases he might find out the true cause of the peculiarity of the soil and be able to give a useful opinion.

Lime and Dung.

Mr. Charles Wills asked how far it was a good system of farming to apply lime and dung in manure at the same time?

Professor Voelcker.—I should not object to use good dung and lime. At times it is necessary to introduce the fertilizing matters lime cannot afford. *It is bad practice to depend on the use of lime alone*, and you are likely to detract from the land by giving it only one substance, while you may be taking out many others that are not in superabundance, or which the plants have not sufficient time in the soil to collect. I should think the use of farmyard manure with lime a good practice—dung, however, not to be in a rotten state.

Mr. Wills asked if they were not injurious one to another?

Professor Voelcker.—Not in the least. In fact you have a certain quantity of lime in farmyard manure, but the cases of soils differ, and more lime may be required than the manure contains. So far from thinking that they neutralize one another, I believe that *by lime you increase the efficacy of farmyard manure.*

Mr. Wills described a practice which was observed in a humid district, and stated that it was usual there to dress the land with 3 or 4 cwt. of lime and 80 seams of dung per acre.

Professor Voelcker said it was a better practice to use lime *in small* quantities at several times, than in large quantities. He thought to use lime in such quantities as Mr. Wills had mentioned was a bad plan.

Mr. Lambshead asked what soils are benefited by lime?

Professor Voelcker.—Clay soils, formed by the decomposition of trap rock —I do not know the local name for it (Mr. Widdecome.—Dunstone)—which I have seen in this neighbourhood, would be very materially benefited by lime.

Guano, Phosphates, and Root Crops.

Mr. W. R. Whiteway asked the Professor in what soils he would recommend the use of guano in preference to superphosphate for root crops?

Professor Voelcker.—I should think hardly any. I would not use guano by itself for root crops; it is a waste so to use it, except on a few soils containing phosphates in abundance, which may be improved by a small dressing of guano. In all other soils it is a waste to use so important a fertilizer by itself for roots.

Mr. Whiteway.—What would you mix with it?

Professor Voelcker —Superphosphate. Remember, I only speak of root-crop cultivation.

Mr. Bickford asked whether superphosphate would be beneficially used here on clay soils?

Professor Voelcker.—Clay soils differ materially.

Mr. Bickford.—I was referring to a heavy yellow clay.

Professor Voelcker.—Even yellow clays have different qualities. It is difficult to answer this question without knowing the description of clay. Now, I have seen superphosphates fail on stiff clay lands, not that they were not wanted, but from other causes; yet if I were to say I had tried it, and see no use in superphosphate, you would say I generalised on false premises; and if I say it is very useful on all lands, you would say I knew nothing at all about it—(laughter). But this is a question on which I can give you some information. Some time since I made some experiments with superphosphates, in order to ascertain the quantity most useful to apply; I began with 1½ cwt., then 3 cwt., then 6 cwt., up to a ton. My object was, not so much to get a good crop, as to ascertain what would be the quantity produced under similar circumstances; ane also whether you can kill seed with the manure. It is a curious fact that you cannot kill seed with it; but guano and sulphate of ammonia, in excess, will kill seed. Experiments were made to ascertain the effects of the chief fertilising matters; and sulphate of ammonia, used in moderately large quantities, retarded the germination of seed in a remarkable manner, whilst the phosphate, instead of retarding it or killing it, made it sprout all the quicker. It is a very remarkable fact. I tried the experiments with the superphosphate on a portion of our farm at Cirencester, which had not been taken into cultivation. It is a description of soil very similar to the one which you have described—a yellow stiff clay. On this soil superphosphate produced no effect—(hear, hear). I did not get 50 lbs. an acre more in those parts where I had put a heavy dose of superphosphate. Now, if I had not also made a little experiment on pulverised soil, I might have come to the conclusion that superphosphate on clay soils is of no use—(hear, hear). You must be very careful how you generalise on a single fact. I very soon discovered why the superphosphate was of no effect on the yellow clay; it was *because the land was not sufficiently pulverised*—(applause). Never use superphosphate on land that is not in a high state of pulverisation. Many useful manures are wasted by application to land not properly pulverised. The introduction of proper manure requires the use of improved implements—(applause). Hence it is that some manure-manufacturers sell improved implements, without a profit, to purchasers of their manures, because they know that with the supply of an improved class of implements for pulverisation, the success of their manure is secured; and the more those implements are used, the better sales their manures meet with—(applause). The Professor then, in reply to Mr. Wills, stated concerning the application of lime to moor-land (granitic) soils which produced much clover, that granite was composed of felspar, mica, and silex, and that by the application of lime the felspar was decomposed. The lime set free the potash, which was largely required by the clover plant.

4.—THE NUTRITIVE VALUE OF OIL-CAKES, &c.

[Delivered at Exeter, January, 1857.]

On Friday, January 23rd, the following Lecture was delivered at the Athenæum, Exeter, on the "Nutritive Value of different Oil-cakes and Substitutes for Oil-cakes." The Mayor, W. Buckingham, Esq. presided.

The Professor said—Gentlemen, last year I had the pleasure of delivering a lecture, in this room, on the principles of nutrition. The time did not permit of my offering illustrations, showing the applicability of the principles then mentioned, as it respects the feeding and fattening of stock. Very cursorily only I could allude to the nutritive qualities of a few articles of food; and I propose now, in continuation of my last year's lecture, to enter more fully into detail, and to afford to you, by illustration which I hope to bring before you, additional evidence as to how necessary it is that the practical man should not remain content with mere general knowledge, but become acquainted with special knowledge acquired for practical purposes. It is all very well for men of education to be generally acquainted with some of the leading principles of nutrition—of the circumstances on which the nutritive value of food depends; but I am afraid such general knowledge will hardly assist the farmer in rearing or fattening stock, for he requires for this purpose special knowledge. He requires to understand the special functions which the various constituents of food play in the animal economy. Those of you who attended my last year's lecture will remember that most articles of food contain the following classes of substances:—

First. Flesh-forming materials, a class of constituents which are required in the animal economy for keeping up the daily waste of muscle, or for supplying new muscle.

Secondly. Respiratory constituents and fat-forming materials are always present in food; and

Thirdly. We have a class of substances which is applied in the animal economy for the formation of bone materials.

Now, it is upon the relative proportion of these materials that the kind of food is more especially adapted for young animals, for fattening stock, for milch cows, or for hard-working animals. Thus, in a general way, food containing a considerable proportion of ready-formed fat is beautifully adapted for the laying on of fat, or for the keeping up of the respiration of animals, and with it the animal heat; whilst food rich in flesh-forming constituents, rich in albumen, fibrine, gluten, and caseine, is particularly well adapted for working animals, inasmuch as working animals waste their muscle more rapidly than fattening animals. Thus beans, peas, and leguminous seeds in general are particularly well adapted for working horses, the reason being that in this description of food a very considerable proportion of ready-made flesh, so to speak, exists.

In the subjoined diagram the proportion of gluten and water in different articles of food is mentioned.

PROPORTION OF GLUTEN AND WATER IN FOOD.

	Per Cent. Gluten.	Per Cent. Water.
Wheaten bread	6	45
Wheat (whole grain)	12	16
Whole bran (outer and inner skins)	14 to 18	13
Fine flour	10	14
Oatmeal	18	14
Peasemeal	24	14
Beans	25	12
Lentils	25	12
Figs	6	21
Rice	7½	12
Potatoes	2	75
Lean Beef	19	78
Cheese	29 to 45	36 to 44
Cabbage	4¾	86
Cauliflower	4	88
Swedes	1·8	89 to 90
White turnips	1·4	90 to 92
Turnip-tops	2	88
Carrots	·6	87
Parsnips	1·2	82 to 84
Mangolds	1·5	87 to 88

You will perceive in beans there is a large proportion of gluten, or flesh-forming matters. In this table the heading gluten comprises not only the particular flesh-forming principle existing in wheaten flour, but it also applies to other similar constituents which are capable of producing flesh. In lentils there exists the same proportion of flesh-forming matters; all leguminous seeds are rich in flesh-forming substances, and are well adapted for working animals; and whilst such food is useful for them it is likewise useful for growing stock or for milch cows. In the milk a very considerable portion of nitrogenised constituents, or of flesh-forming matters, is secreted; and hence much nitrogenised food—or food containing the same principles which are contained in cheese—must be given to animals, if they are to supply good milk; and experience has established this fact, that nothing is so conducive to rich milk as peasemeal, or beans, or oil-cake. Bean-meal however is not so well adapted for fattening animals as oil-cake; for this reason, that fattening animals, in addition to flesh-forming matters, require food which either contains ready-made fat or constituents from which fat is easily produced.

Now, constituents from which fat is easily formed are the following: sugar, starch, and the young cellular fibre. These matters are readily transformed into fat, but it is well to remember that fat which pre-exists in food is better adapted for fattening purposes than constituents which can be transformed into fat. Bearing those general remarks on the adaptation of the two great classes of the nutritive value of food in mind, you will have no difficulty in understanding that oil-cake, especially linseed-cake, is well adapted for fattening purposes, and may be given with great advantage to young stock. In other words, it is an article of food which is useful, not only for one purpose, but indeed for most purposes for which concentrated food is supplied by the farmer.

The following diagram represents the average composition of some kinds of oil-cake.

AVERAGE COMPOSITION OF OIL-CAKES.

	Linseed Cake.	Rape Cake.	Poppy Cake.	Cotton-Seed-cake.	Mustard Cake.
Moisture	12·44	10·68	11·63	11·19	11·90
Oil	12·79	11·10	5·75	9·08	6·69
Nitrogenized or flesh-forming principles	27·28	29·53	31·46	25·16	23·48
Substances not containing Nitrogen:—					
Heat-giving substances	41·36	40·90	38·18	48·93	52·14
Mineral Matters (Ash)	6·13	7·79	12·98	5·64	5·79
	100·00	100·00	100·00	100·00	100·00

Glancing at this diagram you will observe that linseed-cake contains a small proportion of moisture; only about 12 per cent. of water exists in well-made and well-preserved cake—whilst the proportion of water which enters into the composition of ordinary articles of food, such as turnips, mangold, swedes, or cabbage, is exceedingly large. Thus, in an ordinary turnip you will find from 90 to 92 per cent. of water, and in large bulbs the proportion of water even rises higher. I might mention, in passing, that it is usually larger in big bulbs than in medium-sized roots, a very striking instance of which was recently brought under my notice. My attention was directed to a field of turnips in my neighbourhood in which same roots of an enormous size had been produced. I weighed some of them, and found that several weighed as much as 22lbs., whilst one weighed as much as 38lbs., which was the heaviest root I have ever had brought under my notice. That bulb contained no less than 94½ per cent. of water, and 4½ per cent. of solid matter, and the latter principally consisted of woody fibre. There was but very little sugar and very little flesh-forming constituents, and it was evident that it had partially undergone decomposition, as the interior was rotten and in a state of putrescence.

In the preceding diagram the woody matter is thrown together in the heat and fat producing constituents; but in a recent examination of oil-cakes, the woody fibre was determined separately by me, and gave 14 per cent. as the average amount of woody fibre in good oil-cake. The other constituents which are particularly valuable in oil-cake—namely, ready-formed oil or fat and ready-formed flesh—are very abundant: more so than in almost any other description of food. The proportion of oil in good linseed-cake amounts to from 10 to 12 per cent.; and the proportion of flesh-forming constituents amounts to from 24 to 27 per cent. Oil-cake, therefore, possesses high fattening properties, and at the same time it is well adapted for supplying the muscle of growing stock; and there is hardly any description of food which, within the same bulk, contains so much nutritive matter; for if you compare the composition of oil-cake with the composition of some other articles of consumption which are held in high esteem by the farmer, you will find that none can stand comparison with oil-cake. If you take, for instance, the composition of barley, you will find that it is rich indeed in fat-producing matter—in starch, which is readily converted into fat, but is, comparatively speaking, poor in flesh-forming constituents. Barley-meal, for this reason, is usually given to fattening animals, but it is not given with so much advantage as oil-cakes to young stock or milch cows. In short, oil-cake is a more concentrated food, and perhaps for some particular purposes it is too concentrated to be given with advantage or with profit to animals. It is a nice question to decide in what proportion oil-cake shall be given to animals, and is one which is often referred to the chemist. It is frequently asked, in what quantity will oil-cake pay the best? But questions of a practical character can not be well decided by theoretical reasoning; they can only be decided by experiments in the feeding-stall, and who is in a better position to make these experiments than the practical farmer? The chemist exercises judgment, and therefore cannot readily be found to give an opinion on such a purely practical question. It is a question which has a great deal to do with £ *s.* *d.*, and it is for the farmer to decide what is profitable for him, and not for the chemist to prescribe to the farmer what is the best for his profit. It must be the aim of the chemist to give a lucid exposition of the leading principles of the science which he professes to the practical farmer, and to leave them to him, and if he is an intelligent and sensible man, and advancing with the times, he will apply them to practical purposes. However, chemistry may frequently give useful hints to the practical farmer, and the case of oil-cake affords him an opportunity of bringing them out. We know practically that the nutritive value of different samples of oil-cake varies very considerably, and the question naturally arises—What is the cause of this difference? It is, no doubt, owing, in a great measure, to a difference in composition that a different practical result follows the application of linseed-cake or rape-cake, or any description of cake which is used for fattening purposes. Whilst I attach considerable importance to the composition of oil-cakes and other descriptions of food in general, I am bound, at the same time, to observe that the mere composition of food does not fully give you an idea of its applicability for feeding or fattening purposes; for I can well imagine the case of two articles of food, presenting little difference in composition, having a very different effect upon the constitution of animals. One kind of food may contain a small ingredient which is extremely injurious, or another kind of food may be in such a physical condition as to be indigestible. Thus we must not merely be guided by theoretical considerations in forming an estimate of the value of food; it depends likewise on whether the food is digestible or not.

Now, with respect to the difference in the value of oil-cake, I would observe that the physical condition in which the cake is offered in the market influences the nutritive value of cake more almost than any other circumstance. The fresher the cake the better it is adapted for fattening purposes. Old, mouldy cake, on account of its physical condition, often does mischief when given to animals. You know very well what effect stale or mouldy bread, which has been ill preserved, has upon the human constitution, and you do not always bear sufficiently in mind that animals have a stomach as well as man. The stomachs of animals are affected by food as well as yours, and in order to bring on animals rapidly, you must flatter their taste a little. You must, to a great extent, give them what they like, and if they reject food by natural instinct, in nine cases out of ten you might depend upon it that there is something in the food which is injurious to their health. Thus, generally speaking, you find that the best cake is liked best by animals, and there is no doubt that this is the reason why English or American barrel-cake is preferred by practical feeders to the cake from the Continent. These foreign cakes, for which a ready sale is not always found, are often kept in the warehouses for a long time, until they get mouldy and damp, and when they are given to animals in this condition they do little good; whilst well-made English cake finds a ready sale, especially in the North of England, but it has not so good a sale as I should like to see in this part of the world; as I feel convinced that oil-cake is one of the most useful and excellent articles of food that can be given to animals.

Another circumstance which is to be taken into consideration in estimating the nutritive value of different oil-cakes is the presence or absence of foreign seeds. In foreign cakes there exist seeds of weeds, seeds of inferior nutritive value, which sometimes possess deleterious properties; whilst in English cake such seeds are, comparatively speaking, few in number, or are altogether absent. Now the comparative absence of such foreign seeds in English cake is another reason of its superiority. Then another circumstance is to be taken into account in forming a correct estimate of the differences we find to prevail in linseed-cake. We have to bear in mind and to examine whether the cake has been hot-pressed or cold-pressed. Cold-pressed cake—that is, cake to which no heat has been applied in pressing out the oil from the linseed—keeps better and is more palatable than hot-pressed cake. Heat used for expressing oil from linseed alters, in a considerable degree, the remaining portion of oil in the cake, as well as other constituents, more especially the albuminous matters in cake. We know very well that in boiling albumen coagulates; and inasmuch as linseed contains a considerable quantity of albumen, or substances closely allied to albumen, heat applied to the seed coagulates the albumen, and the higher the heat has been applied the more thoroughly it coagulates. In consequence of this the cake becomes less digestible—just like a hard-boiled egg is indigestible. But it is not only the coagulation that causes the difference in the quality of hot-pressed cake, but it also alters the mucilage and gum which exist therein. When too strong a heat is applied in the process, cake loses its gelatinous properties altogether, or, at any rate, in a great measure; whilst good cake, when mixed with cold water, becomes very gelatinous.

And this leads me, in the next place, to make a few observations on the modes of examining, practically, the quality of linseed-cake. The result of a great many examinations, which I have made quite recently, has shown me that it is not generally desirable to submit cake to chemical analysis. The practical farmer may save himself the trouble and expense of an analysis, inasmuch as he has the means at hand of examining for himself whether the cake is of a superior or inferior character. A number of experiments I have made with the view of finding out for the practical man an easy method for examining this cake have given me the following result as the best plan. I would recommend you to proceed as follows:—Take about a half an ounce of cake, powder it roughly in pieces, mix it in a tumbler or in a jug with six fluid ounces of water, and leave the whole (stirring it occasionally) for about 12 hours. The best cake, after that time, renders the quantity of water just mentioned particularly gelatinous, so that the water hardly separates from the jelly; whilst inferior cake renders water much less gelatinous, and in standing separates a much larger bulk of water.

Recently, linseed-cake, for which there is a great demand in the Midland Counties and in the North of England and Scotland, has been adulterated with bran and also with sawdust. By distributing cake in water in the way just indicated, you can easily recognise the particles of bran or sawdust, or any other foreign matters. You can also ascertain whether there is much foreign seed mixed with the linseed. In short, you can easily examine whether the cake is made of pure seed or not. Likewise, you may ascertain whether there is sand mixed with the cake, for it will settle in the bottom of the tumbler or jug, and readily, by its physical character, show itself to be sand. The same examination applied to rape-cake will enable you to detect whether it is mixed with mustard, either purposely or by accident. Rape-cake is often made from seed which contains a good deal of mustard, especially foreign rape-cake, which is often largely mixed with mustard. This arises more especially from the fact that on the Continent mustard and rape are often grown together; and when seed of that description is made into cake it produces a very inferior quality of rape-cake, and when the mustard enters into it in considerable quantities it may prove injurious to animals. Rape-cake, containing too much mustard, when mixed with water, produces the volatile oil of mustard, which is extremely injurious to animals, but the pungent smell due to the production of the volatile oil of mustard affords a useful indication to the farmer of the presence of a large and probably injurious quantity of mustard-seed.

Before I speak of some other kinds of cake, besides linseed and rape cake, I would particularly allude to the discussions which have been carried on for several years respecting the value of American and English cake. There are advocates in support of the English as well as advocates for American cake. The question is, which is right? Is American cake, as some say, really more nutritious than English, or is English cake better than American, and worth more money? I remember, a few years ago, that it was the fashion to buy nothing but English cake; it fetched a higher price in the market, and perhaps for a good reason—there was a great demand for English cake, and it was really of a very superior character. Within the last year or two much more American cake has been imported, and it is of much better quality than it was a few years ago.

No doubt our American brethren on the other side of the Atlantic became aware of the fact, that nothing injures good cake so much as bad keeping, and hence they incurred considerable expense in packing it. Instead of packing the cake in bags, they put it in barrels, the consequence of which is, that it arrives more fresh in this country, and since then the American barrel cake has been sold even at a higher price than English cake. I believe this is the true secret why American barrel cake is so highly esteemed by those who have tried it, in comparison with other cakes; or rather, I should say, not in comparison with other cake, for it will not do to compare one kind of cake in a different physical condition with the same kind of cake in another physical condition. If you compare two cakes of equal freshness, and equally well-preserved, I have no hesitation in saying that you cannot find out any difference between English and American cake. I have carefully examined two equally good kinds of linseed-cake.

COMPOSITION OF LINSEED CAKE.

	English Cake.	American Cake.
Water	13·20	11·64
Oil	10·30	10·43
Woody fibre	12·90	14·26
Albuminous compounds (flesh-forming substances)	29·75	24·01
Mucilage, gum, &c. (respiratory compounds) ..	28·23	34·44
Ash	5·62	5·22
	100·00	100·00
Containing phosphate of lime and magnesia (bone earth)	2·78	2·90
Alkaline salts	1·86	1·90
Sand and soluble silica	·98	·42

Both were excellent, and closely resembled each other in composition, but, if anything, the English cake is superior to American cake, inasmuch as it contains a little more of flesh-forming substance. However, we must not draw too nice a distinction. I have, therefore, no hesitation in saying that well-made English cake will stand comparison with any cake, no matter where it is produced. It is therefore injudicious on the part of the farmer to pay 1*l.* per ton more for American barrel cake, if he can get an English cake in equally as good a condition.

With respect to other cakes I may observe that, although the composition of many of these cakes, lately introduced into the market, resembles intimately the composition of oil-cake, yet their practical effect is a very different one. There is the cotton-seed and poppy-cake, both of which contain a large proportion of flesh-forming constituents. As regards their power of acting on muscle they are quite as good as linseed-cake, but they are not so well adapted for fattening purposes. They are poor in oil, and, moreover, do not contain so much starch or mucilage as linseed-cake. I believe we must apply greater refinement to our analyses of articles of food. In most analyses of food the amount of indigestible fibre—of woody matter—is not mentioned at all. But it is a very important consideration to determine the amount of indigestible fibre, for if you have it in excess it may render otherwise useful food, comparatively speaking, useless. And I believe that the difference we observe in the practical effect of cotton-seed and poppy-cake, and even of rape-cake, is particularly—if not in a great measure—due to the fact that the three last-mentioned cakes contain a larger amount of indigestible fibre than good linseed-cake. Thus you will find that there is always a good reason for the experience which a practical man possesses respecting the nutritive value of food or the fertilising properties of manure; and it remains for us to find out those reasons, and to put the practical man in possession of them, so that he may judge for himself in similar cases. Oil-cake of every kind, and more especially linseed-cake, as mentioned in the beginning of this Lecture, is a very concentrated kind of food, but, unfortunately, its high price precludes its general application in many instances, and it has been the desire of late to introduce substitutes for cake as well as substitutes for barley-meal, which at present is very high in price.

Among those substitutes the following may be mentioned:—carob-beans, Indian corn, Irish moss, and rice-meal.

COMPOSITION OF CAROB BEANS (KENSINGTON).

	In Natural State.	Dry.
Water	14·22	—
Sugar	54·07	63·03
Mucilage and other digestible respiratory principles	17·41	20·30
Woody fibre	3·88	4·52
Oil	·96	1·12
Flesh-forming principles	7·72	9·00
Soluble inorganic matters (soluble ash)	1·12	1·31
Insoluble inorganic matters (insoluble ash)	·62	·72
	100·00	100·00

First, with respect to the carob-bean, I would observe that perhaps its value as a feeding material has been over-estimated, and the price which is sometimes paid for it—12*l.* per ton—in comparison with oil-cake, is far too high. Carob-bean is a food which is exceedingly rich in sugar, but is, comparatively speaking, poor in flesh-forming substances. For these reasons it is well adapted for fattening purposes, but even for these purposes it is not, I believe, so useful as oil-cake, for although we have a large quantity of sugar in the carob-bean, the quantity of fat, or oil, is small, and does not amount to one per cent., whilst in oil-cake we find at least from 10 to 12 per cent. of ready-formed oil and a considerable quantity of mucilage or gum, which fulfils the same purpose to which sugar is applied in the animal economy. Now the power of mucilage, sugar, or oil in producing fat in the animal economy depends mainly on the proportion of carbon contained in sugar, gum, mucilage, or fat. In sugar, gum, or mucilage the proportion of carbon, in round numbers, amounts to from 50 to 54 per cent., whilst in oil it rises to from 80 to 86 per cent., therefore, ready-formed fat or oil goes a much longer way in producing fat than sugar or gum.

I think, practically speaking, you may say that one pound of oil, or ready-made fat, goes as far in producing fat in the animal economy as two pounds of sugar or mucilage. The amount of fat-forming constituents in linseed-cake is 58 per cent., which is not much less than the quantity of sugar and mucilage together in the carob-bean. Still carob-beans may be usefully employed for fattening purposes. At the farm attached to the Agricultural College at Cirencester, some experiments were made with carob-beans. Without entering into particulars, I would observe that the effect produced was about equal to that produced by barley-meal.

With respect to the other substances mentioned—Irish moss, rice-meal, and Indian corn—I would observe that they are inferior in value to the carob-bean. Irish moss may be usefully given to calves, where it is no consideration to use an expensive article of food; but when you have to use it in quantities it is not an economical food, and the price at which it is sold precludes its general application. Its chief merit is that it is rich in mucilage, and well adapted for animals which have not got a very good digestion.

Then Indian meal is a food which I think will come more and more into use, inasmuch as it is particularly well adapted for fattening purposes. Its chief merit is its fattening properties, for it is richer in fat-forming matters than almost any other description of food. I have recently discovered that the ready-made fat in Indian corn amounts to from 5½ to 6 per cent., or a larger proportion than is found in any other kind of corn. Indian corn, therefore, is particularly well adapted for fattening purposes.

Mr. Bere—And producing milk.

The Professor—Not so much for milk, as food richer in nitrogen is required for that. A more nitrogenized food should be given to fattening animals; that is to say, you should not feed animals entirely with Indian corn, for the proportion of flesh-forming matters in Indian corn is small. A very good admixture with Indian corn is bean-meal, as that supplies a material deficiency in Indian corn; and such a mixture as that named I have seen used with great advantage, both for fattening cattle and pigs. A very good proportion of bean-meal to Indian corn is five pounds of the former to one pound of the latter. That produces a mixture which contains the proportion of flesh-forming matters and fat-producing matters nicely balanced, so as to meet the wants of fattening animals.

There are other substitutes for concentrated food which I will pass by unnoticed. I cannot however part with you without thanking you for the great attention you have paid to me to-night.

It is to me exceedingly gratifying to find that I have had such an attentive audience (cheers).

Mr. T. D. Acland wished to ask a question, not so much for his own information (as he had a decided opinion on the subject) but to correct an opinion which prevailed in the minds of some farmers; viz. that the fat in the oil-cake made a fat farm—that was to say made wheat, and that the oil that did not go into the animal went into the land.

Professor Voelcker—There can be no question that oil-cake is extremely useful, not only from the fat produced on the animal but also on account of the nitrogenized and other constituents which pass into the manure. However the superior quality of the manure yielded by animals fed on oil-cake is not due to the fat. In the first place, the fat is consumed in the animal economy, but even if it were not, and passed away with the excrement, it would be a very undesirable constituent in the manure. I have no hesitation in saying that fat is worse than useless as a manure. It ought to be well remembered that fat, as a manuring constituent, is worse than nothing—for this reason, that it prevents the decomposition of animal substances and of organic matters in general. We know very well that in order for manure to enter into the plant it must be decomposed; and must be rendered soluble. But how do we prevent decomposition? Why by putting a layer of grease over potted meat.

The Mayor mentioned blubber.

The Professor—Blubber acts beneficially as a manure in spite of the oil in it, because the oil is very impure, containing extraneous matter, such as scales of fish, entrails, and other animal matter. These, on decomposition, furnish ammonia, which is a most desirable constituent in all good manures. In some parts of the country gas-tar is largely used as a manure, and preferred to gas-water. But gas-tar in its pure state is, I have no hesitation in saying, injurious to vegetation. I would not speak so decidedly if I had not made experiments on the very point, but you can, by simple reasoning, show that tar injures vegetation, for, like oil, tar consists only of carbon, hydrogen, and a little oxygen. It does not contain anything which is useful as a manure, and which is readily converted into a constituent of manure. But gas-tar, in spite of its injurious qualities, acts usefully, because ammoniacal water adheres to it. It is better to use the ammoniacal liquor of gas-works, diluted with considerable quantities of water—say from ten to twenty parts—before applying it to the land (cheers).

The meeting separated, after a vote of thanks to the Professor.

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ON THE COMPOSITION OF FARMYARD MANURE,

AND

THE CHANGES WHICH IT UNDERGOES ON KEEPING UNDER DIFFERENT CIRCUMSTANCES.

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ON THE

COMPOSITION OF FARMYARD MANURE.

It is generally admitted that the management of farmyard manure, as carried out in many parts of England, more especially in the western counties, is often attended with much loss in valuable fertilising matters. In a country in which large sums are annually expended by the farming community in the purchase of artificial food and foreign manures, it might naturally be expected that the utmost care would be bestowed on the treatment of home-made dung, and that in its preparation the suggestions of improved practice and modern science would frequently be called into requisition by the cultivator of the soil. Experience, however, teaches that this is far from being the case. It is, indeed, a matter of surprise, no less to the agricultural chemist than to the more intelligent portion of the agricultural community, that there should exist on the one hand so much ignorance on the first principles involved in the management of farmyard manure, and on the other so much indifference as to the best means of preventing the deterioration of the most important of all fertilizers. For my own part, however, I cannot share the opinions of those zealous and, no doubt, sincere agricultural reformers, who describe the practical farmer as adverse to every new improvement, and turning a deaf ear to the suggestions of modern science. I know well how little of what commonly passes as a law of nature, or a scientific principle, rests on a firm basis, and is derived from the constant recurrence of a number of well-established facts. I am well aware how many so-called improvements are the emanations of the heated imagination of empirical theorists, and how few of the suggestions of even eminent scientific men can be practically carried out with economy on a large scale. I therefore find it quite natural that the agriculturist, often bewildered, and scarcely knowing how to meet the difficulties that beset his path in carrying out modern improvements, should relapse into his old and accustomed course.

The inquiry into the changes which farmyard manure undergoes in keeping, under various modes of management, unquestionably is a subject of great importance; and I cannot help therefore expressing astonishment that it has not been taken up long ago, and submitted to a thorough and searching investigation. Hitherto our knowledge of this subject has been altogether very narrow, and this limited knowledge is of such a general character that it could not have been attended with any marked general improvement in the management of farmyard manure. General, and, in several respects, superficial information on so important a subject will as little assist the practical farmer in husbanding his home-made manure as similar information in the cultivation of root-crops would enable him to grow an abundant and remunerative crop of turnips. Agricultural chemistry, it strikes me, has reached that point at which, in order to become really useful to the practical man, it can no longer be prosecuted with success by amateur chemists, nor even by scientific chemists, who do not throw their whole energy into the inquiry, and give their undivided attention and time to this noble and eminently practical branch of applied science. This view appears to be daily gaining ground; and the time is fast approaching when agriculturists will no longer look with a certain suspicion on scientific investigations, but hail them with pleasure, aud willingly render that practical assistance which chemists have long earnestly desired. Many important inquiries, which neither the analyst in his laboratory nor the farmer in his fields can solve alone, will then be brought to a happy issue, and the principle which the Royal Agricultural Society has adopted for its motto, "Practice with Science," then, and then only, will bring forth its choicest blossoms, and be crowned with abundant fruit.

These thoughts were suggested to me on undertaking an extended inquiry into the changes which farmyard manure undergoes on keeping, under different modes of management; and I feel bound publicly to express my obligations to the enlightened Principal of our College, for the readiness with which he has met my wishes, and placed at my disposal horse and cart, men and manure, and, in short, that practical apparatus, without which I could not have entered on the investigation. During a period of more than twelve months my leisure and that of my assistant, Mr. Sibson (to whom I feel greatly indebted for his persevering zeal and skill in this laborious task), has been almost constantly occupied in studying the changes which farmyard manure undergoes on keeping.

It is not my intention to write a paper on the best management of farmyard manure, a subject on which considerable diversity of opinion prevails. I may do so, probably, at a future occasion; for the present I purpose simply to lay before the reader the results of my practical and analytical experiments, and to accompany them with some remarks, which I trust may help to solve the question, how home-made dung ought to be prepared and kept in the most profitable manner, so as to develop the full efficacy of the excrements of our domestic animals, and the litter, and to guard against loss in the fertilising constituents of dung?

In undertaking this investigation I encountered a difficulty, which every one must have felt in experimenting on farmyard manure, namely, the difficulty of obtaining a sample sufficiently homogeneous to serve as the basis for future operations. In experimenting on fresh, or long dung, especially, it is no easy matter to incorporate the long straw uniformly with the more minutely divided droppings of animals; perhaps altogether a perfect mixture of both cannot be realised, and we must therefore be satisfied to make the mixture as intimate as the nature of the materials will permit. I endeavoured to reach this point by employing two men for the greater part of the day in turning a considerable quantity of fresh long dung, composed of horse, cow, and pig dung. By frequent turnings and distributions of the droppings amongst the long straw I thus obtained a tolerably uniform sample of mixed farmyard manure, which served as the basis for all future experiments and analyses with fresh dung. In the same way, but more easily, a well-mixed sample of well-rotten dung, composed of horse-dung, cows' and pigs' manure, was obtained a month later. This rotten dung, however, was not from the same heap from which the fresh dung last mentioned was obtained, but probably had undergone fermentation for a period of more than six months. It was well fermented, dark brown, almost black spit-dung, taken from the bottom of a corner of the manure-pit, where the more perfectly decomposed manure is used to be kept.

In order not to encumber the description of my experiments, and the statements of the results obtained in them, I shall give, in an Appendix to this paper, a brief account of the methods made use of in the performance of the following analyses. I may observe, however, in this place that the water-determinations in the experimental heaps were made on the same day on which they were put up, and that the samples for analysis were taken at the same time.

FRESH FARMYARD MANURE.

Difficult as it is to prepare several tons of dung of a tolerably uniform character for the experimental heaps, the difficulty is greatly enhanced when a sample fit for analysis has to be chosen. For analytical purposes large quantities are inadmissible; and it becomes therefore a matter of great importance thoroughly to prepare the small proportion of manure which can be employed in actual analysis as carefully as possible. To this end I spread out a weighed quantity of about 20 lbs. of fresh dung, previously well mixed in the manure-pit, thoroughly pulled it to pieces, and then allowed it to become air-dry, by keeping it for some days in a safe place, in a heated room. The partial loss in moisture having been ascertained by the difference in the second weight, as compared with that of the first: the whole of the partially dried manure was passed through a common coal-sieve; and the pieces of long straw which refused to pass through the meshes of the sieve were cut in small pieces with a large pair of scissors: 1 lb. of the partially dried and now much more thoroughly mixed manure was then dried in a water-bath, at 212°, until it ceased to lose in weight. The loss calculated for the original quantity of manure, and added to the loss which it sustained in becoming air-dry, gave the total percentage of moisture in the fresh dung. Another quantity of the partially dried manure, amounting to 1000 grains, was employed for the analysis, taken in hand on the 3rd of November, 1854.

This analysis furnished the following general results:—

General Composition of Fresh Long Dung (composed of Horse, Cow, and Pig Dung).

Made Nov. 3, 1855.

	In Natural State.	Calculated Dry.
Water	66·17	..
*Soluble organic matter	2·48	7·33
Soluble inorganic matter	1·54	4·55
†Insoluble organic matter	25·76	76·15
Insoluble inorganic matter	4·05	11·97
	100·00	100·00
* Containing nitrogen	·149	·44
Equal to ammonia	·181	·53
† Containing nitrogen	·494	·146
Equal to ammonia	·599	·177
Total per centage of nitrogen	·643	1·90
Equal to ammonia	·780	2·30

A delicate reddened litmus paper held over the fresh-mixed dung was not affected at first; but after the lapse of a couple of hours, the red colour was slightly changed into blue, thus showing that this fresh dung contained but a very small quantity of free or, properly speaking, volatile carbonate of ammonia; for it is in the state of carbonate, and never in a free and uncombined form, that ammonia is given off from putrefying substances.

I have endeavoured to determine quantitatively the amount of volatile compounds of ammonia in fresh manure, by distilling about 1000 grs., mixed with about 8 ounces of water, into a vessel containing dilute hydrochloric acid. This glass vessel was connected air-tight with the retort on the one hand, and on the other with a bulb apparatus, used in nitrogen combustions, and containing likewise dilute hydrochloric acid. By this means very small quantities of volatile ammoniacal compounds may be thoroughly fixed, and obtained, on evaporation of the acid, in the receiving vessel and bulb apparatus as chloride of ammonium. In this and the following analyses the amount of ammonia in the volatile ammoniacal compounds contained in manure is given, and, for brevity's sake, called free ammonia. At the same time I have endeavoured to ascertain the proportion of ammonia which, after the volatile ammonia compounds are distilled off, remains behind in the manure in a fixed state. This portion is mentioned in the analyses as ammonia in the state of salts. Both the free ammonia, and ammonia in the form of salts, are included in the determinations of the total amount of nitrogen (ammonia) contained in the manure.

The fresh manure analysed on the 3rd of November, 1854, contained in its natural state, and when perfectly dry—

	In Natural State.	Calculated Dry.
Per centage of free ammonia	·034	·10
" ammonia in the state of salts	·088	·26

The amount of volatile ammonia, as well as ready formed ammonia, existing in the form of ammoniacal salts in fresh manure, thus appears to be very trifling.

Since there exists no complete, trustworthy analysis of the ash of fresh farmyard manure, I thought it advisable to analyse separately the soluble and the insoluble portion of the inorganic matters present in farmyard manure.

One hundred parts of the soluble inorganic matters in fresh farmyard manure were found to have the subjoined composition:—

Fresh Farmyard Manure.

Analysis made Nov. 3, 1854.

Composition of Ash of portion Soluble in Water.

Soluble silica	15·45
Phosphate of lime	19·44
Lime	4·30
Magnesia	·73
Potash	37·26
Soda	3·36
Chloride of Sodium	1·97
Sulphuric acid	3·49
Carbonic acid and loss	14·00
	100·00

The portion insoluble in water on analysis yielded the following results :—

Fresh Farmyard Manure.

Analysed Nov. 3, 1854.

Composition of Ash of portion Insoluble in Water.

Soluble silica	23·94
Insoluble silicious matter	13·86
Oxides of iron and alumina, with phosphates	14·73
Containing phosphoric acid	(4·41)
Equal to bone earth	(9·55)
Lime	27·92
Magnesia	3·54
Potash	2·46
Soda	·48
Sulphuric acid	1·76
Carbonic acid and loss	14·31
	100·00

In the next table the composition of the whole ash which was produced by this sample of fresh manure is stated :—

Fresh Farmyard Manure.

Analysis made Nov. 3, 1854.

Composition of the whole Ash.

Soluble in Water 27·55 per cent.	Soluble silica	4·25
	Phosphate of lime	5·35
	Lime	1·10
	Magnesia	·20
	Potash	10·26
	Soda	·92
	Chloride of sodium	·54
	Sulphuric acid	·22
	Carbonic acid and loss	4·71

			Arranged together.
Insoluble in Water 72·45 per cent.	Soluble silica	17·34	21·59
	Insoluble silicious matter (sand)	10·04	10·04
	Phosphate of lime	..	5·35
	Oxide of iron and alumina, with phosphates	8·47	8·47
	Containing phosphoric acid	(3·18)	(3·18)
	Equal to bone earth	(6·88)	(6·88)
	Lime	20·21	21·31
	Magnesia	2·56	2·76
	Potash	1·78	12·04
	Soda	·38	1·30
	Chloride of sodium	..	·54
	Sulphuric acid	1·27	1·49
	Carbonic acid and loss	10·40	15·11
		100·00	100·00

Before offering any remarks on the composition of fresh manure, it may be well to insert in this place a table representing the detailed composition of fresh farmyard manure:—

Composition of Fresh Farmyard Manure (composed of Horse, Pig, and Cow Dung, about 14 *days old).*

Analysis made Nov. 3, 1854.

Detailed Composition of Manure in Natural State.

Water		66·17
*Soluble organic matter		2·48
Soluble inorganic matter (ash):—		
Soluble silica	·237	
Phosphate of lime	·299	
Lime	·066	
Magnesia	·011	
Potash	·573	
Soda	·051	
Chloride of Sodium	·030	
Sulphuric acid	·055	
Carbonic acid and loss	·218	
		1·54
†Insoluble organic matter		25·76
Insoluble inorganic matter (ash):—		
Soluble silica	·967	
Insoluble silica	·561	
Oxide of iron, alumina, with phosphates	·596	
Containing phosphoric acid	(·178)	
Equal to bone earth	(·386)	
Lime	1·120	
Magnesia	·143	
Potash	·099	
Soda	·019	
Sulphuric acid	·061	
Carbonic acid and loss	·484	
		4·05
		100·00

* Containing nitrogen	·149
Equal to ammonia	·181
† Containing nitrogen	·494
Equal to ammonia	·599
Whole manure contains ammonia in free state	·034
„ „ in form of salts	·088

According to these results, the same manure in a perfectly dry condition will have the following composition:—

Detailed Composition of Fresh Farmyard Manure in Dry State.

*Soluble organic matter		7·33
Soluble inorganic matter (ash):—		
Soluble silica	·703	
Phosphate of lime	·884	
Lime	·185	
Magnesia	·033	
Potash	1·695	
Soda	·153	
Chloride of sodium	·089	
Sulphuric acid	·035	
Carbonic acid and loss	·772	
		4·55
†Insoluble organic matter		76·15
Insoluble inorganic matter:—		
Soluble silica	2·865	
Insoluble silica	1·659	
Oxide of iron and alumina, with phosphates	1·404	
Containing phosphoric acid	(·528)	
Equal to bone earth	(·822)	
Lime	3·335	
Magnesia	·424	
Potash	·294	
Soda	·077	
Sulphuric acid	·210	
Carbonic acid and loss	1·722	
		11·97
		100·00

* Containing nitrogen	·44
Equal to ammonia	·53
† Containing nitrogen	1·46
Equal to ammonia	1·77
Whole manure contains ammonia in free state	·10
” ” in form of salts	·26

Fresh farmyard manure being composed of the droppings of horses, cows, and pigs, and the straw used for litter, according to the above determination, in round numbers consists of two-thirds of water and one-third of dry matters. Since this fresh manure was not more than fourteen days old, and no rain had fallen during the time it had lain in the dung-pit, all the water is due to the urine and the moisture of the droppings and litter. The quantity of straw employed as litter must necessarily affect the general composition of fresh dung, and more especially the amount of moisture which it contains; but, I believe, we are not far wrong by saying that fresh mixed dung, in the production of which litter has been liberally supplied to the animals, when free from rain, consists of one-third of dry matters and two-thirds of moisture.

An inspection of the analytical results just mentioned will further bring to view several interesting particulars:—

1. *In fresh dung the proportion of soluble organic and mineral substances is small.* This circumstance fully explains the slow action of fresh dung when compared with the effect which well-rotten manure is capable of producing.

2. The proportion of insoluble matters, more especially of insoluble organic matters, in fresh dung, on the contrary, is very large. By far the larger proportion of the insoluble organic matters consists of straw, changed but little in its physical character and chemical composition.

In the sample of manure analysed the amount of insoluble organic matters is ten times as great as that of soluble organic matters, and the proportion of insoluble mineral substances nearly three times as large as the amount of soluble mineral matters.

3. Fresh dung contains a mere trace of ammonia in a volatile state of combination, and but a trifling quantity of ammonia in the form of ammoniacal salts.

4. The total amount of nitrogen contained in the *soluble portion* of fresh manure likewise is inconsiderable. Most of the nitrogen which, as we shall see by and by, is gradually liberated as the fermentation of dung progresses, is contained in the portion of the manure which is insoluble in water. In other words, comparatively speaking, little nitrogen exists in fresh dung in a state in which it can be assimilated by the growing plants. Thus, in the sample analysed, the readily available amount of nitrogen in 100 lbs. of fresh dung is only ·149 of a lb., whilst about four times as much nitrogen, or, in exact numbers, ·494 lb., occurs in the insoluble portion of 100 lbs. of fresh dung.

5. A comparison of the composition of the organic soluble matters with the composition of the organic insoluble matters of fresh dung, however, shows that the former are far more valuable than the latter, inasmuch as the soluble organic matters contain a very much larger percentage of nitrogen, and in a state of combination in which nitrogen is available to the immediate use of plants.

This will appear from the following numbers:—

100	parts of organic	soluble matters	in fresh dung	contain	6·04 of nitrogen.
100	„	insoluble matters	„	„	1·92 „

In the same weight of each there is thus more than three times as much nitrogen in the soluble organic matters as in the insoluble organic matters.

6. With respect to the inorganic or mineral constituents of fresh dung, it will be seen that it contains all those mineral matters which are found in the ashes of all our cultivated plants.

7. Comparing the composition of the soluble inorganic matters with that presented by the insoluble, no essential *qualitative* difference is perceived between both, for the same constituents which occur in the soluble ash are found also in the insoluble ash. But there exists a striking difference in the quantitative composition of the soluble and the insoluble mineral matters of fresh dung.

8. The principal constituent of the soluble ash of fresh dung, so far as quantity is concerned, is *potash;* 100 parts of soluble ash, it will be seen, contain no less than 37·26 parts of real potash, or a quantity which is equivalent to 54·7 of pure carbonate of potash. The analysis of the soluble portion of ash of fresh dung gave only 14 per cent. of carbonic acid, including the loss in analysis; and as 37·26 of potash take up 17·5 of carbonic acid in becoming carbonate of potash, and moreover much of the soluble lime existed in the water-solution as bicarbonate of lime, it is evident that a considerable quantity of potash is united with silicic acid in the soluble ash. The large percentage of soluble silica confirms this view; fresh farmyard manure thus contains much soluble silicate of potash.

9. The large amount of soluble silica, both in the soluble and in the insoluble ash, are deserving notice. In the soluble ash this silica is united principally with potash, and probably also with some soda; in the insoluble ash it is combined chiefly with lime, or exists in a finely divided state, in which it is readily soluble in dilute caustic potash.

10. The most prominent constituent of the soluble ash of fresh dung is silicate of potash.

11. The most prominent constituent of the insoluble ash is lime.

12. It is particularly worthy of notice that the soluble ash of even *perfectly fresh* dung contains a very *high percentage* of *phosphate* of *lime.*

The proportion of phosphate of lime in the soluble portion of ash was in fact found to amount to no less than 19½ per cent. of the whole soluble ash, whilst the percentage of phosphate of lime in the insoluble ash was found to be only 9½.

I must confess that I was not prepared to find so large an amount of a compound which is generally considered insoluble in water, and for this reason is not enumerated in the published analyses of farmyard manure amongst the soluble constituents of dung. Repeated experiments, however, executed with all care to avoid any possible source of error, have shown me that water dissolves phosphate of lime or bone-earth much more rapidly and to a much greater extent than it has hitherto been supposed. This observation gains much in interest, if it be remembered that the late Mr. Pusey suggested many years ago a method of rendering bone-dust more efficacious as a manure for root-crops. His plan was to place bone-dust moistened with water and mixed with ashes, sand, or other porous matters in a heap, and to keep this heap moist by pouring occasionally water upon it, or, better still, stale urine or liquid manure. The suggestion has been followed by many with much success. But few may have known that by adopting Mr. Pusey's plan of reducing bone-dust still further they have been instrumental in generating that combination which gives peculiar value to superphosphate of lime, namely, soluble phosphate of lime.

In one of the latest numbers of the 'Annalen der Chemie und Pharmacie,' edited by Liebig, Wöhler, and Kopp, Professor Wöhler, of the University of Göttingen, makes the important observation that bone-dust moistened with a little water, in the course of a few days yields a considerable quantity of phosphate of lime to water, and that this solubility rapidly increases with the putrefaction of the gelatine of bones. My analysis of farmyard manure, made a year before the recent notice, which Professor Wöhler gave in the 'Annalen der Chemie,' respecting the solubility of phosphate of lime in water, may be regarded as a confirmation of Wöhler's direct experiments upon bone-dust, as well as an interesting scientific commentary on Mr. Pusey's practical suggestion of rendering bone-dust more efficacious as a manure for root-crops.

13. The insoluble part of the ash of fresh farmyard-manure includes the sand, earth, and other mineral impurities, which mechanically get mixed with the dung. Most of these impurities are mentioned in the ash-analyses as insoluble silicious matter; another portion is comprehended under oxides of iron and alumina with phosphates; and a third part, probably a considerable portion of the mechanical impurities, is included under lime, for the gravel and soil at Cirencester abounds in carbonate of lime.

Due allowance must be made for these mechanical impurities in all considerations respecting farmyard manure, otherwise conclusions will be drawn which the facts of the case do not warrant.

14. *Chemically considered Farmyard Manure must be regarded as a perfect and universal Manure.*—It is a universal manure, because it contains *all* the constituents which our cultivated crops

require to come to perfection, and is suited for almost every description of agricultural produce.

As far as the inorganic fertilising substances are concerned, we find in farmyard manure: potash, soda, lime, magnesia, oxide of iron, silica, phosphoric acid, sulphuric acid, hydrochloric and carbonic acid—in short, all the minerals, not one excepted, that are found in the ashes of agricultural crops.

Of organic fertilising substances we find in farmyard manure some which are readily soluble in water and contain a large proportion of nitrogen, and others insoluble in water and containing, comparatively speaking, a small proportion of nitrogen. The former readily yield ammonia, the latter principally give rise to the formation of humic acids and similar organic compounds. These organic acids constitute the mass of the brown vegetable substance, or rather mixture of substances, which, practically speaking, pass under the name of humus.

Farmyard manure is a perfect manure, because experience as well as chemical analysis shows that the fertilising constituents are present in dung in states of combination, which appear to be especially favourable to the luxuriant growth of our crops. Since the number of the various chemical compounds in farmyard manure is exceedingly great, and many no doubt exist in a different state of combination from that in which they are obtained on analysing farmyard manure, in our present state of knowledge it is impossible artificially to produce a concentrated, universal, and perfect manure, which might entirely supersede home-made dung.

I do not refer to the mechanical effect which farmyard manure is capable of producing. This mechanical effect, especially important in reference to heavy clay soils, ought to be duly regarded in estimating the value of common dung, but for the present it may suffice to draw attention to the fact, that even fresh dung contains a great variety of both organic and inorganic compounds of various degrees of solubility. Thus, for instance, we find in fresh manure volatile and ammoniacal compounds, salts of ammonia, soluble nitrogenized organic matters, and insoluble nitrogenized organic substances, or no less than four different states in which the one element, nitrogen, occurs in fresh manure. In well-rotten dung the same element, nitrogen, probably is found in several other forms. This complexity of composition—difficult, if not impossible, to imitate by art—is one of the reasons which render farmyard manure a perfect as well as a universal manure.

ROTTEN FARMYARD MANURE.

With a view of ascertaining the changes which farmyard manure undergoes in keeping, I submitted to analysis a well-mixed sample of rotten dung produced under the same circumstances under which the fresh manure was obtained. The rotten dung probably was at least six months' old, possessed a dark-brown, almost black, colour, and appeared to be well-fermented, short dung.

The general composition of this dung is presented in the subjoined Table:—

Composition of well-rotten Manure (Mixed Horse, Cow, and Pig Dung).

Analyzed Dec. 5th, 1854.

	In natural state.	Calculated dry.
Water	75·42	..
*Soluble organic matter	3·71	15·09
Soluble inorganic matter	1·47	5·98
†Insoluble organic matter	12·82	52·15
Insoluble inorganic matter	6·58	26·78
	100·00	100·00

* Containing nitrogen	·297	1·21
Equal to ammonia	·360	1·47
† Containing nitrogen	·309	1·26
Equal to ammonia	·375	1·53
Total amount of nitrogen	·606	2·47
Equal to ammonia	·735	3·00

I have determined in this manure likewise the proportion of ammonia present in a volatile form, as well as the ammonia which is disengaged on distilling with quicklime the residue, from which the free ammonia has been driven off, and have obtained the following results:—

	In natural state.	Calculated dry.
Percentage of free ammonia	·046	·189
„ ammonia in form of salts (readily decomposed by quicklime)	·057	·232

The proportion of free ammonia in well-rotten dung thus appears not much larger than in fresh dung produced under the same circumstances; and the amount of ammonia present in rotten dung in the form of salts, which are readily decomposed by quicklime, to be almost identical with that contained in the fresh manure. Further remarks on the composition of rotten dung I shall reserve until I have stated the composition of the soluble and insoluble ash and the detailed composition of the whole manure in its natural and dry state. In the following Table the composition of the soluble part of the inorganic matters in well-rotten farmyard manure is given:—

Analysis made Dec. 5, 1854.

Composition of Ash of Portion soluble in Water.

Soluble silica	17·31
Phosphate of lime	26·00
Lime	7·97
Magnesia	3·24
Potash	30·37
Soda	1·60
Chloride of sodium	2·53
Sulphuric acid	3·93
Carbonic acid and loss	7·05
	100·00

On comparing these analytical results with those obtained in the analyses of the soluble ash of fresh dung, it will be seen that the amount of soluble phosphate of lime (bone-earth) in the rotten dung is much greater than in the fresh. Phosphate of lime, next to potash, is the most abundant constituent of this ash.

Other differences between the soluble ash of fresh and rotten dung are too trifling to call for any special remarks. On the whole, a close similarity in the composition of both is sufficiently apparent.

The next table represents the composition of the insoluble ash of rotten dung:—

Analysis made Dec. 5, 1854.

Composition of Ash of Portion insoluble in Water.

Soluble silica	21·65
Insoluble silica	15·35
Oxides of iron and alumina and phosphates	14·40
Containing phosphoric acid	(4·17)
Equal to bone earth	(9·03)
Lime	25·34
Magnesia	1·38
Potash	·69
Soda	·58
Sulphuric acid	·96
Carbonic acid and loss	19·65
	100·00

The same constituents which occur in the insoluble ash of fresh manure are found in the insoluble ash of the rotten dung in very nearly the same relative proportions. The insoluble ash of rotten dung, however, contains still less potash, as nearly all potash is contained in the soluble ash.

From the foregoing results the composition of the whole ash left on burning of well-rotten dung has been calculated.

Analysis made December 5, 1854.

Composition of whole Ash.

			Arranged together.
Soluble in water, 18·27 per cent.	Soluble silica	3·16	
	Phosphate of lime	4·75	
	Lime	1·44	
	Magnesia	·59	
	Potash	5·58	
	Soda	·29	
	Chloride of sodium	·46	
	Sulphuric acid	·72	
	Carbonic acid and loss	1·28	
Insoluble in water, 81·73 per cent.	Soluble silica	17·69	20·85
	Insoluble silica	12·54	12·54
	Phosphate of lime	..	4·75
	Oxides of iron, alumina, with phosphates	11·76	11·76
	Containing phosphoric acid	(3·40)	(3·40)
	Equal to bone earth	(7·36)	(7·36)
	Lime	20·70	22·14
	Magnesia	1·17	1·76
	Potash	·56	6·14
	Soda	·47	·46
	Chloride of sodium	..	·76
	Sulphuric acid	·79	1·51
	Carbonic acid and loss	16·05	17·33
		100·00	100·00

As the relative proportion of soluble to insoluble ash differs in rotten from that in fresh dung, the composition of the whole ash of both presents some variations, observable especially in the amount of potash, which is much greater in the ash of fresh dung, and in a minor degree in the proportion of phosphate of lime.

In the next place I beg to direct attention to the subjoined Table, representing the detailed composition of rotten dung :—

Analysis made Dec. 5, 1854.

Detailed Composition of Manure in Natural State.

Water		75·42
*Soluble organic matter		3·71
Soluble inorganic matter (ash) :—		
Soluble silica	·254	
Phosphate of lime	·382	
Lime	·117	
Magnesia	·047	
Potash	·446	
Soda	·023	
Chloride of sodium	·037	
Sulphuric acid	·058	
Carbonic acid and loss	·106	
		1·47
Carry forward		80·60

Brought forward		80·60
†Insoluble organic matter		12·82
Insoluble inorganic matter (ash) :—		
Soluble silica	1·424	
Insoluble silica	1·010	
Oxides of iron and alumina, with phosphates	·947	
Containing phosphoric acid	(·274)	
Equal to bone earth	(·573)	
Lime	1·667	
Magnesia	·091	
Potash	·045	
Soda	·038	
Sulphuric acid	·063	
Carbonic acid and loss	1·295	
		6·58
		100·00
* Containing nitrogen	·297	
Equal to ammonia	·36	
† Containing nitrogen	·309	
Equal to ammonia	·375	
Whole manure contains ammonia in free state	·046	
„ „ form of salts	·057	

Dried at 212° F. the composition of this manure is as follows:—

Composition of the same Manure in dry state.

*Soluble organic matter		15·09
Soluble inorganic matter :—		
Soluble silica	1·035	
Phosphate of lime	1·554	
Lime	·476	
Magnesia	·193	
Potash	1·816	
Soda	·140	
Chloride of sodium	·151	
Sulphuric acid	·235	
Carbonic acid and loss	·380	
		5·98
†Insoluble organic matter		52·15
Insoluble inorganic matter :—		
Soluble silica	5·79	
Insoluble silica	4·11	
Oxides of iron and alumina, with phosphates	3·85	
Containing phosphoric acid	(1·11)	
Equal to bone earth	(2·41)	
Lime	6·78	
Magnesia	·37	
Potash	·18	
Soda	·15	
Sulphuric acid	·29	
Carbonic acid and loss	5·26	
		26·78
		100·00
* Containing nitrogen	1·21	
Equal to ammonia	1·47	
† Containing nitrogen	1·26	
Equal to ammonia	1·53	
Whole manure contains ammonia in free state	·189	
„ „ form of salts	·232	

The comparison of these analytical results with the numbers obtained in the analysis of the fresh manure, exhibits several striking differences, to some of which I beg to direct attention.

1. The well-rotten dung contains nearly 10 per cent. more water than the fresh. The larger percentage of water, it is true, may be purely accidental; but, considering the tendency of the liquid excrements to sink to the lower part of the manure pit in which the rotten dung accumulates, I believe rotten dung will always be found moister than fresh dung upon which no rain has fallen.

2. Notwithstanding the much larger percentage of moisture in the well-rotten dung, it contains in its natural state, with 75½ per cent. of water, almost as much nitrogen as the fresh dung, with only 66 per cent. of moisture. Supposing both to be equally moist, there would thus be considerably more nitrogen in rotten dung than in an equal weight of fresh. This is clearly observed by comparing the total amount of nitrogen in the perfectly dry fresh and rotten dung. In the former it amounts to 1·90 per cent. of nitrogen, in the latter to 2·47. As far as this most valuable element is concerned, farmyard manure becomes much richer, weight for weight, in becoming changed from fresh into rotten dung.

3. During the fermentation of the dung the proportion of insoluble organic matters greatly diminishes; thus the dry fresh manure contained 76 per cent. of insoluble organic matters, whilst there were only 52 per cent. in the dry rotten dung.

4. It is especially worthy of observation that, whilst the insoluble organic matter is much reduced in quantity during the fermentation, the insoluble organic matter which remains behind in rotten dung is richer in nitrogen than an equal quantity of insoluble organic matter from fresh dung. Thus 76 per cent. of insoluble organic matter of fresh dung contain 1·46 per cent., whilst 52 per cent. of it from rotten dung very nearly contain the same quantity, namely, 1·26. Or,—

100 parts of insoluble organic matter from fresh dung contain	1·92 per cent. of nitrogen.
100 parts of insoluble organic matter from rotten dung contain	2·41 " "

5. On the other hand, the relative proportion of insoluble inorganic matters increases much during the fermentation of the dung, since dry fresh dung contains about 12 per cent. of insoluble mineral matters, and dry well-rotten dungs 26·8 per cent., or more than double the amount which is found in fresh dung.

6. But perhaps the most striking difference in the compo-

sition of fresh and rotten dung is exhibited in the relative proportions of soluble organic matter. Well-rotten dung, it will be observed, contains rather more than twice as much soluble organic matters as the fresh; with this increase the amount of nitrogen present in a soluble state rises from ·44 per cent. to 1·21 per cent.

7. Not only does the absolute amount of soluble nitrogenised matters increase during the fermentation of dung, but the soluble organic matters relatively get richer in nitrogen also. Thus,—

100 parts of dry organic soluble matter from fresh dung contain	6·14 per cent. of nitrogen.
100 parts of dry organic soluble matter from rotten dung contain	8·02 ,, ,,

8. Lastly, it will be seen that the proportion of soluble mineral matters in rotten dung is more considerable than in fresh.

9. On the whole, weight for weight, well-rotten farmyard manure is richer in soluble fertilizing constituents than fresh dung, and contains especially more readily available nitrogen, and therefore produces a more immediate and powerful effect on vegetation.

Bearing in mind the differences observable in the composition of fresh and rotten dung, we can in a general manner trace the changes which take place in the fermentation of dung. Farmyard manure, like most organic matters, or mixtures in which the latter enter largely, is subject to the process of spontaneous decomposition, which generally is called fermentation, but more appropriately putrefaction. The nature of this process consists in the gradual alteration of the original organic matters, and in the formation of new chemical compounds. All organic matters, separated from the living organism, are affected by putrefaction, some more readily, others more slowly. Those organic substances which, like straw, contain but little nitrogen, on exposure to air and moisture at a somewhat elevated temperature decompose spontaneously and slowly, without disengaging any noxious smell. On the other hand, the droppings of animals, and especially their urine, which is rich in nitrogenous compounds, rapidly enter into decomposition, producing disagreeable-smelling gases. In a mixture of nitrogenous substances and organic matters free from nitrogen, the former are always first affected by putrefaction; the putrefying nitrogenised matters then act as a ferment on the other organic substances, which by themselves would resist the process of spontaneous decomposition much longer. Without air, moisture, and a certain amount of heat, organic matters cannot enter into putrefaction. These conditions exist in the droppings of cattle and the litter of the stables, hence putrefaction soon affects fresh dung. Like many chemical processes, putrefaction is accompanied with evolution of heat. Air and water exercise an important influence on the manner in which the decomposition of organic matters proceeds. Both are absolutely requisite in order that putrefaction may take place. Perfectly dry organic substances remain unaltered for an indefinite period, as long as they are kept perfectly dry. But too large an amount of water, again, retards the spontaneous decomposition of organic substances, as it excludes the access of air and prevents the elevation of temperature, both of which conditions greatly increase the rapidity with which organic matters are decomposed. Although air is an essential element in the putrefaction of organic matters, the unlimited access is unfavourable to this process of spontaneous decomposition, and is productive of new changes. In farmyard manure the unlimited access of air is prevented by the compact nature of dung-heaps, consequently only a limited quantity of air can find its way into the interior of the mass. During the fermentation of fresh dung, disagreeable smelling gases are given off. These arise principally from the sulphur, and from the phosphorus of the nitrogenized compounds present in dung. A considerable proportion of this sulphur and the phosphorus combine with hydrogen, and form sulphuretted and phosphoretted hydrogen—two extremely nauseous gases, which both escape from fermenting dung-heaps. Another portion of the sulphur and the phosphorus unites with atmospheric oxygen, and in the presence of porous substances becomes changed into sulphuric and phosphoric acid, two non-volatile compounds, which are left behind.

We have seen the relative proportion of inorganic matters in well-rotten dung is much greater than in fresh. This increase in mineral matters can have only been produced on the expense of organic substances, the quantity of which during the process of fermentation must decrease in a corresponding relative degree. Thus the total amount of organic and inorganic matters in fresh dung, dried at 212° Fahr., is,—

Organic matters	83·48
Inorganic matters	16·52
	100·00

Whilst in rotten dung there are in 100—

Organic substances	68·24
Mineral substances	31·76
	100·00

It is clear therefore that, during the fermentation of dung, much of the organic substances must become changed into compounds which are either readily soluble in water, and easily washed out by heavy rains, or into gaseous products, which are readily volatilized. In point of fact, both volatile gases and readily soluble organic compounds are formed. Amongst the former, carbonic acid and ammonia deserve especial mention; amongst the latter, soluble humates and ulmates may be named. These ulmates and humates are dark-brown-coloured compounds of humic and ulmic acids, with the alkalies, potash, soda, and ammonia. Ulmic and humic acids in a free state are scarcely soluble in water, and for this reason colour it only light brown. These organic acids have a very powerful affinity for ammonia, in consequence of which they lay hold of any free ammonia, which is generated in the fermentation of dung, and fix it perfectly, as long as no other compound is present or produced in fermenting dung, which at an *elevated temperature* again destroys the union of ammonia with humic, ulmic, and similarly constituted acids. Now, ammonia is generated during the putrefaction of the nitrogenized constituents of dung in large quantities, and would be dissipated into the air much more rapidly than is the case in reality, if there were not formed in the dung itself a group of organic compounds, which act as most excellent fixers of the volatile ammonia. I refer to the humus substances, which are gradually produced from the non-nitrogenized constituents of dung. In other words, the straw employed as litter during the putrefaction of dung is to a great extent converted into humic and ulmic acids, which fix to a certain extent the ammonia produced from the more nitrogenous excrementitious matters. The pungent smell of fermenting dung, however, shows that the volatile ammonia cannot be fixed entirely by these means. In the course of this inquiry I shall point out the reason of this, and content myself in this place by saying that the proportion of ammonia which passes into the atmosphere from fermenting dung-heaps, and the loss which hereby is occasioned, is much less considerable than it is generally assumed to be. In fermenting dung-heaps the carbonaceous constituents at first are changed into humus substances, but these are rapidly oxidized by atmospheric oxygen, and partly changed into carbonic acid, a gaseous substance which, in conjunction with oxide of carbon and carburetted hydrogen, is given off abundantly from all putrefying organic matters.

I have endeavoured to describe briefly the principal changes which take place in the fermentation of farmyard manure. It has been shown:—

1. That during the fermentation of dung the proportion of both soluble organic and soluble mineral matters rapidly increases.

2. That peculiar organic acids, not existing—at least, not in considerable quantities—are generated, during the ripening of dung from the litter and other non-nitrogenized organic constituents of manure.

3. That these acids (humic, ulmic, and similar acids) form, with potash, soda, and ammonia, dark-coloured, very soluble compounds. Hence the dark colour of the drainings of dung-heaps.

4. That ammonia is produced from the nitrogenous constituents of dung, and that this ammonia is fixed, for the greater part, by the humus substances produced at the same time.

5. That a portion of the sulphur and phosphorus of the excrementitious matters of dung is dissipated, in the form of sulphuretted and phosphoretted hydrogen.

6. That volatile ammoniacal compounds, apparently in inconsiderable quantities, escape into the air.

7. That the proportion of organic substances in fresh dung rapidly decreases during the fermentation of dung, whilst the mineral substances increase in a corresponding degree.

8. That this loss of organic substances is accounted for by the formation of carbonic acid, oxide of carbon, and light-carburetted hydrogen, or marsh-gas.

9. That the proportion of nitrogen is larger in rotten than in fresh dung.

The practical result of these changes is, that fresh manure, in ripening, becomes more concentrated, more easily available to plants, and, consequently, more energetic and beneficial in its action. It may be questioned, with much propriety,—Is this apparently desirable result attained without any appreciable loss? or is it realised at too great an expense? In other words, Is the fermentation of dung, or is it not, attended with considerable loss of really valuable fertilizing substances?

In putting this question we have to bear in mind that the loss in valuable mineral matters, under proper management, practically speaking, can be avoided, since they are non-volatile, and, therefore, must remain incorporated with the dung, if care be taken to prevent their being washed away by heavy falls of rain. We have likewise to bear in mind that, in an agricultural point of view, the carbonaceous, non-nitrogenized manure-constituents do not possess a very high intrinsic value; and that we therefore need not trouble ourselves about their diminution, if it can be shown that it is accompanied with other beneficial changes. The only other constituents which can come into consideration are the nitrogenized matters. The question may therefore be thus simplified: Is the fermentation of farmyard-manure necessarily attended with any appreciable loss in nitrogen?

Any one may ascertain that fermenting dung gives off ammonia, by holding over a dungheap, in active fermentation, a moistened reddened litmus-paper. The change of the red colour into blue sufficiently shows that there is an escape of ammonia. However, this experiment does not prove as much as is sometimes believed; for inasmuch as the most minute traces of ammonia produce this change of colour, the escape of this volatile fertilizing matter may be so small that it is practically altogether insignificant. The comparison of fresh with rotten dung, we have seen already, does not decide whether or not fresh farmyard manure sustains a loss in nitrogen in becoming changed into rotten manure. Apparently there is a gain in nitrogen, for we have seen that rotten dung contains more nitrogen than fresh. This gain in nitrogen, however, is explained by the simultaneous disappearance of, relatively, a much larger quantity of carbonaceous organic matter. Still the accumulation of nitrogen in rotten dung is important, and hardly to be expected; for, since a considerable portion of the nitrogenized organic matters is changed into volatile ammonia during fermentation, a loss, instead of a gain, in nitrogen naturally might be expected. A much greater loss in nitrogen than is actually experienced would, indeed, take place during the fermentation of dung, if this process were not attended with the simultaneous formation within the manure-heap of excellent fixers of ammonia.

Already at the beginning of my experiments I was thoroughly convinced that the mere analysis of farmyard manure would not decide the question which has just been raised, and therefore at once determined to make the analyses in conjunction with direct weighings of dung in various stages of decomposition. To this end I weighed out carefully two cartloads-full of the same well-mixed sample of fresh farmyard manure, the full analysis of which is given in the preceding pages. The manure was placed in a heap set against a stone wall, but otherwise exposed to the influence of the weather. The entire crude loss which this experimental heap sustained in the course of time was ascertained by periodical weighings on the weighbridge. Simultaneously with these weighings the manure was submitted to analysis, and thus I was enabled not only to determine from time to time the loss in weight which the experimental heap sustained in keeping, but also to ascertain which constituents were affected by this loss, and in which relative proportions. I shall call this experimental heap "Fresh Farmyard Manure, No. I., Exposed."

Another object I had in view was to examine the relative merits of various practical methods of the treatment of dung on the farm. This I endeavoured to attain by a series of strictly comparative practical and analytical experiments. For this purpose, I carefully weighed out two additional cartloads of fresh, well-mixed farmyard manure, taken from the same heap from which the experimental heap, No. I., was formed. It was placed next to the heap No. I., but sheltered from rain, sun, and sweeping winds by being kept under a shed. This heap will be described, in the following pages, as "Fresh Farmyard Manure, No. II., Under Shed."

In order to examine the merits of making farmyard manure in open yards, I weighed out 1 cartload of the same fresh, well-mixed manure, and spread it evenly to about the same thickness in which manure is found under cattle in open yards, in an enclosed space, in close proximity to the other experimental heaps. This heap is called "Fresh Farmyard Manure, No. III., Spread."

Finally, I put up a small heap of the same well-rotten dung, the analysis of which has been stated above. Like the experimental heap No. I., it was placed against a stone wall, but otherwise exposed to the influence of the weather. Under the name of "Well-rotten Farmyard Manure, No. IV., Exposed," it will be described in the succeeding pages.

All four experimental heaps were again weighed on the 14th of February, 1855, after having thus been kept for 3 months and 11 days. At the same time at which the weighings were made, samples of each were taken for analysis, and the water-determinations made immediately. Unfortunately, I discovered, just when the last heap was placed on the weighbridge, that the frost had impaired the accuracy of the balance, and I had, therefore, no alternative but to reject the weighings in toto, and can supply therefore for this month only the analyses. This is the more to be regretted, as I submitted samples of three of the experimental heaps to a strict and detailed analysis. I trust, however, the subjoined analyses will not be void of interest.

The following Table exhibits the composition of "Experimental Heap No. I., Exposed," in its natural state :—

Composition of Fresh Farmyard Manure (No. I.), *Exposed, in Natural State.*

Taken for analysis, Feb. 14, 1855.

Water		69·83
*Soluble organic matter		3·86
Soluble inorganic matter (ash) :—		
Soluble silica	·279	
Phosphate of lime	·300	
Lime	·048	
Magnesia	·019	
Potash	1·096	
Soda	·187	
Chloride of sodium	·106	
Sulphuric acid	·160	
Carbonic acid and loss	·775	
		2·97
†Insoluble organic matter		18·44
Insoluble inorganic matter (ash) :—		
Soluble silica	·712	
Insoluble silica	·857	
Oxide of iron and alumina, with phosphates	·810	
Containing phosphoric acid	(·177)	
Equal to bone earth	(·277)	
Lime	1·291	
Magnesia	·029	
Potash	·127	
Soda	·046	
Sulphuric acid	·099	
Carbonic acid and loss	·929	
		4·90
		100·00

* Containing nitrogen	·27
Equal to ammonia	·32
† Containing nitrogen	·47
Equal to ammonia	·57
Whole manure contains ammonia in free state	·019
" " in form of salts	·064

The same manure, in a perfectly dry state, contains in 100 parts :—

* Soluble organic matter		12·79
Soluble inorganic matter (ash) :—		
Soluble silica	·924	
Phosphate of lime	·985	
Lime	·160	
Magnesia	·065	
Potash	3·632	
Soda	·621	
Chloride of sodium	·351	
Sulphuric acid	·532	
Carbonic acid and loss	2·570	
		9·84
Carry forward		22·63

Brought forward		22·63
†Insoluble organic matter		61·12
Insoluble inorganic matter:—		
Soluble silica	2·364	
Insoluble silica	2·844	
Oxides of iron and alumina, with phosphates	2·689	
Containing phosphoric acid	(·589)	
Equal to bone earth	(·919)	
Lime	4·281	
Magnesia	·097	
Potash	·422	
Soda	·166	
Sulphuric acid	·329	
Carbonic acid and loss	3·066	
		16.25
		100·00

* Containing nitrogen	·91
Equal to ammonia	1·10
† Containing nitrogen	1·55
Equal to ammonia	1·88
Whole manure contains ammonia in free state	0·62
,, ,, in form of salts	·212

Composition of Ash of portion Soluble in Water of the same Manure.

Soluble silica	9·40
Phosphate of lime	10·12
Lime	1·63
Magnesia	·67
Potash	36·92
Soda	6·32
Chloride of sodium	3·57
Sulphuric acid	5·41
Carbonic acid and loss	25·96
	100·00

Composition of Ash of portion Insoluble in Water of the same Manure.

Soluble silica	14·55
Insoluble silicious matter (sand)	17·50
Oxides of iron and alumina, with phosphates	16·55
Containing phosphoric acid	(3·63)
Equal to bone earth	(5·66)
Lime	26·35
Magnesia	·60
Potash	2·60
Soda	·95
Sulphuric acid	2·03
Carbonic acid and loss	18·87
	100·00

In the next Table is given the composition of the whole ash left on burning the manure.

Composition of whole Ash of Fresh Farmyard Manure (No. I.), *Exposed.*

			Arranged together.
Soluble in Water 37·74 per cent.	Soluble silica	3·55	
	Phosphate of lime	3·82	
	Lime	·62	
	Magnesia	·25	
	Potash	13·93	
	Soda	2·38	
	Chloride of sodium	1·35	
	Sulphuric acid	2·04	
	Carbonic acid	9·80	
Insoluble in Water 62·26 per cent.	Soluble silica	9·06	12·61
	Insoluble silica	10·89	10·89
	Phosphate of lime	..	3·82
	Oxide of iron and alumina, with phosphates	10·30	10·30
	Containing phosphoric acid	(2·26)	(2·26)
	Equal to bone earth	(3·52)	(3·52)
	Lime	16·41	17·03
	Magnesia	·37	·62
	Potash	1·62	15·55
	Soda	·59	2·97
	Chloride of sodium	..	1·35
	Sulphuric acid	1·27	3·31
	Carbonic acid	11·75	21·55
		100·00	100·00

A comparison of these analytical results with the analysis which was made of the fresh manure, on the 3rd of November, 1854, will show:—

1. That there is more water in the manure on the 14th of February, 1855.

2. That, notwithstanding the larger proportion of water, the soluble organic and mineral matters have become more abundant, whilst the insoluble organic matters have become diminished in quantity.

Thus, in November, the manure contained 2·48 per cent. of soluble organic matter, and 1·54 mineral substances; and in February, 3·86 per cent. organic and 2·97 mineral substances; whilst the proportion of insoluble organic matters in November amounts to 25·76 per cent, and in February to only 18·44 per cent.

These differences are still more striking, if we make the comparison with the perfectly dry manure. It will then be found that the manure contained:—

	Nov. 3, 1854. per Cent.	Feb. 14, 1855. per Cent.
Soluble organic matters	7·33	12·79
Soluble mineral matters	4·55	9·84
Insoluble organic matter	76·15	61·12
Insoluble mineral matters	11·97	16·25
	100·00	100·00

3. That the total percentage of organic substances decreases, whilst that of mineral matters increases. Thus the fresh manure contained—

	In Nov.	In Feb.
Organic matters	28·24	22·30
Mineral matters	5·59	7·87

And the perfectly dry manure—

Organic matters	83·48	73·91
Mineral matters	16·52	26·09

4. That the percentage of nitrogen in the February analysis is slightly greater than in November.

5. That there is about the same inconsiderable amount of free ammonia, and ammonia in the form of readily decomposable salts, in the manure in February which has been found in November, 1854.

6. With respect to the inorganic constituents, a careful perusal of the furnished ash-analyses will show that the soluble portion of the ash of the February manure contains less phosphates of lime and less soluble silica, but more sulphuric acid, than the soluble ash of the perfectly fresh manure analyzed in November. The insoluble portion of the ash in February likewise contains less phosphates and soluble silica than in November, and the same differences will be observed on comparing the whole ash of February with that of November. It would appear thus that a three months' exposure to the weather has had the effect of removing from the manure an appreciable quantity of two very important fertilizing substances, namely, phosphate of lime (bone-earth) and soluble silica.

I purposely abstain from pointing out minor differences, which will be observed in the November and February analyses of this manure; for it must be borne in mind that, in experiments with farmyard manure, a perfectly uniform mixture can scarcely be obtained. Minor variations in the composition of the manure of November and February, therefore, may result as likely from purely accidental causes as from any real difference in composition. The particulars, however, just mentioned are sufficiently marked to prove that they are not due to accident, but to a series of changes which the fresh manure has undergone in the course of 3 months and 11 days.

Fresh Farmyard Manure (No. II.), *Under Shed.*—Put up Nov. 3, 1854. Analyzed again in Feb. 14, 1855.

The fresh manure used for all experiments was rather dry, no rain having fallen during the fortnight, in which the dung was collected from the stable, cow-house, and piggeries.

Plenty of litter having been supplied to the animals, the fresh manure appeared to me drier than usual, and as the experimental heap under shed necessarily must lose a good deal of moisture on keeping, I thought it desirable to pour water upon it, just sufficient to make it as moist as fresh dung generally appears. This addition of water, which was not repeated, explains that the manure under shed contained a little more moisture in February, 1855, than when first put up in November, 1854.

The following Table exhibits the composition of this manure in its natural state:—

Fresh Farmyard Manure (No. II.), *Under Shed.*

Analysis made Feb. 14th, 1855.

Composition of Manure in natural state.

Water		67·32
*Soluble organic matter		2·63
Soluble inorganic matter (ash):—		
Soluble silica	·239	
Phosphate of lime	·331	
Lime	·056	
Magnesia	·004	
Potash	·676	
Soda	·192	
Chloride of sodium	·058	
Sulphuric acid	·119	
Carbonic acid and loss	·445	
		2·12
†Insoluble organic matter		20·46
Insoluble inorganic matter (ash):—		
Soluble silica	1·893	
Insoluble silicious matter (sand)	1·075	
Oxide of iron and alumina, with phosphates	1·135	
Containing phosphoric acid	(298)	
Equal to bone earth	(646)	
Lime	1·868	
Magnesia	·078	
Potash	·208	
Soda	·038	
Sulphuric acid	·098	
Carbonic acid and loss	1·077	
		7·47
		100·00

* Containing nitrogen	·17
Equal to ammonia	2·06
† Containing nitrogen	·58
Equal to ammonia	·70
Whole manure contains ammonia in free state	0·22
,, ,, in form of salts	0·54

Composition of the same Manure in dry state.

*Soluble organic matter		8·04
Soluble inorganic matter (ash):—		
Soluble silica	·733	
Phosphate of lime	1·013	
Lime	·171	
Magnesia	·013	
Potash	2·068	
Soda	·578	
Chloride of sodium	·179	
Sulphuric acid	·366	
Carbonic acid and loss	1·359	
		6·48
†Insoluble organic matter		62·60
Insoluble inorganic matter :—		
Soluble silica	3·294	
Insoluble silica	5·800	
Oxide of iron and alumina, with phosphates	3·477	
Containing phosphoric acid	(·91)	
Equal to bone earth	(1·979)	
Lime	5·722	
Magnesia	·240	
Potash	·613	
Soda	·116	
Sulphuric acid	·302	
Carbonic acid and loss	2·316	
		22·88
		100·00

* Containing nitrogen	·53
Equal to ammonia	·66
† Containing nitrogen	1·77
Equal to ammonia	2·14
Whole manure contains ammonia in free state	0·67
„ „ in form of salts	1·65

One hundred parts of the *soluble portion* of the mineral matters of the same manure contain :—

Soluble silica	11·32
Phosphate of lime	15·64
Lime	2·64
Magnesia	·21
Potash	31·92
Soda	9·07
Chloride of sodium	2·77
Sulphuric acid	5·66
Carbonic acid and loss	20·77
	100·00

One hundred parts of the insoluble portion of the ash of the same manure furnished the following results :—

Soluble silica	25·35
Insoluble silica	14·40
Oxide of iron and alumina, with phosphates	15·20
Containing phosphoric acid	(4·00)
Equal to bone earth	(8·66)
Lime	25·01
Magnesia	1·05
Potash	2·73
Soda	·51
Sulphuric acid	1·32
Carbonic acid and loss	14·43
	100·00

Taking into account the relative proportions in which the soluble mineral matters are mixed with the insoluble in this manure, the composition of the whole ash left, on burning of the manure, has been calculated.

Composition of whole Ash, produced by the same Manure.

			Arranged together.
Soluble in water, 22·10 per cent.	Soluble silica	2·50	
	Phosphate of lime	3·45	
	Lime	·58	
	Magnesia	·04	
	Potash	7·05	
	Soda	2·03	
	Chloride of sodium	·61	
	Sulphuric acid	1·25	
	Carbonic acid and loss	4·59	
Insoluble in water, 77·90 per cent.	Soluble silica	19·74	22·24
	Insoluble silica	11·21	11·21
	Phosphate of lime	..	3·45
	Oxide of iron and alumina, with phosphates	11·84	11·84
	Containing phosphoric acid	(3·11)	(3·11)
	Equal to bone earth	(6·74)	(6·74)
	Lime	19·48	20·06
	Magnesia	·82	·86
	Potash	2·12	9·17
	Soda	·39	2·42
	Chloride of sodium	..	·61
	Sulphuric acid	1·02	2·27
	Carbonic acid and loss	11·28	15·87
		100·00	100·00

On comparing these results with the analyses of the fresh manure of November, 1854, it will be found that the manure kept under the shed for 3 months and 11 days has suffered very little change both as regards organic and mineral constituents. It will be perceived that the proportion of soluble compounds has very little increased in the course of this time, and that the percentage of nitrogen in the manure, practically speaking, has remained unaltered. Thus comparing the composition of the dry manure of February with that of the fresh of November, it will be seen that the fresh manure contained in November 7·33 of soluble organic matter, and in February hardly 1 per cent. more, namely, 8·04 per cent.

In the fresh, the percentage of nitrogen in the soluble organic matter is ·44, and in the same manure kept 3 months 11 days under shed, the nitrogen amounts to ·53 of a per cent. It also contains but a trifling amount of free ammonia, and ammonia in the form of salts.

Apparently the manure has lost a good deal of organic insoluble matter, almost as much as the exposed heap. If, however, we scrutinize the results obtained in the analysis, it will be seen that the manure under shed contains a more considerable proportion of insoluble ash, and in this more lime and insoluble silicious matter, than occurs in the experimental heap (No I.) exposed to the weather for the same length of time. In the latter the mineral insoluble matter we would naturally expect to increase, since the soluble constituents are exposed to the solvent action of falling rain. The manure under shed cannot be subject to this deteriorating influence. If we find, notwithstanding, more insoluble mineral matters than in the manure exposed to the weather, it is plain that the larger amount of insoluble mineral matters, which causes the apparent diminution of insoluble organic compounds, can only be due to a larger proportion of mechanical earthy impurities in the sample analysed. In proof of this view of the matter it may further be stated that the manure kept under shed for another 3 months furnished even a little less insoluble mineral matter than in February. And as in the warmer spring months a more considerable diminution of organic substances has really taken place, as shown by the analyses to be mentioned hereafter, the excess of insoluble mineral matters in the February analysis can only be accounted for by mechanical impurities in the sample of which the analysis has been made.

If we make due allowance for this disturbing influence, it will be observed that the composition of the soluble and insoluble portion of the ashes, furnished by the fresh manure in November, and of the same heap kept under shed for 3 months 11 days, is almost identical. It deserves to be noticed specially, that the ash of the manure kept under shed contains more phosphate of lime (bone-earth) than the ash produced by the heap exposed to the weather for the same length of time, during which the second experimental heap has been kept under shed.

I also beg to direct attention to the fact that this manure, as well as the preceding experimental heap, contains more sulphuric acid than the heap when first put up. On keeping of dung some of the sulphur, which we know occurs in nitrogenized substances in a peculiar state of organic combination, appears to become oxydised and changed into sulphuric acid, which acid entering into combination with lime, produces in its turn gypsum. Farmyard manure thus contains a quantity of gypsum, which becomes more considerable as the fermentation of the dung proceeds. Without pushing deductions from this fact too far, it may be observed that it is interesting at all events to find that in the fermentation of dung, gypsum, a well known fixer of ammonia, is produced simultaneously with volatile compounds of ammonia.

Besides the humus-like organic substances which we have seen are produced in fermenting dung-heaps, an additional fixer of ammonia, *i. e.* gypsum, is generated; and thus great care is manifested by nature to prevent, if possible, the loss of this valuable fertilizing substance.

Fresh Farmyard Manure (No. III.), *Spread.*

The manure being covered with snow on the 14th of February, when the other experimental heaps were analysed, and it having been found next to impossible to remove the snow completely, or to mix it thoroughly with the manure, nothing was done in this month with the spread experimental farmyard manure.

Well-rotten Dung (No. IV.), *Exposed.*—Put up Dec. 5, 1854. Analysed again, Feb. 14, 1855.

This experimental heap has been exposed to the influence of the weather for a period of 2 months and 9 days. During that time it had shrunk considerably in size. The diminution in bulk, however, I believe, is not so much the result of an actual very great loss, as it is due to the manure gradually settling down and becoming firmer. Still it has undergone some loss in keeping even during the cold time of the year, as will be seen from the subjoined analyses.

In the state in which the well-rotten dung was analysed on the 14th of February it furnished the following results:—

Well-rotten Farmyard Manure (No. IV.), *Exposed.*

Analysis made Feb. 14, 1855.

Composition of Manure in Natural State.

Water		73·90
*Soluble organic matter		2·70
Soluble inorganic matter (ash):—		
Soluble silica	·147	
Phosphate of lime	·129	
Lime	·018	
Carry forward		76·60

Brought forward		76·60
Magnesia	·018	
Potash	·960	
Soda	·082	
Chloride of sodium	·052	
Sulphuric acid	·072	
Carbonic acid and loss	·584	
		2·06
†Insoluble organic matter		14·39
Insoluble inorganic matter (ash):—		
Soluble silica	1·10	
Insoluble silica	1·54	
Oxide of iron and alumina, with phosphates	0·37	
Containing phosphoric acid	(·06)	
Equal to bone earth	(·10)	
Lime	2·25	
Magnesia	·02	
Potash	·12	
Soda	·01	
Sulphuric acid	·10	
Carbonic acid and loss	1·44	
		6·95
		100·00

* Containing nitrogen	·149
Equal to ammonia	·180
† Containing nitrogen	·061
Equal to ammonia	·074
Whole manure contains ammonia in free state	·015
” ” in form of salts	·048

Well-rotten Farmyard Manure (No. IV.), *Exposed.*

Analysis made Feb. 14, 1855.

Composition of Manure in Dry State.

*Soluble organic matter		10·34
Soluble inorganic matter (ash):—		
Soluble silica	·564	
Phosphate of lime	·493	
Lime	·067	
Magnesia	·068	
Potash	3·680	
Soda	·321	
Chloride of sodium	·194	
Sulphuric acid	·278	
Carbonic acid and loss	2·225	
		7·89
†Insoluble organic matter		55·13
Insoluble inorganic matter:—		
Soluble silica	4·24	
Insoluble silica	5·91	
Oxide of iron and alumina, with phosphates	1·41	
Containing phosphoric acid	(·24)	
Carry forward		73·36

Brought forward		73·36
Equal to bone earth	(·38)	
Lime	7·65	
Magnesia	·08	
Potash	·45	
Soda	·06	
Sulphuric acid	·38	
Carbonic acid and loss	6·46	
		26·64
		100·00

* Containing nitrogen	·57
Equal to ammonia	·69
† Containing nitrogen	2·35
Equal to ammonia	2·85
Whole manure contains ammonia in free state	·57
,, ,, in form of salts	·183

Composition of Ash of Portion soluble in Water of same Manure.

Soluble silica	7·15
Phosphate of lime	6·25
Lime	·86
Magnesia	·87
Potash	46·65
Soda	4·07
Chloride of sodium	2·47
Sulphuric acid	3·52
Carbonic acid and loss	28·16
	100·00

Composition of Ash of Portion insoluble in Water of same Manure.

Soluble silica	15·93
Insoluble silica	22·20
Oxides of iron and alumina, with phosphates	5·30
Containing phosphoric acid	(·93)
Equal to bone earth	(1·45
Lime	32·48
Magnesia	·30
Potash	1·70
Soda	·23
Sulphuric acid	1·42
Carbonic acid and loss	20·44
	100·00

Well-rotten Farmyard Manure.

Analysis made Feb. 14, 1855.

Composition of whole Ash.

Soluble in water, 22·85 per cent.	Soluble silica	1·63
	Phosphate of lime	1·43
	Lime	·19
	Magnesia	·20
	Potash	10·66
	Soda	·93
	Chloride of sodium	·56
	Sulphuric acid	·80
	Carbonic acid and loss	6·45

			Arranged together.
Insoluble in water, 77·15 per cent.	Soluble silica	12·13	13·76
	Insoluble silicious matter (sand)	17·12	17·12
	Phosphate of lime	..	1·43
	Oxides of iron, alumina, with phosphates	4·08	4·08
	Containing phosphoric acid	(·71)	(·71)
	Equal to bone earth	(1·11)	(1·11)
	Lime	25·05	25·24
	Magnesia	·23	·43
	Potash	1·31	11·97
	Soda	·17	1·10
	Chloride of sodium	..	·56
	Sulphuric acid	1·09	1·89
	Carbonic acid and loss	15·97	22·41
		100·00	100·00

A glance at these analytical results will show that the proportion of soluble organic matters in the well-rotten dung is smaller in February 1855 than in December 1854. It would thus appear that a portion of the soluble constituents has been washed away by rain or melting snow. As the heap was small, it was no doubt more readily affected by this deteriorating cause than a large heap would have been. It is moreover probable that the sample of the manure which was analysed in February did not fairly represent the whole heap. It appears to me therefore very likely that the proportion of soluble matters in the whole heap is in reality larger than is indicated by the foregoing analysis.

It will further be observed that the dry manure in February contains about 2 per cent. less of organic matters than in December. We have thus here a direct proof that the proportion of organic matters decreases in dung-heaps even in the coldest months of the year—it is true in a less considerable degree than in summer, but yet to an appreciable extent.

I would call attention to the manner in which the nitrogen is distributed amongst the constituents of this manure. When just removed from a well-constructed dung-pit in December 1854, 100 lb. of the perfectly dry manure contained 1·21 per cent. of nitrogen in the form of soluble compounds; in February 1855, the soluble portion of the manure contained only ·57 per cent. of nitrogen, thus showing that a portion of the soluble nitrogenized matters has escaped either into the air, or, what is more probable, has been washed out by the rain or melting snow. Notwithstanding this loss in nitrogen, the total percentage of nitrogen has become slightly greater by keeping for 2 months and 9 days.

With respect to the free ammonia, it will be observed that rotten dung contains rather more free ammonia than fresh. The free ammonia, which under all circumstances constitutes but a small fraction of a per cent. of the manure, however, sinks again in February to a mere trace. Direct experiments, made with a view of ascertaining the cause of this difference, have shown me that farmyard manure gives off no ammonia when quite cold, and that free ammonia can only be disengaged when the dung-heap is in an active state of fermentation, which is always accompanied with evolution of heat. In the interior of large heaps the heat of the dung is often very great, and it is in this part of the heap that ammonia is given off largely. Before, however, it can escape into the air it has to pass a portion of manure which is kept cold by the surrounding air. This external and cold part of dung-heaps acts as a mechanical and chemical filter with reference to the ammonia which is given off from the interior and heated portion of the heap. On account of the porous condition of the litter and partly dried excrements the ammonia is fixed mechanically; but as all organic substances exposed to the atmosphere and moisture are gradually changed into humus, which as we have seen already is an excellent fixer of ammonia, the external parts of dung-heaps may also be called a chemical filter which prevents the loss of ammonia.

Dung-heaps that have been placed in a field, after a short time, when settled down to a firm mass, do not give off any ammonia, but on turning such heaps a very powerful and pungent smell is readily perceptible. Each turning of a manure-heap thus is attended with a certain loss in ammonia, since it escapes from heated manure. It may therefore be advisable not to turn manure-heaps more frequently than is absolutely necessary.

In the preceding pages I have given detailed organic and inorganic analyses of the fresh and the rotten dung in the state in which both were used in the experimental heaps. I have likewise given such analyses of the fresh manure, after it had been kept for 3 months and 11 days in two different ways, and of the rotten dung after having been exposed to the weather for 2 months and 9 days.

Another detailed analysis of the fresh manure, after having been spread out in an open yard for a period of 6 months, will be found in the succeeding pages. The various experimental heaps were weighed for the second time on the 30th of April, 1855, and at the same time samples for analysis taken from each heap.

The two heaps made on the 3rd of November, 1855, with fresh mixed farmyard manure and the portion of fresh dung spread out in an open yard, thus were kept for 6 months, minus 3 days; whilst the rotten dung, being placed in a heap on the 5th of December, was kept for only 5 months, minus 5 days. The loss in weight having been ascertained in each case, the manure was carted back in its former place and kept under the same respective circumstances until the 23rd of August, 1855, when again each experimental portion was weighed separately and again analysed.

The rotten dung thus had been kept by the 23rd of August for a period of 8 months and 18 days, the rest of the experimental manure heaps for a period of 9 months 20 days.

Finally the different experimental heaps were weighed and analysed for the last time on the 15th of November, 1855. The rotten dung thus had been exposed to the influence of the atmosphere for a period of 11 months and 10 days, and the 3 remaining experimental portions of originally fresh dung had been kept for a period of 12 months and 12 days.

In order to render more conspicuous the results obtained in the direct weighings and in the different analyses, I shall incorporate them in separate Tables, which will be given under the respective heads of

1. Fresh farmyard manure, (No. I.) Exposed.
2. .. .. .. (No. II.) Under shed.
3. .. .. .. (No. III.) Spread.
4. Well-rotten farmyard manure, (No. IV.) Exposed.

Before stating these details I may say that I have taken especial care in determining accurately the nitrogen in each series of analyses. Frequently two combustions were made of one and the same substance, and invariably closely agreeing results obtained.

Fresh Farmyard Manure (No. I.), *Exposed* (mixed horse, cow, and pig dung).

In the subjoined Table is stated the actual weight of the first experimental heap at different periods of the year, and the loss which it sustained in these periods.

Table showing the Weight of Experimental Heap of Fresh Farmyard Manure (No. I.), Exposed, at different periods, and Percentage of Loss in Weight, expressed in lbs.

	Weight of Manure in lbs.	Loss in Original Weight in lbs.	Percentage of Loss.
Put up on the 3rd of November, 1854	2838	—	—
Weighed on the 30th of April, 1855, or after a lapse of 6 months	2026	812	28·6
Weighed on the 23rd of August, 1855, or after a lapse of 9 months and 20 days	1994	844	29·7
Weighed on the 15th of November, 1855, or after a lapse of 12 months, and 12 days ..	1974	864	30·4

In the course of a year and 12 days the original weight of this heap, amounting to 1 ton 5 cwts. 1 quarter and 10 lbs. thus became reduced to 17 cwts. 2 quarters and 14 lbs. by being exposed to the influence of the weather, or 100 tons lost 30·4 tons.

We shall see presently in what this loss consisted. I may mention, however, already in this place that the direct weighings do not represent in an unmistakable manner the loss which farmyard manure undergoes in reality in keeping. We shall see, namely, that the loss during the last 3 months is much greater than stated in the foregoing Table, after we shall have become acquainted with the composition, which the manure presented at the different periods, when it was weighed.

In the first place I would therefore direct the attention of the reader to the following Table, in which is given the composition of the manure in the state in which it was found at the different experimental weighings.

Composition of Fresh Farmyard Manure (No. I.), Exposed in Natural State, at different periods of the Year.

	When put up on the 3rd Nov. 1854.	Feb. 14th, 1855.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Water	66·17	69·83	65·95	75·49	74·29
*Soluble organic matters ..	2·48	3·86	4·27	2·95	2·74
Soluble inorganic matters ..	1·54	2·97	2·86	1·97	1·87
†Insoluble organic matters ..	25·76	18·44	19·23	12·20	10·89
Insoluble mineral matters ..	4·05	4·90	7·69	7·39	10·21
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·149	·27	·30	·19	·18
Equal to ammonia	·181	·32	·36	·23	·21
†Containing nitrogen	·494	·47	·59	·47	·47
Equal to ammonia	·599	·57	·71	·62	·57
Total amount of nitrogen ..	·643	·74	·89	·66	·65
Equal to ammonia	·780	·89	1·07	·85	·78
Ammonia in a free state ..	·034	·019	·008	·010	·006
Ammonia in form of salts, easily decomposed by quicklime	·088	·064	·085	·038	·041
Total amount of organic matters	28·24	22·30	23·50	15·15	13·63
Total amount of mineral substances	5·59	7·87	10·55	9·36	12·08

It will be seen that in February this manure contained about 3½ per cent. more moisture than when first put up. At the end of April, little or no rain having fallen in the interval, it dried up to its original state of dryness. The loss in weight in April amounting to 28·6 per cent., therefore, is real loss, that is to say it is loss which affects the dry manure, and is not due to evaporation of water. In other words 100 lbs. of dry manure, on keeping for a period of 6 months exposed to the weather, lost 28·6 lbs., and became only 71·4 lbs. In August the manure gained a very large quantity of water, by heavy showers of rain, and this large proportion of water, which is greater than the original quantity of moisture by nearly 10 per cent., was reduced only 1 per cent. on keeping of the manure for another 3 months.

The direct-weighings, as well as the composition of the manure, are therefore much affected by the rain that falls at the different periods, and for this reason, neither the analyses nor the weighings by themselves are fit to determine the loss which farmyard-manure undergoes on keeping.

Before any further remarks can be offered on these analyses it will be necessary to calculate the composition of the manure in a dry state, for as the percentage of water differs so much at the various times of analysis, the results in the preceding Table are not comparable. In the next Table, therefore, I have stated the composition of the perfectly dry manure at various epochs.

Composition of Fresh Farmyard Manure (No. I.), Exposed. Calculated Dry.

	When put up. Nov. 3rd, 1854.	Feb. 14th, 1855.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
*Soluble organic matters	7·33	12·79	12·54	12·04	10·65
Soluble inorganic matters ..	4·55	9·84	8·39	8·03	7·27
†Insoluble organic matters ..	76.15	61·12	56·49	49·77	42·35
Insoluble mineral matters ..	11·97	16·25	22·58	30·16	39·73
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·44	·91	·88	·77	·72
Equal to ammonia	·53	1·10	1·06	·93	·88
†Containing nitrogen	1·46	1·55	1·75	1·92	1·85
Equal to ammonia	1·77	1·88	2·12	2·33	2·24
Total amount of nitrogen ..	1·90	2·46	2·63	2·69	2·57
Equal to ammonia	2·30	2·98	3·18	3·26	3·12
Ammonia in free state	·10	·062	·023	·041	·023
Ammonia in form of salts, easily decomposed by quicklime ..	·26	·212	·249	·154	·159
Total amount of organic matters	83·48	73·91	69·03	61·81	53·00
Total amount of mineral substances	16·52	26·09	30·97	38·19	47·00

A comparison of these different analyses points out clearly the changes which fresh farmyard manure undergoes on keeping in a heap, exposed to the influence of the weather during a period of twelve months and twelve days.

1. It will be perceived that the proportion of organic matter steadily diminishes from month to month, until the original percentage of organic matter in the dry manure, amounting to 83·48 per cent., became reduced to 53 per cent.

2. On the other hand, the total percentage of mineral matters rises as steadily as that of the organic matters falls.

3. It will be seen that the loss in organic matters affects the percentage of insoluble organic matters more than the percentage of soluble organic substances.

4. The percentage of soluble organic matters indeed increased considerably during the first experimental period; it rose, namely, from 7·33 per cent. to 12·79 per cent. Examined again on the 30th of April, very nearly the same percentage of soluble organic matters as on February the 14th was found. The August analysis shows but a slight decrease in the percentage of soluble organic matters, whilst there is a decrease of 2 per cent. of soluble organic matters when the November analysis is compared with the February analysis.

5. The soluble mineral matters in this manure rise or fall in the different experimental periods in the same order as the soluble organic matters. Thus, in February, 9·84 per cent. of soluble mineral matters were found, whilst the manure contained only 4·55 per cent., when put up into a heap in November, 1854. Gradually, however, the proportion of soluble mineral matters again diminished, and became reduced to 7·27 per cent., on the examination of the manure in November, 1855.

6. A similar regularity will be observed in the percentage of nitrogen contained in the soluble organic matters.

7. In the insoluble organic matters the percentage of nitrogen regularly increased from November, 1854, up to the 23rd of August, notwithstanding the rapid diminution of the percentage of insoluble organic matters. For the last experimental period the percentage of nitrogen in the insoluble matters is nearly the same as in August 23rd.

8. With respect to the total percentage of nitrogen in the fresh manure, examined at different periods of the year, it will be seen that the February manure contains about one-half per cent. more of nitrogen than the manure in a perfectly fresh state. On the 30th of April the percentage of nitrogen again slightly increased; on August 23rd it remained stationary, and had sunk but very little when last examined on the 15th of November, 1855.

This series of analyses thus shows that fresh farmyard manure rapidly becomes more soluble in water, but that this desirable change is realised at the expense of a large proportion of organic matters. It likewise proves in an unmistakable manner that there is no advantage in keeping farmyard manure for too long a period; for after February neither the percentage of soluble organic nor that of soluble mineral matters has become greater; and the percentage of nitrogen in the manure of April and August is only a very little higher than in February.

Weight for weight, the February manure thus will be as good as the manure in April or August, and slightly superior to the manure in November, 1855. The direct weighings, however, of the whole heap have shown us already that a considerable loss in weight is experienced in the different periods during which the manure was kept. And as the fresh manure did not improve in composition after the 14th of February, it is clear that the loss in weight is not due to the mere evaporation of water or the dissipation of other useless constituents, but is a real loss in valuable fertilising constituents.

That this is really the case appears still more decidedly if we consult the direct weighings of the experimental heap, and the composition of the manure at the time at which the weighings were made. This will enable us to calculate the composition of the whole heap at the different experimental periods, and we shall then see in what manner the loss in weight is distributed amongst the various constituents of the manure.

In the following Table the composition which the whole experimental heap, No. I., exhibited at different periods of the year, has been calculated from data already given. The actual weight of the manure heaps is again stated in the first horizontal column; in the second horizontal column, the actual amount of water in the whole heap is stated; and in the third, the total amount of dry matter. The next four (bracketed together) show the composition of the dry matter. All numbers in the Table express pounds or fractions of pounds.

A careful study of the Table will convince the reader that the real loss in valuable fertilising matters which farmyard manure sustains in keeping is very much greater than is indicated by the direct weighings of the experimental heap. It will be remembered that the manure, when put up in a heap on the 3rd of November, 1854, contained 66·17 per cent. of water, and consequently 33·83 per cent. of dry matters. The total amount of dry matter in the perfectly fresh experimental heap amounted to 960·10 lbs.; but, after having been exposed to the influence of the weather for a period of nine months, only 488·7 lbs. of dry substance are left behind. The direct weighing of the heap in August indicates a loss of 29·77 per cent., whereas in reality a loss of very nearly 50 per cent. in the solid constituents of the manure has been incurred. This *enormous waste* in manuring matters, it will appear likewise from a careful perusal of the Table, may be prevented, at least to a very great extent, by applying either the manure in a fresh state to the land, or, if this is inadmissible, by keeping it no longer than is absolutely necessary.

Table showing Composition of the Whole Heap: Fresh Farmyard Manure (No. I.), Exposed. Expressed in lbs.

	When put up. Nov. 3rd, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Weight of manure in lbs.	2838	2026	1994	1974
Amount of water in the manure	1877·9	1336·1	1505·3	1466·5
Amount of dry matter in the manure ..	960·1	689·9	488·7	507·5
Consisting of—				
*Soluble organic matter	70·38	86·51	58·83	54·04
Soluble mineral matter	43·71	57·88	39·16	36·89
†Insoluble organic matters	731·07	389·74	243·22	214·92
Insoluble mineral matter	114·94	155·77	147·49	201·65
	960·1	689·9	488·7	507·5
*Containing nitrogen	4·22	6·07	3·76	3·65
Equal to ammonia	5·12	7·37	4·56	4·36
†Containing nitrogen	14·01	12·07	9·38	9·38
Equal to ammonia	17·02	14·65	11·40	11·39
Total amount of nitrogen in manure ..	18·23	18·14	13·14	13·03
Equal to ammonia	22·14	22·02	15·96	15·75
The manure contains ammonia in free state	·96	·15	·20	·11
,, ,, ammonia in form of salts, easily decomposed by quicklime	2·49	1·71	·75	·80
Total amount of organic matters	801·45	476·25	302·05	268·96
Total amount of mineral matters	158·15	213·65	186·65	238·54

It will be remarked that in the first experimental period the fermentation of the dung, as might have been expected, proceeded most rapidly, but that, notwithstanding, very little nitrogen was dissipated in the form of volatile ammonia; and that on the whole the loss which the manure sustained was inconsiderable when compared with the enormous waste to which it was subject in the subsequent warmer and more rainy seasons of the year. Thus we find at the end of April very nearly the same amount of nitrogen which is contained in the fresh; whereas, at the end of August, 27·9 per cent. of the total amount of nitrogen, or nearly one-third of the nitrogen in the manure, has been wasted in one way or the other.

It is worthy of observation that, during a well-regulated fermentation of dung, the loss in intrinsically valuable constituents is inconsiderable, and that in such a preparatory process the efficacy of the manure becomes greatly enhanced. For certain purposes fresh dung can never take the place of well-rotten dung.

The farmer will, therefore, always be compelled to submit a portion of home-made dung to fermentation, and will find satisfaction in knowing that this process, when well regulated, is not attended with any serious depreciation of the value of the manure. In the foregoing analyses he will find the direct proof that, as long as heavy showers of rain are excluded from manure heaps, or the manure is kept in waterproof pits, the most valuable fertilising matters are preserved. But let us now see how matters stand when manure heaps, the component parts of which have become much more soluble than they were originally, are exposed to heavy showers of rain.

In the first experimental period little rain fell, and this never in large quantities at a time, whilst in the interval of April and August rain was more abundant, and fell several times in continuous heavy showers. In consequence of this the soluble matters in the heap have been washed out, and with them a considerable portion of available nitrogen, and the more valuable mineral constituents of dung have been wasted.

The above analytical data, if I am not mistaken, afford likewise a proof that even in active fermentation of dung little nitrogen escapes in the form of volatile ammonia, but that this most valuable of all fertilising materials, along with others of much agricultural importance, is washed out in considerable quantities by the rain which falls on the heaps and is wasted chiefly in the drainings of the dungheaps.

A single fact, it has been truly said, is worth more than a dozen vague speculations. We hear frequently people talk of the loss in ammonia which farmyard manure undergoes on keeping, and this loss is referred by them to the volatilization of the ammonia which is produced in the putrefaction of the nitrogenized constituents of dung. I have, however, already mentioned that simultaneously with the ammonia, ulmic, humic, and other organic acids are generated from the non-nitrogenized constituents of manure, and that these acids possess the power of fixing the ammonia in an excellent manner. If this were not the case it would be difficult, if not impossible, to explain the circumstance that the proportion of soluble nitrogenized matters increased considerably in the manure on keeping for a period of six months, and that during this period the total amount of nitrogen scarcely suffered any diminution. In April the amount of nitrogen in the soluble matters of the entire heap is 6·07 lbs., and by the 23rd of August it is reduced to 3·76 lbs. Why, it may be asked, is it not likely that most of this nitrogen has passed into the air in the form of volatile ammoniacal compounds? In reply to this question I would answer that a loss taking place in this way would be felt much more sensibly in the period of active fermentation, in which, however, we have seen that scarcely any nitrogen is dissipated. In the August and November analyses, moreover, it will be observed that not only the amount of soluble organic matters, and with it that of the nitrogen, decreases, but that the soluble mineral matters, which in April amount to 57·88 lbs. in the entire heap, became reduced to 39·16 lbs. by the 23rd of August. Now, this decrease in soluble mineral substances can only be ascribed to the rain which fell in this period, and it is plain that the deteriorating influence of heavy showers of rain must equally affect the soluble nitrogenized constituents of dung. That this is really the case will appear still more conspicuously by the analysis of experimental heap No. III., to be mentioned hereafter.

It may perhaps appear strange to the reader that the total amount of dry matter in the manure is greater in November, 1855, than in August, and likewise that there is a good deal more insoluble mineral matter at the end of the experimental year than at the beginning. In explanation of these apparent inconsistencies, I would observe that the increase in insoluble mineral matters is accounted for in the difficulty of shovelling the manure into the dung-cart without mixing with it each time the weighing is made a certain portion of the soil on which the heap is placed. It must likewise be borne in mind that it is almost next to impossible to incorporate mechanical impurities so thoroughly with the dung that differences amounting to 2 or 3 per cent. in the amount of insoluble matters may not occur in the analyses of 2 samples taken from the same heap. In the percentic composition of farmyard manure such differences appear inconsiderable, but when applied to the whole heap they strike us as being great. In short, it is impossible to determine accurately the total amount of insoluble mineral matters in the whole heap. The general deductions, however, which may legitimately be made from the foregoing analyses are not in any perceptible degree affected by this unavoidable source of inaccuracy; but it is well to remember not to dwell too much on minor differences which perhaps may strike the reader; some such differences may be due to purely accidental causes.

Before I pass over to the experimental heap No. II., I would direct attention to the subjoined Table, in which I have calculated the loss or gain which the experimental heap No. I. sustained in the different constituents in the course of the year. Where there is a gain the sign * is prefixed to the number to which it applies; all numbers without this sign express loss in lbs. and in fractions of lbs. The loss for the whole heap has been calculated for 100 lbs. of fresh manure, as well as per ton.

In the columns headed per cent. thus may be seen how much of each of the constituents of fresh dung is lost by 100 lbs., cwts., or tons, in the course of 6, 9, or 12 months; whilst the columns headed loss per ton, give the loss in lbs. for every ton of fresh farmyard manure.

Table showing Loss in the different constituents of Experimental Heap, No. I., at different Periods of the Year; likewise Percentage of Loss and Loss per Ton of Fresh Manure. (N.B. The numbers preceded by the sign * express Gain and not Loss.)

	From November 3, 1854,								
	To April 30, 1855. Kept 6 Months.			To August 23, 1855. Kept 9 Months.			To November 15, 1855. Kept 12 Months.		
Loss in weight of—		Per cent.	Per ton.		Per cent.	Per ton.		Per cent.	Per ton.
Entire heap	812·	28 61	640·86	844·	29·77	666·84	864·	30·45	682·07
Water	541·8	19·09	427·61	372·6	13·12	239·88	411·4	14·49	324·57
Soluble organic matter	*16·13	*·56	*12·54	11·45	·40	8·96	16·34	·57	12·76
Soluble mineral matter	*14·17	*·49	*10·97	4·55	·16	3·58	6·82	·24	5·37
Insoluble organic matter	341·33	12·03	269·47	487·85	17·18	384·83	516·15	18·17	407·00
Insoluble mineral matter	*40·83	*1·43	*32·03	*32·55	*1·14	*25·53	*86·71	*3·05	*68·32
Containing nitrogen	*1·85	*·065	*1·456	·46	·016	·358	·57	·020	·448
Equal to ammonia	*2·25	*·079	*1·769	·56	·019	·425	·76	·026	·582
Containing nitrogen	1·94	·068	1·523	4·63	·160	3·58	4·63	·160	3·584
Equal to ammonia	2·37	·083	1·859	5·62	·19	4·25	5·63	·19	4·25
Total amount of nitrogen	·09	·003	·067	5·09	1·79	4·099	5·20	·18	4·03
Equal to ammonia	·12	·004	·089	6·18	·21	4 70	6·39	·22	4·92
Ammonia in free state	·81	·028	·627	·76	·026	·582	8·5	·029	·649
Ammonia in form of salts	·78	·027	·604	1·74	·06	1·34	1·69	·059	1·321
Total amount of organic matter	325·20	11·45	256·48	499·40	17·59	394·01	532·49	18·76	420·22
Total amount of mineral matter	*55·00	*1·92	*43·00	*28·00	*·99	*21·95	*79·89	*2·81	*62·94

Experimental Heap (No. II.), *Fresh Farmyard Manure under Shed.*—Horse, cow, and pig dung mixed.

The direct weighings were made on the same days on which the weighings of the heap exposed to the influence of the weather were executed.

The following Table contains the results of these weighings:—

Table showing the actual Weighings, and Percentage of Loss in Weight, of Experimental Heap (No. II.), fresh Farmyard Manure under Shed, at different periods of the Year.

	Weight of Manure in lbs.	Loss in Original Weight in lbs.	Percentage of Loss.
Put up on the 3rd of November, 1854 ..	3258	..	..
Weighed on the 30th of April, 1855, or after a lapse of 6 months	1613	1645	50·4
Weighed on the 23rd of August, 1855, or after a lapse of 9 months and 20 days ..	1297	1961	60·0
Weighed on the 15th of November, 1855, or after a lapse of 12 months and 12 days ..	1235	2023	62·1

Apparently the loss which the heap under shed sustained is much greater than the loss which was incurred by keeping a heap of fresh farmyard manure exposed to the influence of the weather for the same length of time. It will be seen, however, by the following analyses, that this greater loss is principally due to the evaporation of water, which, not being replaced by falling rain, is especially marked in the warmer months of the year.

This will appear from the following Table, containing the results of analyses made at the fixed experimental periods.

Table showing the Composition of Experimental Heap (No. II.), fresh Farmyard Manure under Shed, in natural state, at different periods of the Year.

	When put up. Nov. 3rd, 1854.	Feb. 14th, 1855.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Water	66·17	67·32	56·89	43·43	41·66
*Soluble organic matters	2·48	2·63	4·63	4·13	5·37
Soluble inorganic matters ..	1·54	2·12	3·38	3·05	4·43
†Insoluble organic matters ..	25·76	20·46	25·43	26·01	27·69
Insoluble mineral matters ..	4·05	7·47	9·67	23·38	20·85
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·149	·17	·27	·26	·42
Equal to ammonia	·181	·20	·32	·31	·51
†Containing nitrogen	·494	·58	·92	1·01	1·09
Equal to ammonia	·599	·70	1·11	1·23	1·31
Total amount of nitrogen ..	·643	·75	1·19	1·27	1·51
Equal to ammonia	·780	·90	1·43	1·54	1·82
Ammonia in free state	·034	·022	·055	·015	·019
Ammonia in form of salts, easily decomposed by quicklime ..	·088	·054	·101	·103	.146
Total amount of organic matters	28·24	23·09	30·06	30·14	33·06
Total amount of mineral substances	5·59	9 59	13·05	26·43	25·28

As these analytical results do not admit of comparison on account of the great variations in the amount of moisture contained in this manure at different periods, the composition of the manure in a perfectly dry state may at once be stated. (See Table, p. 49.)

These analytical results give rise to the following observations:—

1. It will be seen that the percentage of organic matter in this manure steadily diminishes the longer the manure is kept, whilst the percentage of mineral matters rises in a corresponding degree.

2. The decrease in organic substances, however, is much less considerable than in the heap No. I., which had been exposed to the influence of the weather.

3. It will likewise be observed that the percentage of soluble

Table showing the Composition of Experimental Heap (No. II.), fresh Farmyard Manure under Shed, calculated dry, at different periods of the Year.

	When put up. Nov. 3rd, 1854.	Feb. 14th, 1855.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
*Soluble organic matters	7·33	8·04	10·74	7·30	9·20
Soluble inorganic matters ..	4·55	6·48	7·84	5·39	7·59
†Insoluble organic matters ..	76·15	62·60	58·99	45·97	47·46
Insoluble mineral matters ..	11·97	22·88	22·43	41·34	35·75
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·44	·53	·63	·46	·72
Equal to ammonia	·53	·66	·76	·56	·88
†Containing nitrogen	1·46	1·77	2·14	1·78	1·88
Equal to ammonia	1·77	2·14	2·59	2·16	2·20
Total amount of nitrogen ..	1·90	2·30	2·77	2·24	2·60
Equal to ammonia	2·30	2·80	3·35	2·72	3·08
Ammonia in free state	·10	·067	·127	·026	·032
Ammonia in form of salts, easily decomposed by quicklime ..	·26	·165	·234	·182	·250
Total amount of organic matters	83·48	70·64	69·73	53·27	56·66
Total amount of mineral substances	16·52	29·36	30·27	46·73	43·34

organic and mineral substances increases, up to the 30th of April, with the time during which the heap has been kept under shed; but that this increase is not so great as in the experimental heap No. I.

4. The proportion of free ammonia, and of ammonia contained in salts which are readily decomposed by quicklime, perceptibly decreases on keeping of the manure.

5. The total amount of nitrogen, on the contrary, perceptibly increases in the several experimental periods.

6. The amount of nitrogen in the soluble organic matters slightly, but regularly, increases with the time during which the manure is kept; and the same remark applies to the nitrogen in the insoluble organic matters.

7. The August analysis exhibits a very much larger percentage of insoluble inorganic substances than the April analysis, and even than the analysis made on the 15th of November, 1855.

It is evident that the sample taken for analysis on the 23rd of August contained a considerable amount of mechanical impurities, which spoil, to some extent, the general results. In a minor degree this source of error will be perceived in the November analysis (November 15th, 1855). If, however, due allowance be made for this evident admixture of accidental earthy matters, the analysis made in August and in November, 1855, will be found to correspond perfectly in their general bearings with the other analyses. Having obtained the results by carefully executed analyses, I did not feel justified in introducing corrections, even in case such corrections seemed desirable to be made. A critical mind will derive from the two last analyses as much instruction as from the three preceding. They afford, at the same time, a direct proof of the necessity of not being satisfied with one or two analyses in researches of this kind, and show that trustworthy deductions can be derived only from a series of carefully conducted analyses. It is too often the case that corrections are introduced into analyses which cannot always be referred to plain and evident disturbing causes; and as such a course, if tolerated, opens at once the door to abuse, I have ever set my face against such a practice, and therefore prefer to state my results as I get them, whether or not they agree with others.

The preceding analyses furnish plain evidence that the constituents of the manure under shed have become far less altered in composition than in the case of the experimental heap No. II. And, indeed, the physical condition of the heap under shed affords a convincing proof of the fact that fresh farmyard manure does not properly ferment when it is kept under cover, and the water, which constantly evaporates from its surface, is not replaced by pumping occasionally water or liquid manure over the heap.

The fermentation, however, of the dung cannot be entirely prevented by this mode of treatment. As might have been expected, fermentation is more perceptible in the first experimental periods than in the succeeding. By the time the percentage of water in this manure had become reduced to 56 per cent., practically speaking a stop was put to further fermentation, and the manure remained very much in the same condition, at the end of the experimental year, in which it was found at the end of April.

In the next Table the composition of the whole heap under shed, as calculated from the preceding analyses, is given (p. 51).

A reference to the Table will show that the loss incurred in keeping of fresh farmyard manure under cover is greatest in the first experimental period, and that this loss principally affects the insoluble organic matter. Thus, when put under cover, the whole heap contained, in round numbers, 839 lbs. of insoluble organic substances, whilst after a lapse of six months only 410 lbs. were left over. One half of the total amount of insoluble organic matters thus has been dissipated, in the form of carbonic acid and other gaseous products of decomposition, in the course

Table showing Composition of entire Experimental Heap (No. II.), fresh Farmyard Manure, under Shed.

	When put up. Nov. 3rd, 1854.	April 30th, 1855	Aug. 23rd, 1855.	Nov. 15th, 1855.
Weight of manure	3258	1613	1297	1235
Amount of water in the manure	2156·	917·6	563·2	514·5
Amount of dry matter	1102·	695·4	733·8	720·5
Consisting of—				
*Soluble organic matter	80·77	74·68	53·56	66·28
Soluble mineral matter	50·14	54·51	39·55	54·68
†Insoluble organic matter	839·17	410·24	337·32	341·97
Insoluble mineral matter	131·92	155·97	303·37	257·57
	1102·	695·4	733·8	720·5
*Containing nitrogen	4·85	4·38	3.46	5.25
Equal to ammonia	5·88	5·33	4·20	6·37
†Containing nitrogen	16·08	14·88	13·08	13·54
Equal to ammonia	19·52	17·46	15·88	16·44
Total amount of nitrogen in manure ..	20·93	19·26	16·54	18·79
Equal to ammonia	25·40	22·79	20·08	22·81
The manure contains ammonia in free state	1·10	·88	·19	·23
,, ,, ammonia in form of salts, easily decomposed by quicklime	2·86	1·62	1·33	1·80
Total amount of organic matters	919·94	484·92	390·88	408·25
Total amount of mineral matters	182·06	210·48	342·92	312·35

of six months. Or, calculating the loss in dry matter, for the whole manure-heap in a dry state, we find that 100 parts of the dry manure have lost, under cover, about 37 per cent. in solid matters. The dissipation of organic matter is not attended with any great loss in nitrogen, for it will be observed that the entire heap contained in November, 1854, when first put up, 20·93 lbs. of nitrogen, and on the 30th of April, 19·26 lbs.; consequently, about 1½ lb. of nitrogen only escaped, in one way or the other, during this period.

It would appear that this inconsiderable amount of nitrogen escaped by evaporation, in the form of volatile carbonate of ammonia; for the differences exhibited by the November and April analyses, in the proportion of free ammonia and ammonia in form of salts readily decomposed by quicklime, very nearly correspond with a loss of about 1½ lb. of nitrogen.

Perhaps it may appear strange that the manure-heap No. I., which was exposed to the weather, lost less nitrogen, in the form of ammonia, during the first six months than the heap under cover. But this apparent anomaly finds a ready explanation in the fact that during an active fermentation organic acids are formed which fix the ammonia, while the same acids are not so readily produced in the absence of the requisite amount of moisture.

At the same time it should be borne in mind that ammonia escapes more readily from a partially-dried substance than one saturated with moisture; and as the manure-heap under shed on keeping became much drier than the heap exposed to the weather, the free ammonia had a better chance of being dissipated into the air.

The August and November, 1855, analyses on account of the accidental impurities, do not give a fair representation of the changes which may have taken place during these periods.

There should be of course the same total amount of mineral matters at the end of the experimental year which occurs in the manure when first placed under cover. Omitting the fractions we have in November, 1855, 182 lbs. of mineral matters, and on the 30th of April, 210 lbs., or a difference which is not greater than might have been expected in two analyses of the same sample of manure.

But assuming the samples, which have been taken for the August and November analyses, to represent fairly the composition of the whole heap, we would have no less than 343 lbs. of mineral matters in August, and 312 lbs. the following November. Now this cannot be the case, and it is therefore plain that the excess of mineral matters must be due to accidental admixture of dirt to the dung. Such an admixture of course will reduce the amount of nitrogen and organic matters in the analyses: but if a correction be made for this palpable inaccuracy it will be found that after the 30th of April the heap under shed sustained but a very trifling loss in nitrogen and organic matters.

Leaving the reader to make this calculation for himself, I append a Table which will furnish the data for similar calculations (p. 53).

Experimental Heap (No. III.), *fresh Farmyard Manure, spread in an open Yard.*—Mixed horse, cow, and pig dung.

Having furnished the reader with a complete analysis of each experimental heap with the exception of the manure spread out in an open yard, I thought it desirable to submit the manure No. III., the originally fresh farmyard manure, to a complete organic and inorganic analysis, after it had been exposed to the influence of rain, sun, and wind for a period of six months. The results of this examination are incorporated in the following Tables.

Table showing Loss in the different component parts of Experimental Heap, No. II., at different periods of the Year; likewise Percentage of Loss and Loss per Ton of Fresh Manure.

(N.B. The numbers preceded by the sign * express Gain instead of Loss.)

	From November 3, 1854,								
	To April 30, 1855. Kept 6 Months.			To August 23, 1855. Kept 9 Months.			November 15, 1855. Kept 12 Months.		
		Per cent.	Per ton.		Per cent.	Per ton.		Per cent.	Per ton.
Loss in weight of—									
Entire heap	1645·	50·49	1130·97	1961·	60·19	1348·25	2023·	62·09	1390·81
Water	1238·4	38·	851·20	1592·8	48·88	1094·91	1641·5	50·35	1127·84
*Soluble organic matter	6·09	·18	4·03	27·21	·83	18·59	14·46	·44	9·85
Soluble mineral matter	*4·37	*·13	*2·91	10·59	·32	7·16	*4·54	*·14	*3·13
†Insoluble organic matter	428·93	13·16	294·78	501·85	15·40	344·96	497·2	15·26	341·82
Insoluble mineral matter	*24·05	*·73	*16·35	*171·45	*5·26	*117·82	*125·65	*3·85	*86·24
*Containing nitrogen	·47	·014	·31	1·39	·042	·94	*·40	*·012	*·26
Equal to ammonia	·55	·016	·35	1·68	·051	1·14	*·49	*·015	*35
†Containing nitrogen	1·20	·036	·80	3·00	·092	2·06	2·54	·078	1·74
Equal to ammonia	2·06	·063	1·41	3·64	·111	2·48	3·08	·094	2·10
Total amount of nitrogen	1·67	·051	1·14	4·39	·134	3·00	2·14	·065	1·45
Equal to ammonia	2·61	·080	1·79	5·32	·163	3·65	2·59	·079	1·76
Ammonia in free state	·22	·006	·13	·91	·027	·60	·87	·026	·58
Ditto in form of salts	1·24	·03	·67	1·53	·046	1·03	1·06	·032	·71
Total amount of organic matter	435·02	13·34	298·81	529·06	16·23	363·55	511·69	15·70	351·67
Ditto mineral matter	*28·42	*86	*19·25	*160·86	*4·94	*110·66	*130·19	*3·99	*89·37

Fresh Farmyard Manure (No. III.), *Spread in open Yard.*

Taken for Analysis, April 30, 1855.

(*a.*) *Composition of Manure in Natural State.*

Water		80·02
* Soluble organic matter		1·16
Soluble inorganic matter (ash) :—		
Soluble silica	·211	
Phosphate of lime	·194	
Lime	·005	
Magnesia	·008	
Potash	·365	
Soda	·037	
Chloride of sodium	·004	
Sulphuric acid	·041	
Carbonic acid and loss	·145	
		1·01
† Insoluble organic matter		11·46
Insoluble inorganic matter :—		
Soluble silica	·955	
Insoluble silicious matter	1·101	
Oxide of iron and alumina, with phosphates	·622	
Containing phosphoric acid	(·177)	
Equal to bone earth	(·276)	
Carry forward		93·65

Brought forward		93·65
Lime	1·964	
Magnesia	·082	
Potash	·052	
Soda	·009	
Sulphuric acid	·066	
Carbonic acid and loss	1·499	
		6·35
		100·00

* Containing nitrogen	·08
Equal to ammonia	·09
† Containing nitrogen	·45
Equal to ammonia	·54
Whole manure contains amm. in free state per cent.	·010
" " in form of salts	·045

(*b.*) *Composition of the same Manure in dry state.*

* Soluble organic matter		5·80
Soluble inorganic matter (ash):—		
Soluble silica	1·05	
Phosphate of lime	1·07	
Lime	·02	
Magnesia	·04	
Potash	1·82	
Soda	·18	
Chloride of sodium	·02	
Sulphuric acid	·20	
Carbonic acid and loss	·65	
		5·05
† Insoluble organic matter		57·37
Insoluble inorganic matter (ash):—		
Soluble silica	4·78	
Insoluble silica	5·51	
Oxide of iron and alumina, with phosphates	3·11	
Containing phosphoric acid	(·89)	
Equal to bone earth	(1·00)	
Lime	9·83	
Magnesia	·41	
Potash	·27	
Soda	·06	
Sulphuric acid	·33	
Carbonic acid and loss	7·48	
		31·78
		100·00

* Containing nitrogen	·42
Equal to ammonia	·51
† Containing nitrogen	2·28
Equal to ammonia	2·76
Whole manure contains amm. in free state per ct.	·05
" " in form of salts	·225

(*c.*) *Composition of Ash of portion insoluble in Water.*

Soluble silica	15·05
Insoluble silicious matter (sand)	17·35
Oxides of iron and alumina, with phosphates	9·80
Containing phosphoric acid	(2·80)
Equal to bone earth	(4·36)
Lime	30·94
Magnesia	1·30
Potash	·87
Soda	·02
Sulphuric acid	1·05
Carbonic acid and loss	23·62
	100·00

Composition of Ash of portion soluble in Water.

Soluble silica	20·93
Phosphate of lime	19·29
Lime	·50
Magnesia	·82
Potash	36·21
Soda	3·69
Chloride of sodium	·41
Sulphuric acid	4·10
Carbonic acid and loss	14·05
	100·00

No. IV. spread out.

Taken for Analysis, April 39, 1855.

Composition of mixed Ash.

			Arranged together.
Soluble in Water, 13·73 per cent.	Soluble silica	2·87	
	Phosphate of lime	2·64	
	Lime	·06	
	Magnesia	·11	
	Potash	4·97	
	Soda	·50	
	Chloride of sodium	·05	
	Sulphuric acid	·50	
	Carbonic acid and loss	2·03	
Insoluble in Water, 86·27 per cent.	Soluble silica	13·05	15·90
	Insoluble silica	14·96	14·96
	Phosphate of lime	..	2·64
	Oxides of iron and alumina with phosphates	8·45	8·45
	Containing phosphoric acid	(2·41)	(2·41)
	Equal to bone earth	(3·76)	(3·76)
	Lime	26·69	26·75
	Magnesia	1·12	1·23
	Potash	·75	5·72
	Chloride of sodium	..	·05
	Soda	·02	·52
	Sulphuric acid	·90	1·40
	Carbonic acid and loss	20·35	22·38
		100·00	100·00

Leaving any remarks on the organic composition of the manure until the general composition at the different experimental periods has been stated, I shall offer in this place merely a few observations on the differences which will be perceived on comparing the ash analyses of the fresh manure with those that have just been given.

1. In the first place it will be seen that the proportion of soluble fresh ash is very much greater in the manure, when the experiment was taken in hand on the 3rd of November, than after a lapse of 6 months, during which the manure was spread out in an open yard and exposed to the deteriorating influence of the weather. Thus we find—

	In fresh Manure, analysed Nov. 3, 1855.	The same Manure, analysed April 30, 1855.
Soluble ash	27·55	13·73
Insoluble ash	72·45	86·27
	100·00	100·00

We have thus here a clear proof that the rain which falls on the manure kept in an open yard, rapidly deteriorates its value by removing from it a very considerable proportion of the most valuable saline constituents.

2. On comparing the insoluble ash of the fresh manure with the corresponding portion of the ash of the manure after having been exposed in an open yard to the weather, it will be seen that there is a much larger proportion of insoluble silicious matter in the April analysis, but less potash and only about half the amount of phosphate of lime which is contained in the insoluble ash of the same manure before it had been spread out in an open yard.

3. The soluble portion of the ash of this manure in April contains, it will be seen, more soluble silica and sulphuric acid than the soluble ash of the manure in November, 1855.

4. The influence of rain on manure spread out in an open yard is best seen by comparing the composition of the whole ash of the manure, analysed in April, with the analysis of the whole ash of the manure in a perfectly fresh state.

In the whole ash of the April manure is less soluble silica, less potash, and much less phosphate of lime, than in the ash of the manure in a fresh state. The most soluble, and at the same time most valuable fertilizing substances thus are washed out by falling rain, and consequently an ash richer in lime and insoluble matters is left on burning the manure on the 30th of April. The actual loss in weight which this experimental heap sustained in the year, is given in the following Table.

Table showing the actual Loss in Weight, and Percentage of Loss in Weight, of Experimental Heap (No. III.), fresh Farmyard Manure, spread, at different periods of the Year.

	Weight of Manure in lbs.	Loss in Original Weight in lbs.	Percentage of Loss.
Put up on the 3rd of November, 1854	1652	..	..
Weighed on the 30th of April, 1855, or after a lapse of 6 months	1429	223	13·4
Weighed on the 23rd of August, 1855, or after a lapse of 9 months and 20 days	1012	640	38·7
Weighed on the 15th of November, 1855, or after a lapse of 12 months and 12 days	950	702	42·4

The loss in weight on the 30th of April, thus amounted to only 13½ per cent.; but as rain had fallen shortly before the weighing was made in April, the real loss in valuable fertilizing matters is much greater than indicated by the direct weighing. This will appear clearly when the composition of the entire quantity of the manure spread in the open yard shall have been stated. Before doing this, however, I shall endeavour to explain the alterations which the spread manure underwent in the course of the experimental year.

The third series of analyses, incorporated in the subjoined Table, I trust will afford a sure guide in drawing satisfactory conclusions.

Table showing Composition of Experimental Heap (No. III.), fresh Farmyard Manure, spread in open yard, at different periods of the Year. In natural state.

	When put up. Nov. 3rd, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Water	66·17	80·02	70·09	65·56
*Soluble organic matters	2·48	1·16	·49	·42
Soluble inorganic matters	1·54	1·01	·64	·57
†Insoluble organic matters	25·76	11·46	10·56	9·94
Insoluble mineral matters	4·05	6·35	18·22	23·51
	100·00	100·00	100·00	100·00
*Containing nitrogen	·149	·08	·06	·03
Equal to ammonia	·181	·09	·07	·036
†Containing nitrogen	·494	·45	·35	·36
Equal to ammonia	·599	·54	·42	·46
Total amount of nitrogen	·643	·53	·41	·39
Equal to ammonia	·780	·63	·49	·496
Ammonia in free state	·034	·010	·012	·0006
Ammonia in form of salts, easily decomposed by quicklime	·088	·045	·051	·030
Total amount of organic matters	28·24	12·62	11·05	10·36
Total amount of mineral substances	5·59	7·36	18·86	24·08

It will be observed that this manure contained, on the 30th of April, 14 per cent. more water than when first spread out in the yard. The fact was, that a day before it was analysed and weighed, a good deal of rain had fallen, which of course thoroughly drenched the manure spread about in the yard, whilst it did not thoroughly saturate with moisture the experimental heap No. I. There is thus less moisture in the heap No. I. than in the manure spread out.

By the 23rd of August a great deal of moisture had evaporated, and on the 15th of November very nearly the same proportion of moisture was found which the manure originally contained. We can therefore compare the first with the last analysis without committing any great error, and shall find, on such a comparison, the following interesting particulars:—

1. At the end of the experiment the manure contained, instead of 2½ per cent., not quite ½ per cent. of soluble organic matters.

2. The insoluble organic matters in the course of the year became reduced from 25·7 per cent. to 10 per cent.

3. The soluble nitrogenized constituents appear to have been washed out almost completely, since at the conclusion of the experiment the manure contained only ·03 per cent., or a mere trace of nitrogen.

4. The total percentage of nitrogen in the manure has become considerably diminished in the manure analysed in November, 1855.

The fertilizing value of the manure spread out in an open yard thus became deteriorated by keeping far more considerably than any other of the experimental heaps.

Before offering any further remarks on the experiments with this manure, a Table (p. 59) stating the composition of the manure in a dry state may find here a convenient place.

The analytical data incorporated in this Table are extremely interesting and practically important, inasmuch as they show to what extent farmyard manure may become deteriorated in value by slovenly practice, and how rapidly the most valuable fertilizing constituents are removed by the rain which falls upon the manure.

It will be perceived that the loss in valuable substances is especially great in the warmer months of the year, but I believe it is not so much due to the more elevated temperature that the manure becomes deteriorated, as to the heavy showers of rain which fall in the summer months.

On comparing the amount of the different constituents of the manure in the various experimental periods, it will be observed that all the manuring constituents, with the exception of the insoluble mineral matters, rapidly diminish, so that at last but a

Table showing Composition of Experimental Heap (No. III.), fresh Farmyard Manure, spread, at different periods of the Year. Calculated dry.

	When put up. Nov. 3rd, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
*Soluble organic matters	7·33	5·80	1·64	1·21
Soluble inorganic matters	4·55	5·05	2·14	1·69
†Insoluble organic matters	76·15	57·37	35·30	28·86
Insoluble mineral matters	11·97	31·78	60·92	68·24
	100·00	100·00	100·00	100·00
*Containing nitrogen	·44	·42	·20	·10
Equal to ammonia	·53	·51	·24	·12
†Containing nitrogen	1·46	2·28	1·17	1·09
Equal to ammonia	1·77	2·76	1·41	1·32
Total amount of nitrogen	1·90	2·70	1·37	1·19
Equal to ammonia	2·30	3·27	1·65	1·44
Ammonia in free state	·10	·05	·040	·0017
Ammonia in form of salts, easily decomposed by quicklime	·26	·225	·171	·087
Total amount of organic matters	83·48	63·17	36·94	30·07
Total amount of mineral substances ..	16·52	36·83	63·06	69·93

small proportion of the original fertilizing matters is left behind.

Thus the soluble organic matters sink from 7·33 per cent. to 5·8 per cent. in the course of six months, to 1·64 per cent. in nine months, and to 1·21 per cent. in twelve months. With this loss in soluble organic matters the percentage of nitrogen, present in the form of soluble compounds, gradually sinks from ·44 per cent. to ·10 per cent. That this loss in nitrogen is not entirely due to the evaporation of ammonia, is shown by the simultaneous diminution of the amount of soluble inorganic matters, which became reduced from 4·55 per cent. to 1·69.

Still more conspicuous is the loss in insoluble organic matters. Thus we have in the fresh dry manure 76·15 per cent. of insoluble organic matters. After a lapse of six months only 57·37 per cent. are left behind; after nine months but 35·3 per cent., and after twelve months merely 28·86 per cent.

Similar striking differences in the composition of the manure at the stated periods will manifest themselves on an attentive perusal of the foregoing tabulated analytical results. They all tend to prove the enormous waste which is incurred by keeping for a lengthy period farmyard manure exposed in thin layers to the influence of the weather. But I must hasten to ascertain the precise loss in the various constituents which this manure sustained in the course of a year.

This loss will become apparent by an inspection of the following Table, in which is stated the composition of the entire mass of the experimental manure No. III.

Table showing Composition of entire mass of Experimental Manure (No. III.), fresh Farmyard Manure, spread. In Natural State. Expressed in lbs. and fractions of lbs.

	When put up. Nov. 3rd, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Weight of manure	1652·	1429·	1012·	950·
Amount of water in the manure	1093·	1143·	709·3	622·8
Amount of dry matter	559·	285·5	302·7	327·2
Consisting of—				
*Soluble organic matter	40·97	16·55	4·96	3·95
Soluble mineral matter	25·43	14·41	6·47	5·52
†Insoluble organic matter	425·67	163·79	106·81	94·45
Insoluble mineral matter	66·93	90·75	184·46	223·28
	559·00	285·50	302·70	327·20
*Containing nitrogen	3·28	1·19	·60	·32
Equal to ammonia	3·98	1·44	·73	·39
†Containing nitrogen	6·21	6·51	3·54	3·56
Equal to ammonia	7·54	7·90	4·29	4·25
Total amount of nitrogen in manure ..	9·49	7·70	4·14	3·88
Equal to ammonia	11·52	9·34	5·02	4·64
The manure contains ammonia in free state	·55	·14	·13	·0055
,, ,, ammonia in form of salts, easily decomposed by quicklime	1·45	·62	·55	·28
Total amount of organic matters	466·64	180·34	111·77	98·40
Total amount of mineral matters	92·36	105·16	190·93	228·80

This Table requires an explanatory notice. It will be observed that the amount of insoluble mineral matters in the manure increases greatly in every succeeding experimental period. Especially it is great in November, 1855. This increase is due entirely to accidental admixtures of earthy matters, which could not be excluded without losing some of the manure. It was found, namely, impossible to collect the manure properly without mixing with it some of the soil over which it was spread. On the 23rd of August, 1855, the manure had shrunk to a very small bulk, and on the 15th of November, 1855, the greater portion of the manure appeared to have gone either into the air or to have been washed into the soil. It was necessary therefore to scrape the soil as close as possible in order not to lose any of the manure, and it is due to this circumstance that at the conclusion of the experiment a very much larger proportion of insoluble mineral substances was found than in the perfectly fresh manure. I may mention, however, that the whole mass of the spread manure has been most carefully mixed before a sample was taken for analysis. The earthy matters I have every reason to believe were intimately mixed with the manure; and since the composition of the entire mass has been calculated from the data already furnished, the general deductions which may be derived from my experiments are not affected by this circumstance. In speaking of the loss which this manure sustained in keeping, I will select the more important fertilizing constituents for illustration, and in reference to them beg to make the following observations:—

1. The weight of the whole manure, when spread out in an enclosed yard, amounted to 1652 lbs. In this quantity were present 40·97, or nearly 41 lbs. of soluble organic matters. After the lapse of six months only 16½ lbs. were left in the manure; in nine months barely 5 lbs., and after twelve months merely 4 lbs.

Thus only about 1-10th part of the original quantity of soluble organic matters was left over by keeping fresh farmyard manure spread out in an open yard.

2. The nitrogen contained in the 41 lbs. of soluble organic matters amounted to 3·28 lbs. After six months only 1·19 lbs. of nitrogen, in the state of soluble compounds, was left; after nine months little more than ½ lb., and after twelve months only ⅓ of a lb. In other words, the nitrogen in the state of soluble compounds has disappeared almost entirely in the course of a year.

3. In an equally considerable degree the soluble mineral matters were dissipated in the manure. Originally the manure contained 25·43 lbs. of soluble mineral matters. After six months this quantity became reduced to 14·41 lbs.; after nine months to to 6·47 lbs., and after a lapse of twelve months to 5·52 lbs.

On the whole the manure thus lost 78·2 per cent. of the original quantity of soluble mineral matters.

4. Still more striking is the loss in insoluble organic matters. In the fresh manure were present 425·67 lbs. of insoluble organic substances. In the course of six months these became reduced to 163·79 lbs.; a further exposure of rather more than three months to the weather reduced this quantity to 106·81 lbs., and after twelve months merely 94·45 lbs. were left over. The manure lost thus no less than 77·7 per cent. of the original quantity of insoluble organic matters.

5. If we look to the total amount of nitrogen, we shall find that the original proportion of nitrogen in the manure, amounting to 9·49 lbs., was reduced in the course of six months to 7·70 lbs., after nine months to 4·14 lbs., and after twelve months to 3·88 lbs.

At the conclusion of the experiment more than half the quantity, or, in exact numbers, 59·1 per cent. of the nitrogen contained in the fresh manure, was wasted.

6. If we replace, in the analysis made on the 15th November, 1855, the number which expresses the amount of insoluble mineral matters by the number 66·93, expressing the proportion of insoluble mineral matters which the manure contained at the commencement of the experiment, and which it would have also contained had no earthy matters been mixed up with the manure, and add to it the other constituents, we obtain for the corrected composition of the whole manure in November, 1855, the following numbers, which for comparison's sake are contrasted with the analysis of the fresh manure of November, 1854:—

	When put up, Nov. 3, 1854. lbs.	At conclusion of experiment, Nov. 15, 1855. lbs.
Weight of the manure	1652	950
Amount of water in the manure	1093	622·8
,, dry substances	559	170·85
Consisting of:—		
Soluble organic matters	40·97	3·95
*Soluble mineral matters	25·43	5·52
†Insoluble organic matters	425·67	94·45
Insoluble mineral matters	66·93	66·93
	559·00	170·85
* Containing nitrogen	3·28	·32
Equal to ammonia	3·98	·39
† Containing nitrogen	6·21	3·56
Equal to ammonia	7·54	4·25
Total amount of nitrogen in manure	9·49	3·88
Equal to ammonia	11·52	4·64
The whole manure contained:—		
Ammonia in free state	·55	·0055
Ammonia in form of salts readily decomposed by quicklime	1·45	·28
Total amount of organic matters	466·64	98·40
,, mineral matters	92·36	72·45

It will hence appear from these results that the experiment was begun with 559 lbs. of dry manure; after the lapse of twelve months, only 170·85 lbs. were left behind. Kept for this length of time spread in an open yard, the manure thus lost no less than 69·8 per cent. in fertilizing matters; or, in round numbers, *two-thirds of the manure were wasted, and only one-third was left behind.* This fact teaches a most important lesson, and speaks for itself so forcibly that any further comment appears to me useless. In conclusion of this third series of experiments, I may, however, give a Table which may be found useful in calculating the loss in the various fertilizing matters in any given quantity of farmyard manure kept in a similar manner, in which the experimental manure No. III. was kept.

Table showing Loss in the different component parts of Experimental Heap, No. III., Fresh Farmyard Manure (No. III.), Spread, at different periods of the Year; also Percentage of Loss and Loss per Ton of Fresh Manure.—Quantities stated in lbs. and Fractions of lbs. (N.B. The sign * prefixed to a number indicates Increase instead of Loss.)

	From November 3, 1854,								
	To April 30, 1855. Kept 6 Months.			To August 23, 1855. Kept 9 Months.			To November 15, 1855. Kept 12 Months.		
Loss in weight of—		Per cent.	Per ton.		Per cent.	Per ton.		Per cent.	Per ton.
Entire heap	223·	13·49	296·77	640·	38·74	867·77	702·	42·49	951·77
Water	*50·	*3·02	*67·64	383·7	23·22	520·12	470·20	28·46	637·50
Soluble organic matter	24·42	1·47	32·92	36·01	2·18	48·83	37·02	2·24	50·17
Soluble mineral matter	11·02	·66	14·78	18·96	1·14	25·53	19·91	1·20	26·88
Insoluble organic matter	261·88	15·85	355·04	318·86	19·29	432·09	331·22	20·05	449·12
Insoluble mineral matter	*23·82	*1·44	*32·25	*117·54	*7·11	*159·26	*156·36	*9·40	*210·56
Containing nitrogen	2·09	·12	2·68	2·68	·16	3·58	2·96	·18	4·03
Equal to ammonia	2·54	·15	3·36	3·25	·19	4·25	3·59	·21	4·70
Containing nitrogen	*·30	*·018	*·40	2·67	.16	3·58	2·65	·16	3·58
Equal to ammonia	*·36	*·021	*·50	3·25	·19	4·25	3·29	·19	4·25
Total amount of nitrogen	1·79	·102	2·28	5·35	·32	7·16	5·61	·34	7·61
Equal to ammonia	2·18	·129	2·95	6·50	·38	8·51	6·88	·41	9·18
Ammonia in free state	·41	·024	·53	·42	·025	·56	·5445	·033	·73
Ditto in form of salts	·83	·050	1·12	·90	·050	1·12	1·17	·07	1·56
Total amount of organic matter	286·30	17·32	387·96	354·87	21·47	480·92	368·24	22·29	499·29
Ditto mineral matter	*12·80	*·78	*17·47	*98·57	*5·97	*133·73	*136·44	*8·25	*184·80

Experimental Heap (No. IV.), *Well-rotten Dung, Exposed.*—Mixed horse, cow, and pig manure.

The fourth and last series of experiments was begun on the 5th of December, 1854, with a view of ascertaining whether or not well-rotten manure is deteriorated in value more rapidly than fresh dung, produced by the same description of animals. The weighings were made on the same days on which the weight of the three preceding experimental heaps were ascertained. In the following Table the results of the direct weighings are stated:

Table showing the Weights of Experimental Heap (No. IV.), Well-rotten Dung, Exposed, and Percentage of Loss.

	Weight of Manure in lbs.	Loss in Original Weight in lbs.	Percentage of Loss.
Put up on the 5th of December, 1854	1613	..	..
Weighed on the 30th of April, 1855, or after a lapse of 4 months and 25 days	1186	427	26·5
Weighed on the 23rd of August, 1855, or after a lapse of 8 months and 18 days ..	1023	590	36·5
Weighed on the 15th of November, 1855, or after a lapse of 11 months and 10 days ..	1003	610	37·8

Analysed at the same periods at which the weighings were made, the following results were obtained:—

Table showing Composition of Experimental Manure (No. IV.), Well-rotten Dung, Exposed. In natural state.

	When put up. Dec. 5th, 1854.	Feb. 14th, 1855.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Water	75·42	73·90	68·93	72·25	71·55
*Soluble organic matters	3·71	2·70	2·21	1·50	1·13
Soluble inorganic matters ..	1·47	2·06	1·68	1·10	1·04
†Insoluble organic matters ..	12·82	14·39	15·87	12·46	12·35
Insoluble mineral matters ..	6·58	6·95	11·31	12·69	13·93
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·297	·149	·14	·090	·09
Equal to ammonia	·360	·180	·17	·109	·11
†Containing nitrogen	·309	·610	·76	·490	·56
Equal to ammonia	·375	·740	·92	·600	·69
Total amount of nitrogen ..	·606	·759	·90	·580	·65
Equal to ammonia	·735	·920	1·09	·709	·80
Ammonia in free state	·046	·015	·006	·013	·003
Ammonia in form of salts, easily decomposed by quicklime ..	·057	·048	·044	·040	·029
Total amount of organic matters	16·53	17·09	18·08	13·96	13·48
Total amount of mineral substances	8·05	9·01	12·99	13·79	14·97

It will be seen that at the conclusion of the experiment the manure contained about 4 per cent. less moisture than it did at the beginning. In each experimental period the percentage of water was different, and consequently the direct weighings do not represent accurately the percentage of real loss. In the next Table is given the composition of the same manure, calculated dry.

Table showing Composition of Experimental Manure (No. IV.), Well-rotten Dung, Exposed, at different periods of the Year. In dry state.

	When put up. Dec. 5th, 1854.	Feb. 14th, 1855.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
*Soluble organic matters	15·09	10·34	7·11	5·41	3·99
Soluble inorganic matters ..	5·98	7·89	5·41	3·96	3·67
†Insoluble organic matters ..	52·15	55·13	51·08	44·90	43·39
Insoluble mineral matters ..	26·78	26·64	36·40	45·73	48·95
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	1·21	·57	·45	·32	·32
Equal to ammonia	1·47	·69	·54	·39	·39
†Containing nitrogen	1·26	2·35	2·44	1·76	1·98
Equal to ammonia	1·53	2·85	2·96	2·16	2·40
Total amount of nitrogen ..	2·47	2·92	2·89	2·08	2·30
Equal to ammonia	3·00	3·54	3·50	2·55	2·79
Ammonia in free state	·189	·057	·018	·047	·012
Ammonia in form of salts, easily decomposed by quicklime ..	·232	·183	·137	·144	·104
Total amount of organic matters	67·24	65·47	58·19	50·31	47·38
Total amount of mineral substances	32·76	34·53	41·81	49·69	52·62

It will appear from these analyses that in well-rotten farmyard manure the soluble constituents are more readily wasted than is the case with fresh dung kept in the same manner. On the other hand, the percentage of insoluble organic matters, practically speaking, sustained no diminution by keeping the manure in a heap exposed to the weather from December 5th, 1854, to April 30th, 1855. In the two succeeding periods, embracing the warmer months of the year, an appreciable loss in the insoluble organic matters appears to have taken place; and it is in the two last periods that the soluble constituents have been wasted more abundantly than in the preceding months.

The nature of this loss will become more conspicuous if we calculate from the foregoing data the composition of the whole experimental heap No. IV. This has been done in the subjoined Table :—

Table showing Composition of Whole Heap (No. IV.), Well-rotten Dung, Exposed. In Natural State. Expressed in lbs. and fractions of lbs.

	When put up. Dec. 5th, 1854.	April 30th, 1855.	Aug. 23rd, 1855.	Nov. 15th, 1855.
Weight of manure	1613·	1186·	1023·	1003·
Amount of water in the manure	1216·5	818·	739·1	737·7
Amount of dry matter	396·5	368·	283·9	285·3
Consisting of—				
*Soluble organic matter	59·83	26·16	15·35	11·38
Soluble mineral matter	23·71	19·90	11·24	10·47
†Insoluble organic matters	206·77	187·97	127·47	123·79
Insoluble mineral matters	106·19	133·97	129·84	139·66
	396·5	368·	283·9	285·30
*Containing nitrogen	4·79	1·73	·90	·92
Equal to ammonia	5·81	2·10	1·09	1·11
†Containing nitrogen	4·99	8·99	4·99	5·65
Equal to ammonia	6·08	10·91	6·06	6·89
Total amount of nitrogen in manure ..	9·78	10·72	5·89	6·57
Equal to ammonia	11·89	13·01	7·15	8·00
The manure contains ammonia in free state	·74	·066	·13	·034
,, ,, ammonia in form of salts, easily decomposed by quicklime	·92	·50	·40	·29
Total amount of organic matters	266·60	214·13	142·82	135·17
Total amount of mineral matters	129·90	153·87	141·08	150·13

A careful comparison of these analytical results will show :—

1. That well-rotten dung loses little in substance during the colder months of the year, provided no heavy rain falls. Should there be continued rainy weather, the result, I have no doubt, would be different from that obtained in my experiments.

2. In the warmer months of the year rotten dung decreases in bulk and in weight more rapidly than in the colder seasons of

3. The loss which well-rotten dung sustains affects principally the soluble constituents.

4. Although rotten dung diminishes less in weight than fresh dung kept in the same manner for the same length of time, yet rotten dung is more readily deteriorated in intrinsic value than fresh. This arises from the circumstance that in rotten dung the proportion of soluble matters is much larger than in fresh. Thus it will be seen that from 59·83 lbs. of soluble organic substances originally present in the manure, only 11·38 lbs. were left over at the conclusion of the experiment, and from 23·71 soluble mineral matters only 10·47 lbs.

5. It will be seen also that hardly a trace of the free ammonia present in the manure when first used for this series of experiments is left over by November, 1855; and that also the ammonia present in the form of salts, which are easily decomposed by quicklime, is almost altogether dissipated.

6. Finally, it may be observed that in rotten dung exposed to the weather (rain), the nitrogen present in the form of soluble compounds (principally ammoniacal salts) is much more rapidly wasted than in fresh dung.

The whole tenor of this fourth series of experiments agrees well with the first series. Having given in the previous pages a detailed account of the changes which fresh manure undergoes in becoming rotten, I shall not offer any further remarks, and conclude this experimental series by the subjoined tabulated statements which may be found acceptable:—

Table showing Loss in the different component parts of Experimental Heap, No. IV., well-rotten Dung, Exposed, at different periods of the Year, in natural state; also Percentage of Loss and Loss per Ton of original Rotten Dung.—Expressed in lbs. and fractions of lbs. (N.B. The sign * prefixed to a number expresses Increase, and not Loss.)

	From December 5, 1854,								
	To April 30, 1855. Kept 5 Months.			To August 23, 1855. Kept 8 Months.			To November 15, 1855. Kept 11 Months.		
Loss in weight of—		Per cent.	Per ton.		Per cent.	Per ton.		Per cent.	Per ton
Entire heap	427·	26·47	615·32	590·	36·57	819·16	610·	37·82	847·16
Water	398·5	24·70	553·28	477·4	29·47	660·12	478·8	29·69	665·05
*Soluble organic matter . . .	33·67	2·06	46·14	44·48	2·81	62·94	48·45	3·00	67·20
Soluble mineral matter . .	4·81	·29	6·49	12·47	·77	17·24	13·24	·82	18·36
†Insoluble organic matter . .	18·80	1·16	25·98	79·30	4·92	110·20	82·98	5·14	115·13
Insoluble mineral matter . .	27·78	*1·72	*38·52	*23·65	*1·46	*32·70	*33·47	*2·07	*46·36
*Containing nitrogen	3.06	·18	4·03	3·89	·24	5·37	3·87	·24	5·37
Equal to ammonia	3·71	·23	5·15	4·72	·29	6·49	4·70	·29	6·49
†Containing nitrogen	*4·00	*·24	*5·37	0·	0·	0·	*·66	*·04	*·89
Equal to ammonia	4·83	·29	6·49	·02	·001	·02	*·81	*·05	1·12
Total amount of nitrogen . .	*·94	*·05	*1·12	3·89	·24	5·37	3·21	·19	4·48
Equal to ammonia	*1·12	*·07	*1.56	4·72	·29	6·49	3·89	·24	5·37
Ammonia in free state . . .	·674	·04	·89	·61	·03	·67	·706	·04	·89
Ammonia in form of salts . .	·42	·02	·44	·52	·03	·67	·63	·04	·89
Total amount of organic matters	52·47	3·22	72·12	123·78	7·73	173·14	131·43	8·14	182·33
Total amount of mineral matters	*22·97	1·43	*32·03	*11·18	*·69	*15·45	*20·23	*1·25	*28·00

In conclusion, I may mention that I have tested the various experimental manures at different times for nitrates, and have been able to detect the presence of nitric acid in most cases in which the manure had been kept for some time in contact with the atmosphere. Under all circumstances, however, the proportion of nitric acid appeared to amount to mere traces; and, as I am not acquainted with any accurate method of determining minute quantities of nitric acid in so complex a mixture of substances as that of farmyard manure, I have not attempted to determine the amount of nitric acid in the manure quantitively. I may be permitted, however, briefly to state the results of my qualitative examinations:—

Qualitative examination for Nitrates.

Fresh farmyard manure (about 14 days old) examined Nov. 3rd, 1854	No reaction.
Well-rotten dung taken from the bottom of manure-pit on the 5th of Dec., 1854	,,

Analyses made February 14th, 1855.

Experimental heap, No. I., fresh farmyard manure exposed	Decided traces of nitric acid.
Experimental heap, No. II., fresh farmyard manure under shed	Doubtful trace of nitric acid.
Experimental heap, No. III., well-rotten dung exposed	Nitric acid distinctly present, apparently in larger proportion than in No. I.

Analyses made April 30th, 1855.

Experimental heap, No. I., fresh manure exposed	Distinct traces of nitric acid.
Experimental heap, No. II., fresh manure under shed	,, ,,
Experimental heap, No. III., fresh manure spread out	No reaction.
Experimental heap, No. IV., well-rotten dung exposed	Distinct traces of nitric acid.

Analyses made August 23rd, 1855.

Experimental heap, No. I., fresh manure exposed	Distinct traces of nitric acid.
Experimental heap, No. II., fresh manure under shed	The same as in May.
Experimental heap, No. III., fresh manure spread out	A faint trace.
Experimental heap, No. IV., well-rotten dung exposed	Stronger reaction of nitric acid, than in May.

It will be seen that there was no nitric acid present in the fresh manure, nor in the rotten dung taken from the bottom of the pit; and, as traces of nitrates were detected in the manure after a three-months' exposure to the weather, it would seem to follow that access of air is essential for the formation of nitrates in the manure. I was rather surprised not to find any decided traces of nitric acid in the manure spread out in the yard. But as nitrates are very soluble in water, and the spread manure contained a very small proportion of soluble saline matters, it is evident that, if nitrates have been formed, they must have been washed into the soil on which the manure was spread.

Conclusion.—Having described at length my experiments with farmyard manure, it may not be amiss to state briefly the more prominent and practically interesting points which have been developed in the course of this investigation. I would therefore observe,—

1. Perfectly fresh farmyard manure contains but a small proportion of free ammonia.

2. The nitrogen in fresh dung exists principally in the state of insoluble nitrogenized matters.

3. The soluble organic and mineral constituents of dung are much more valuable fertilizers than the insoluble. Particular care, therefore, should be bestowed upon the preservation of the liquid excrements of animals, and for the same reason the manure should be kept in perfectly waterproof pits, of sufficient capacity to render the setting up of dungheaps in the corner of fields, as much as it is possible, unnecessary.

4. Farmyard manure, even in quite a fresh state, contains phosphate of lime, which is much more soluble than has hitherto been suspected.

5. The urine of the horse, cow, and pig, does not contain any appreciable quantity of phosphate of lime, whilst the drainings of dungheaps contain considerable quantities of this valuable fertilizer. The drainings of dungheaps, partly for this reason, are more valuable than the urine of our domestic animals, and therefore ought to be prevented by all available means from running to waste.

6. The most effectual means of preventing loss in fertilizing matters is to cart the manure directly on the field whenever circumstances allow this to be done.

7. On all soils with a moderate proportion of clay no fear need to be entertained of valuable fertilizing substances becoming wasted if the manure cannot be ploughed in at once. Fresh, and even well-rotten, dung contains very little free ammonia; and since active fermentation, and with it the further evolution of free ammonia, is stopped by spreading out the manure on the field, valuable volatile manuring matters cannot escape into the air by adopting this plan.

As all soils with a moderate proportion of clay possess in a remarkable degree the power of absorbing and retaining manuring matters, none of the saline and soluble organic constituents are wasted even by a heavy fall of rain. It may, indeed, be questioned whether it is more advisable to plough-in the manure at once, or to let it lie for some time on the surface, and to give the rain full opportunity to wash it into the soil.

It appears to me a matter of the greatest importance to regulate the application of manure to our fields so that its constituents may become properly diluted and uniformly distributed amongst a large mass of soil. By ploughing in the manure at once, it appears to me, this desirable end cannot be reached so perfectly as by allowing the rain to wash in gradually the manure evenly spread on the surface of the field.

By adopting such a course, in case practical experience should confirm my theoretical reasoning, the objection could no longer be maintained that the land is not ready for carting manure upon it. I am much inclined to recommend as a general rule: Cart the manure on the field, spread it at once, and wait for a favourable opportunity to plough it in. In the case of clay soils, I have no hesitation to say the manure may be spread even six months before it is ploughed in, without losing any appreciable quantity of manuring matters. I am perfectly aware that, on stiff clay-land, farmyard manure, more especially long dung, when ploughed in before the frost sets in, exercises a most beneficial action by keeping the soil loose and admitting the free access of frost, which pulverizes the land,—and would therefore by no means recommend to leave the manure spread on the surface without ploughing it in. All I wish to enforce is, that when no other choice is left but either to set up the manure in a heap in a corner of the field, or to spread it on the field, without ploughing it in directly, to adopt the latter plan. In the case of very light sandy soils it may perhaps not be advisable to spread out the manure a long time before it is ploughed in, since such soils do not possess the power of retaining manuring matters in any marked degree. On light sandy soils I would suggest to manure with well-fermented dung shortly before the crop intended to be grown is sown.

8. Well-rotten dung contains likewise little free ammonia, but a very much larger proportion of soluble organic and saline mineral matters than fresh manure.

9. Rotten dung is richer in nitrogen than fresh.

10. Weight for weight, rotten dung is more valuable than fresh.

11. In the fermentation of dung a very considerable proportion of the organic matters in fresh manure, is dissipated into the air in the form of carbonic acid and other gases.

12. Properly regulated, however, the fermentation of dung is

not attended with any great loss of nitrogen nor of saline mineral matters.

13. During the fermentation of dung, ulmic, humic, and other organic acids are formed, as well as gypsum, which fix the ammonia generated in the decomposition of the nitrogenized constituents of dung.

14. During the fermentation of dung the phosphate of lime which it contains is rendered more soluble than in fresh manure.

15. In the interior and heated portions of manure-heaps ammonia is given off; but, on passing into the external and cold layers of dungheaps, the free ammonia is retained in the heap.

16. Ammonia is not given off from the surface of well-compressed dungheaps, but on turning manure-heaps it is wasted in appreciable quantities. Dungheaps for this reason should not be turned more frequently than absolutely necessary.

17. No advantage appears to result from carrying on the fermentation of dung too far, but every disadvantage.

18. Farmyard manure becomes deteriorated in value, when kept in heaps exposed to the weather; the more the longer it is kept.

19. The loss in manuring matters, which is incurred in keeping manure-heaps exposed to the weather, is not so much due to the volatilization of ammonia as to the removal of ammoniacal salts, soluble nitrogenized organic matters, and valuable mineral matters, by the rain which falls in the period during which the manure is kept.

20. If rain is excluded from dung-heaps, or little rain falls at a time, the loss in ammonia is trifling, and no saline matters of course are removed; but, if much rain falls, especially if it descends in heavy showers upon the dungheap, a serious loss in ammonia, soluble organic matters, phosphate of lime, and salts of potash is incurred, and the manure becomes rapidly deteriorated in value, whilst at the same time it is diminished in weight.

21. Well-rotten dung is more readily affected by the deteriorating influence of rain than fresh manure.

22. Practically speaking, all the essentially valuable manuring constituents are preserved by keeping farmyard manure under cover.

23. If the animals have been supplied with plenty of litter, fresh dung contains an insufficient quantity of water to induce an active fermentation. In this case fresh dung cannot be properly fermented under cover, except water or liquid manure is pumped over the heap from time to time.

Where much straw is used in the manufacture of dung, and no provision is made to supply the manure in the pit at any time with the requisite amount of moisture, it may not be advisable to put up a roof over the dung-pit. On the other hand, on farms where there is deficiency of straw, so that the moisture of the excrements of our domestic animals is barely absorbed by the litter, the advantage of erecting a roof over the dung-pit will be found very great.

24. The worst method of making manure is to produce it by animals kept in open yards, since a large proportion of valuable fertilizing matters is wasted in a short time; and after a lapse of twelve months at least two-thirds of the substance of the manure is wasted, and only one-third, inferior in quality to an equal weight of fresh dung, is left behind.

25. The most rational plan of keeping manure in heaps appears to me that adopted by Mr. Lawrence of Cirencester, and described by him at length in Morton's 'Cyclopædia of Agriculture,' under the head of 'Manure.'

APPENDIX.

The methods employed for determining the water, and selecting samples for analysis, have been stated already in the preceding pages. I can, therefore, proceed at once with the description of the other methods which were adopted in the analysis of the manure.

One thousand, and sometimes two thousand, grains of a carefully mixed sample of manure were digested in a glass beaker with about 16 ounces of cold distilled water for about three or four hours. The liquid was then strained through calico, and the residue digested a second time with about 10 ounces of water; the liquid was again passed through calico, and the residue thoroughly squeezed out. It was next digested again in water, pressed out, and repeatedly washed on the calico until the water came perfectly clear through the calico, and left on evaporation merely a trace of solid matter. In this way a quantity of liquid was obtained (by employing 1000 grains of manure), which filled about a Winchester quart. As it was impossible to obtain a perfectly clear liquid by repeated filtrations through fine filtering paper, the watery solution of the dung was kept in carefully-stoppered Winchester quarts for three or four days, or until the liquid became perfectly clear on standing. It was then drawn off with a syphon into another bottle, and the deposit in the first bottle carefully collected in a weighed filter, and this weight added afterwards to that of the portion of dung insoluble in water. The insoluble portion was previously dried in the air-bath at 212° Fah.

The weight of the whole solution having been ascertained, separate portions of it were employed for the determination of the total amount of soluble matters. Generally three, sometimes four, weighed portions of the liquid were evaporated separately to dryness, first in glass beakers, and finally in a large platinum basin over the water-bath. The platina basin and residue was then dried in the air-bath, until it ceased to lose in weight.

The dry residue of two evaporations was burned over the gas-lamp to a whitish ash, and thus the amount of soluble organic and inorganic matters determined. The dry residue of the third and fourth evaporation was reserved for the determination of the nitrogen in the soluble matters of the manure.

In a similar manner the proportions of organic and inorganic matters in the insoluble portion of the manure was ascertained.

The nitrogen was determined in each portion separately by combustion with soda-lime, and collecting the ammonia produced in sulphuric acid of known strength, according to Peligot's method of determining nitrogen in organic matters.

Frequently two combustions were made with one and the same substance, and invariably closely-agreeing results obtained.

The ash-analyses of the soluble and the insoluble mineral matters of manure, were executed according to the method described in Professor Wöhler's 'Handbook of Inorganic Analysis,' under the head "Analyses of the Ashes of Plants."

The amount of free ammonia in the manure was ascertained by placing into a wide-mouthed retort from 500 to 1000 grains of manure, adding about 8 ounces of water, and distilling off about 4 ounces into a glass bottle, connected air-tight with the retort on the one hand, and on the other with the bulb apparatus usually employed in nitrogen combustions. Both the bottle and the bulb apparatus contained some hydro-chloric acid. The contents of both were evaporated to dryness on the water-bath, and from the dried residue the amount of free ammonia calculated.

To the manure in the retort, from which the free ammonia was distilled off, quicklime and a little more water was added, and the whole distilled nearly to dryness into hydro-chloric acid as before.

Distilled water was next poured upon the mixture of quicklime and manure in the retort, and after some time the liquid filtered through filtering paper. The insoluble portion was washed several times, and the washings added to the first filtrate, and the whole clear solution evaporated to a very small bulk.

This condensed liquid, which in most cases was coloured merely light yellow, finally was tested for nitric acid with the usual tests.

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ON

FARMYARD MANURE,
THE DRAININGS OF DUNG-HEAPS,
AND THE
ABSORBING PROPERTIES OF SOILS.

BY

DR. AUGUSTUS VOELCKER.

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ON

FARMYARD MANURE,

&c.

It is a prevailing opinion amongst farmers that the peculiar smell which emanates from dung-heaps is caused by the escape of ammonia, and that the deterioration of farmyard manure is due, in a great measure, to the loss of this most fertilizing substance, which is incurred by careless management of dung-heaps. In a paper published in the volume for 1856 of the Journal of the Royal Agricultural Society, however, I showed that the proportion of free ammonia, or rather volatile carbonate of ammonia—for it is in this form that ammonia makes its appearance in putrefying organic matters—is so inconsiderable in fresh as well as in fermented dung in all stages of decomposition, that it is not worthy to be noticed in a practical point of view. This being the case, it is evident that the escape of ammonia cannot be the cause of manure-heaps losing much in fertilizing property even when freely exposed to the atmosphere for a considerable length of time. Consequently the chemical means which have been suggested from time to time for preventing the loss of ammonia in dung-heaps may be altogether dispensed with. As there is, practically speaking, no free ammonia in either fresh or rotten dung to be fixed, the addition of dilute sulphuric acid, a solution of green vitriol, and other chemical agents which change volatile compounds of ammonia into non-volatile combinations, is unnecessary and useless. At any rate, these and other fixers of ammonia are useful additions to dung-heaps only in so far as they themselves possess fertilizing properties. In the paper to which reference has been made, I furnished experimentally the proof that, simultaneously with the formation of ammonia—which always proceeds when organic substances containing nitrogen enter into putrefaction—under ordinary circumstances, ulmic, humic, and similar organic acids are produced, which, on account of their great affinity for ammonia, lay hold of any free ammonia generated from excrementitious matters and effectually fix it, provided the temperature of the heap is kept down sufficiently low. In the interior of a dung-heap, where the heat rises often to a temperature of from 120° to 150° F., ammonia, indeed, is given off so abundantly that its presence here becomes patent by its characteristic pungent smell. Such a smell is always observed on turning a manure-heap in an active state of fermentation. Fortunately, the external cold layers of dung-heaps act as a chemical filter, and retain the ammonia proceeding from the heated interior portions of the heap so effectually that even a delicate red litmus paper is not altered in the least. As the faintest traces of ammonia turn reddened litmus paper distinctly blue, it is plain that, however strong the smell of a dung-heap may be, it cannot be due to the escape of ammonia if the red colour of the paper is not turned blue by holding it, previously moistened with water, close to a dung-heap. Some doubts having been expressed of the accuracy of this observation, I have repeatedly examined manure-heaps for free ammonia. Numerous experiments, which need not be described in detail, have fully confirmed my former observations. It is true a manure-heap which has just been turned, or which is examined the day after, gives off a small quantity of ammonia. Although this amounts to a mere trace, yet it distinctly affects red litmus paper; but when a dung-heap is allowed to consolidate for a week or so, and is then examined with litmus paper, not a trace of free ammonia can be detected in the air close to the dung-heap, whilst no difficulty is experienced in detecting free ammonia in the interior heated portions of the same heap. I have since found that farmyard manure, perfectly free from volatile carbonate or uncombined ammonia, when macerated in boiling water, gives off a slightly pungent smell, which, as far as its pungency is concerned, is caused by the escape of ammonia.

It appeared to me a matter of some interest to investigate the circumstance that ammonia is given off only in the interior of the heap and not from its surface, and also how it is that manure which does not contain a trace of free ammonia at the heat of boiling water gives off this gas in appreciable quantity. In the course of this investigation, I was led to the chemical examination of the drainings of dung-heaps, and obtained results which, I believe, are of sufficient interest to be recorded in a Journal devoted to the promotion of good agricultural practice and sound scientific principles.

Before describing the nature of my experiments with drainings of dung-heaps, and stating the analytical results obtained in the analyses of this liquid, I may be allowed to offer a few additional experimental proofs in support of some of the opinions advanced in my paper on the changes which farmyard manure undergoes on keeping. In order to obviate frequent reference to this paper, I would observe that, amongst other particulars, I showed that perfectly fresh as well as rotten dung contained but a very trifling amount of free ammonia; that short dung, when properly fermented, contains more nitrogen than long dung; for which reason, weight for weight, rotten dung is more valuable than fresh. Respecting the loss which farmyard manure sustains under various circumstances, I furnished numerous experiments, which prove that farmyard manure is deteriorated in value when kept in heaps exposed to the weather—the more the longer it is kept; and that the loss in manuring matters which is incurred in this way is not so much due to the volatilization of ammonia as to the removal of ammoniacal salts, soluble nitrogenized organic matters, and soluble mineral matters, by the rain which falls in the period during which the manure is kept. I further showed that well-rotten dung is more readily affected by the deteriorating influence of rain than fresh, and that no advantage appears to result from carrying on the fermentation of dung too far. Finally, I described several experiments, which led me to the conclusion that the worst method of making manure is to produce it by animals kept in open yards, inasmuch as a large proportion of valuable fertilizing matters is thereby wasted in a short time, and suggested, as the most effectual means of preventing loss in fertilizing matters, to cart the manure directly on the field, and to spread it at once, whenever circumstances allow this to be done.

Since the publication of my former experiments on farmyard manure, I have had an opportunity of examining some sheep-dung in a highly advanced state of decomposition. This examination has brought out strikingly that the richest excrementitious matters are greatly deteriorated in value by keeping for an immoderate lengthy period, and I may therefore be permitted to state here the results in full.

The sheep-dung operated upon was furnished to me by a farmer residing in the neighbourhood of Cirencester, who kept this dung for three years in a heap, probably with a view of manufacturing it into a first-rate turnip manure. It was completely decomposed, appeared as a black greasy mass, and possessed more of an earthy than an animal smell.

A well-mixed sample, on analysis, yielded the following general results:—

General Composition of Decomposed Sheep Dung (3 *years old*).

	In Natural State.	Calculated Dry.
Water	73·66	..
*Soluble organic matter	2·70	10·25
Soluble inorganic matter	2·66	10·09
†Insoluble organic matter	9·95	37·78
Insoluble mineral matter	11·03	41·88
	100·00	100·00

	In Natural State.	Calculated Dry.
* Containing nitrogen	·157	·590
Equal to ammonia	·190	·716
† Containing nitrogen	·470	1·790
Equal to ammonia	·580	2·170
Total amount of nitrogen	·627	2·380
Equal to ammonia	·770	2·886

A delicate reddened litmus paper inserted into the neck of a wide-mouthed bottle, into which some of this sheep-dung was placed, was not altered in the slightest degree; there was thus not a trace of free ammonia present in the dung.

When boiled with water, a small portion of ammonia was given off, but that quantity was so insignificant that I determined at once the total amount of ammonia which existed in the dung in the form of ammoniacal salts. This was done by distillation with quick lime and collecting the liberated ammonia in hydrochloric acid, evaporation to dryness in a water-bath, and weighing the residue consisting of sal ammoniac.

Proceeding in this way, I obtained from 100 parts of completely decomposed sheep-dung—

	In Natural State.	Calculated Dry.
Ammonia (In the state of ammoniacal salts.)	·034	·129

It appears, therefore, that the amount of ammonia present in the form of ammoniacal salts is exceedingly small.

In separating the soluble from the insoluble portion some very finely divided silica passed through the filter, and was obtained in the soluble portion of the ash.

This portion of the ash contained in 100 parts:—

Completely Rotten Sheep-Manure.

Composition of Ash of portion Soluble in Water.

Soluble silica	30·70
Insoluble silica	15·90
Phosphate of lime	21·70
Lime	3·93
Magnesia	6·37
Potash	14·14
Soda	3·15
Chloride of sodium	·85
Sulphuric acid	2·86
Carbonic acid and loss	·40
	100·00

The composition of the insoluble portion of the ash is stated in the next diagram:—

Completely Rotten Sheep-Manure.

Composition of Ash of portion Insoluble in Water.

Soluble silica	11·25
Insoluble silica	62·81
Oxides of iron and alumina, with phosphates	9·12
containing phosphoric acid	(4·93)
equal to bone earth	(10·68)
Lime	7·95
Magnesia	2·88
Potash	·59
Soda	·50
Sulphuric acid	1·18
Carbonic acid and loss	3·72
	100·00

From these results the composition of the whole ash of sheep's dung, kept for three years, has been calculated and embodied in the subjoined table.

Completely Rotten Sheep-Manure.

Composition of whole Ash.

Soluble in Water, 19·41 per cent.	Soluble silica	5·95
	Insoluble silica	3·08
	Phosphate of lime	4·21
	Lime	·76
	Magnesia	1·28
	Potash	2·74
	Soda	·61
	Chloride of sodium	·16
	Sulphuric acid	·55
	Carbonic acid and loss	·07
		(19·41)

			Arranged together.
Insoluble in Water, 80·59 per cent.	Soluble silica	9·06	15·01
	Insoluble silica	50·61	53·69
	Oxides of iron and alumina with phosphates	7·34	7·34
	containing phosphoric acid	(4·07)	(4·07)
	equal to bone earth	(8·52)	(8·52)
	Phosphate of lime	..	4·21
	Lime	6·40	7·16
	Magnesia	2·32	3·60
	Potash	·47	3·21
	Soda	·40	1·01
	Chloride of sodium	..	·16
	Sulphuric acid	·95	1·50
	Carbonic acid and loss	3·04	3·11
		(80·59)	100·00
		100·00	

A comparison of the ash of sheep's dung, kept for three years, with the ash of well-rotten good common farmyard manure, will show that in the latter the proportion of phosphate of lime is somewhat larger, and that it is especially much richer in potash than this sheep's dung. On the other hand, this sample of sheep's dung contains a great deal more of silica and earthy matters insoluble in water.

It is thus evident that by long keeping the most valuable inorganic constituents of sheep's dung are washed out gradually, and by their loss the dung becomes greatly deteriorated in fertilising properties.

The next Table exhibits the detailed composition of this completely rotten sheep's dung.

Completely Rotten Sheep-Manure.

Detailed Composition of Manure in Natural State.

Water		73·66
* Soluble organic matter		2·70
Soluble inorganic matter (ash):—		
Soluble silica	·801	
Insoluble silica	·422	
Phosphate of lime	·577	
Lime	·104	
Magnesia	·169	
Potash	·376	
Soda	·083	
Chloride of sodium	·022	
Sulphuric acid	·076	
Carbonic acid and loss	·030	
		2·66
Carry forward		79·02

Brought forward		79·02
† Insoluble organic matter		9·95
Insoluble inorganic matter (ash):—		
Soluble silica	1·240	
Insoluble silica	6·927	
Oxides of iron and alumina, with phosphates	1·005	
containing phosphoric acid	(·543)	
equal to bone earth	(1·176)	
Lime	·876	
Magnesia	·317	
Potash	·065	
Soda	·055	
Sulphuric acid	·130	
Carbonic acid and loss	·415	
		11·03
		100·00

* Containing nitrogen	·157
Equal to ammonia	·190
† Containing nitrogen	·47
Equal to ammonia	·58
Whole manure contains ammonia in free state, and in form of salts	·034

According to these results, the same dung in a perfectly dry condition has the following composition:—

Completely Rotten Sheep's Dung.

Detailed Composition of Manure in Dry State.

*Soluble organic matter		10·25
Soluble inorganic matter (ash):—		
Soluble silica	3·097	
Insoluble silica	1·604	
Phosphate of lime	2·189	
Lime	·405	
Magnesia	·642	
Potash	1·426	
Soda	·317	
Chloride of sodium	·085	
Sulphuric acid	·288	
Carbonic acid and loss	·040	
		10·09
†Insoluble organic matter		37·78
Insoluble inorganic matter (ash):—		
Soluble silica	4·711	
Insoluble silica	26·304	
Oxide of iron and alumina, with phosphates	3·819	
containing phosphoric acid	(2·06)	
equal to bone earth	(4·46)	
Lime	3·329	
Magnesia	1·196	
Carry forward		58·12

Brought forward		58·12
Potash	·247	
Soda	·209	
Sulphuric acid	·494	
Carbonic acid and loss	1·557	41·88
		100·00
* Containing nitrogen	·59	
Equal to ammonia	·716	
† Containing nitrogen	1·79	
Equal to ammonia	2·17	
Whole manure contains ammonia in free state, and in form of salts	·129	

From these analytical results it appears—

1. That completely rotten dung contains less soluble organic matters than well rotten common farmyard manure.

2. That the proportion of insoluble organic matters in such sheep's dung is also much smaller than in rotten yard manure.

3. That the amount of nitrogen in rotten farmyard manure is greater than in this sheep's dung.

4. That, weight for weight, ordinary well rotten dung is more valuable than such completely decomposed sheep's dung.

When it is considered that the diminution of manure in weight by long keeping is very considerable, and that the remaining manure, reduced it may be to one-third its original weight, is less valuable than even common farmyard manure, the folly of keeping sheep's dung in a heap for a number of years will become apparent.

As it may not be uninteresting to compare this manure with fresh sheep's dung, I will insert here a Table representing the general composition of fresh sheep's dung, as recently determined by me:—

General Composition of Fresh Sheep's Dung (Sheep fed upon Roots on old Pasture.)

	In Natural State.	Calculated Dry.
Moisture	73·13	..
* Organic matters	20·28	75·47
Inorganic matters (ash)	6·59	24·53
	100·00	100·00
* Containing nitrogen	·95	3·53
Equal to ammonia	1·15	4·29

Fresh sheep's dung thus contains considerably more nitrogen than the sample of completely rotten dung which was analysed by me.

During the first stages of the fermentation of dung the proportion of nitrogen in manure increases, but when well-fermented dung is then exposed to the weather, the nitrogenized constituents which have been rendered soluble during the process of fermentation are liable to be washed out by rain. The analyses of fresh and completely rotten sheep's dung confirm my former observations—that in this way a great loss is incurred in valuable fertilising matters.

As a further proof of the fact that both fresh and rotten farmyard manure contains but a trifling amount of free ammonia, I have to mention two experiments.

The first was made with fresh horse-dung, or, more properly speaking, with the recent droppings of horses mixed with straw; that is, horse-dung as found in stables before its removal to the dung-pit.

This manure contained in 100 parts:

Water	76·60
Solid matter	23·40
	100·00

The percentage of ammonia, which was driven out by long-continued boiling, amounted to ..	0·0033	
Quicklime added to remainder expelled in addition to this quantity	0·062	p. ct. of am.
The total amount of nitrogen in this manure amounted to	0·387	p. ct.
Which is equal to	0·469	p. ct. of am.

Or dried at 212° F. the manure contained—

Nitrogen	1·655	p. ct.
Equal to ammonia	2·019	p. ct.

The second experiment was made with hot fermenting horse-dung, taken from the middle of a heap of good farmyard-manure, consisting chiefly of horse-dung. It emitted a strong and somewhat pungent smell, for reddened litmus paper inserted into the neck of a bottle into which some of this manure was placed turned blue after some time, showing that it contained some free ammonia. The quantity of the latter, however, was very inconsiderable, as will be seen by the following numbers, obtained like those in the experiment with fresh horse-dung:—

Percentage of free ammonia in fermenting horse-dung	0·049	
Distilled with quicklime, it furnished additional ..	0·1103	p. ct. of am.

This manure calculated in 100 parts:

		Calculated Dry.
Moisture	68·74	..
* Solid matters	31·26	100
	100·00	
Containing nitrogen	0·659	2·109
Equal to ammonia	·800	2·561

In fermenting horse-dung, the proportion of nitrogen is thus larger than in fresh, which agrees well with previous analyses of fresh or rotten common yard-manure; whilst in perfectly fresh horse-dung the amount of free ammonia is scarcely weighable, it being only about 3 parts in every 100,000 parts of dung, or 3 lbs. for every 40 tons; the same description of manure in an active state of fermentation yields somewhat more, but still a very inconsiderable quantity of free ammonia. Thus under the most favourable circumstances 100,000 parts of horse-dung yield only 49 parts of free ammonia; or in other words 40 tons in round numbers yield on long-continued boiling only 49 lbs. of ammonia. It must not be supposed, however, that this quantity of ammonia is dissipated into the air during the fermentation of the dung, for it is only in the interior of the dung-heap that ammonia is liberated. It is, indeed, only on turning a heap that ammonia escapes at all in any perceptible degree; but as soon as the external layers have become cooled down to the ordinary temperature of the air its escape is arrested. There can, therefore, be not the slightest doubt that a very minute quantity of ammonia passes into the air and the remainder is fixed in the heap, provided the heap is kept in such a manner that rain cannot remove from it much of the soluble matters, and with them ammoniacal salts.

The strong smell which is observed on turning a dung-heap no doubt has led many greatly to over-estimate the amount of ammonia which escapes from farmyard manure in an active state of fermentation. But I would observe that nothing is more fallacious than the estimation of the amount of ammonia by the pungency of the smell which is given off from fermenting animal matters. Such matters often give off a very powerful smell, which is due to peculiar volatile organic combinations—to some sulphuretted and phosphoretted hydrogen and a great variety of gaseous matters, amongst which there is ammonia gas in very minute quantities. The smell of this highly complicated and but scantily examined mixture of gaseous matters as a whole is ascribed by the popular mind to ammonia. From these products of putrefaction, however, ammonia can be completely separated, without in the least destroying the peculiar offensive smell which emanates from organic matters in a state of decomposition. If, for instance, dilute sulphuric acid is added to farmyard manure or liquid manure, the smell of these substances, instead of becoming neutralised by the acid, in reality becomes more offensive. This arises in a great measure from the liberation of sulphuretted hydrogen. Hence acids are not well adapted for disinfecting cesspools or nightsoil. As dilute sulphuric acid neutralises instantly free ammonia, forming with it an inodorous salt, which is not volatile at the ordinary temperature, it is evident that the fœtid smell of putrefying matters has much less to do with ammonia than is generally believed.

The following experiment is decisive in this respect. A couple of ounces of genuine Peruvian guano were completely drenched with dilute sulphuric acid. Any free ammonia in the guano by the addition of acid must therefore have been instantly converted into sulphate of ammonia. The characteristic smell of the guano, however, was not removed nor even weakened by the acid. The guano moistened with acid was next dried in a water-bath for five or six hours, and during all that time gave off the strong peculiar smell which characterises genuine Peruvian guano. When dry it still smelt strongly, though weaker than when wet; but moistened again with a little water the smell again became as strong as before. In order to make quite certain that no ammonia would remain in a free state, I employed a great excess of acid, in consequence of which the guano, after drying up with acid, tasted as acid as any of the most concentrated samples of superphosphate.

I may further mention that I dried guano for days at a temperature of boiling water without being able to remove its peculiar smell.

Whilst speaking of guano it may interest some of my readers to learn that genuine Peruvian guano contains a very small quantity of volatile carbonate of ammonia.

There are many people who run wild with the idea that everything that smells strongly must contain free ammonia. Hence it is not surprising that salt, gypsum, acids, and various other substances should have been suggested to be mixed with guano for the purpose of fixing the ammonia, as it is said, in guano.

It is not my purpose to enter here into a discussion of the merits of salt or gypsum as fixers of ammonia, but I cannot help observing that both salt and gypsum are ill adapted for fixing any free ammonia in putrefying organic matters. I do not mean to speak disparagingly of the mixing of salt or gypsum with guano, for I believe this to be attended with very great benefit. The good effected by mixing guano with salt, however, I feel assured is not due to the salt fixing the ammonia in guano, as generally believed by practical men, and transcribed from one text-book on agricultural chemistry to the other; for in the first place salt is incapable of fixing any free ammonia in guano, and in the second place the amount of free ammonia in genuine Peruvian guano is so inconsiderable, that salt, even supposing it to fix ammonia, finds very little free ammonia in Peruvian guano upon which to exercise its supposed power of fixing ammonia.

A year or two ago Mr. Barrall, a French chemist, published some experiments, which purpose to prove the power of salt to fix ammonia in Peruvian guano, and to account thereby for the benefit which results from the mixing of guano with salt. I have carefully repeated Mr. Barrall's experiments, and shall publish the details of my analytical results shortly elsewhere; but, fearing I might be considered dogmatic in distinctly stating that salt is incapable of fixing free ammonia in guano, I beg to observe that I have been led to this conclusion by a series of experiments which are opposed in their results to Mr. Barrall's.

For the purpose of giving an idea of the actual quantity of free ammonia (carb. of ammonia) in Peruvian guano, I would mention in this place the following experiment:—A quantity of Peruvian guano, which on analysis gave the subjoined analytical results, was mixed with a little water, and distilled in a retort to dryness at a temperature not exceeding 212° F., and the distillate carefully collected in hydrochloric acid. On evaporation of the acid liquor in the receiver, sal ammoniac was obtained, from the weight of which that of ammonia volatilised with the watery vapours produced on distillation was calculated.

The following is the result of this determination. 100 parts of genuine Peruvian guano were found to yield ·573 of ammonia:—

Composition of Peruvian Guano used in this Experiment.

Moisture	12·78
* Organic matter and ammoniacal salts	53·08
Phosphates of lime and magnesia (bone-earth)	24·50
Alkaline salts	8·99
Insoluble silicious matter (sand)	·65
	100·00
* Containing nitrogen	13·18
Equal to ammonia	15·96

The same guano distilled with an excess of quicklime and some water, with a view of liberating the ammonia which existed in this sample of Peruvian guano in the form of ammoniacal salts, produced 6·931 of ammonia. Though we are in the habit of speaking of guano as an ammoniacal manure, it appears from these determinations that the smaller proportion of nitrogen is contained in Peruvian guano as ready-formed ammonia, and the larger proportion as uric acid, urea, and other nitrogenised compounds, which, however, in contact with water, are readily decomposed and yield ammonia.

The quantity of free ammonia and ammonia in the form of ammoniacal salts, of course, is not constant in different samples: I may state, however, that in dry genuine Peruvian guano I never found a larger amount of free ammonia than ¾ per cent. This small proportion of free ammonia cannot excite surprise if the conditions are taken into account under which guano is deposited in the rainless regions from which good Peruvian guano is imported into this country. The dry and hot climate of the Peruvian guano islands has the effect of leaving very little free ammonia in the fresh birds' excrements, and of rapidly dissipating the moisture which they contain. With the expulsion of the moisture the further decomposition of the excrements is at once arrested, and the further development of ammonia prevented.

It follows from these remarks that as long as Peruvian guano is kept perfectly dry it may be preserved for any length of time without losing in the slightest degree in fertilising properties, and also that there exists no need of resorting to chemical substances which are known to possess the property of fixing ammonia.

The case is different with damaged and inferior descriptions of guano. These frequently contain considerable quantities of volatile carbonate of ammonia; they are therefore liable to become deteriorated on long keeping, and may be improved by the addition of an acid which fixes the free ammonia. Indeed, all guanos which are deposited in districts occasionally visited by heavy rains contain much carbonate of ammonia, a salt which in inferior guanos is often seen in beautiful large crystals, and which, being volatile, is gradually dissipated by keeping.

It has been stated already that there exists no necessity for fixing ammonia in farmyard manure by chemical means. But I refer again to this subject on account of a statement which has been widely circulated and been reported in most agricultural periodicals. It has been stated, namely, by a Mr. M'Dougall, the patentee of a disinfecting powder, that by the use of the patent article, not only the air in stables may be kept perfectly sweet and wholesome, but that also the quality of the dung is improved in an astonishing degree, so much so, that in the neighbourhood of Manchester fabulous prices have been paid for farmyard manure, in the preparation of which M'Dougall's powder has been used. I am bound to state at once, that this powder possesses, indeed, excellent disinfecting properties; and had the inventor confined his remarks to the sanitary question involved in the use of his powder, no room would have been left to call in question its utility as a disinfectant. But as he describes, in addition to its disinfecting properties, others which I have not found confirmed in my experiments on the subject, I am anxious to correct any erroneous views to which some of Mr. M'Dougall's statements may have given rise. It is maintained by this gentleman that his disinfecting powder possesses the property of fixing ammonia in dung, and thereby rendering it more valuable than manure made in the ordinary manner. According to the published accounts, M'Dougall's powder consists chiefly of sulphite of lime and sulphite of magnesia, and contains also some carbolic acid in combination with lime, and free lime. It is said to be prepared by passing sulphurous acid into slaked lime, obtained on burning magnesian limestones, and by mixing with this product a certain quantity of crude carbolic acid, probably in the state of gas-tar.

The theory of the action of this disinfecting powder is described by the inventor in the following words:—

> "The only agent we know which will decompose the noxious emanations from putrescent excreta, or other animal offal, without creating any detrimental action upon those elements which we wish to preserve, is sulphurous acid.
>
> "Let us take two atoms of sulphuretted hydrogen, and one of sulphurous acid; when they are brought into contact, they are mutually decomposed, and form three of sulphur and two of water, both of which are entirely odourless. A similar reaction will ensue if we put phosphoretted hydrogen in the place of sulphuretted hydrogen, only the products would be two of phosphorus, one of sulphur, and two of water as before, both of which are also entirely odourless.
>
> "Here, then, we have the means of solving the first condition of the problem. By the agency of sulphurous acid the offensive smell of putrescent substances may be removed. Further than this, sulphurous acid has a conservative action, which is highly favourable to our object. It has a strong affinity for oxygen, and will not permit other substances in its presence to combine with oxygen till its own affinity is satisfied. It thus exercises an influence highly anti-putrescent, besides decomposing the offensive compounds which have been already formed.
>
> "We have another guarantee, however, for the prevention of putrefactive fermentation; this is the carbolic acid, which has the property of coagulating albuminous substances, and generally of preventing putrescence. As it is a liquid oily compound, we combine it with lime, and are thus enabled to dry it and reduce it to a powder, so rendering its application easy and simple.
>
> "It only remains now that I explain the reason why we use magnesia in combination with the sulphurous acid. The reason is, that the compounds to be preserved are ammonia and phosphoric acid, and magnesia is the only available element which combines with them both and forms a triple compound, perhaps of all other possible combinations the best for agricultural purposes, viz. the triple phosphate of magnesia and ammonia.
>
> "In the treatment of sewage or other similar matter in an advanced stage of decomposition, containing any considerable percentage of ammonia, we find it advantageous to add a soluble phosphate, as the quantity of phosphoric acid in the substances to be operated upon is not, in the circumstances, sufficient to permit the formation of the triple phosphate.
>
> "Thus, then, we use sulphurous acid to remove the offensive smell, carbolic acid to prevent putrefactive fermentation, a little lime to neutralize and dry this latter acid, and magnesia to combine with and preserve the phosphoric acid and ammonia; and, in special cases, we add a soluble phosphate to prevent the loss of any of the ammonia."

These are Mr. M'Dougall's own words respecting the theory of the action of his disinfecting powder. The passage cited will be found (pp. 18, 19) in Mr. M'Dougall's pamphlet, entitled, 'On the Preservation of the Natural Manures, by Alexander M'Dougall. 1856.'

In page 20 of this pamphlet it is said—"Theoretically, it is perfect, leaving nothing to be desired; and in practice, it has not fallen short of the just expectations which were formed of its probable results in actual use."

I regret that I cannot share this opinion, for Mr. M'Dougall's powder is neither theoretically perfect, nor does it answer in practice the purpose for which it is recommended to the notice of agriculturists, for it is destitute of the property of fixing any free ammonia in liquid manure or in dung-heaps.

It is not my intention to criticise in detail Mr. M'Dougall's "perfect theory, which leaves nothing to be desired;" but I trust he will excuse me for reminding him that when two or more elements unite together chemically, a new compound substance is produced, which possesses properties not shared by its constituents. Thus sulphuric acid uniting with lime produces sulphate of lime, a combination in which neither the most striking characters of sulphuric acid nor of lime are any longer perceptible.

In the same manner sulphurous acid uniting chemically with lime produces a new compound substance, in which the most prominent features of lime and sulphurous acid have become permanently altered. Unless it can be shown experimentally that the action of sulphurous acid in combination with lime and magnesia upon sulphuretted or phosphoretted hydrogen is the same as that of free sulphurous acid, Mr. M'Dougall's attempted explanation of the action of the disinfecting powder upon sulphuretted and phosphoretted hydrogen must indeed be regarded as a theory—a theory, however, which I imagine every sound chemist will more likely call a wild than a perfect one. M'Dougall's powder possesses the power, though only in a slight degree, of removing sulphuretted hydrogen from liquids. This property it owes not to the sulphite of lime or magnesia which it contains, but, as it appears to me with much greater probability, to the free lime which enters into the composition of M'Dougall's powder.

In order to decide positively this point, the following experiment was made:—

To a strong and clear solution of M'Dougall's powder in water a small quantity of sulphuretted hydrogen water was added; the smell disappeared, no deposit of sulphur was produced. Some more sulphuretted hydrogen water was added to the same liquid; a strong smell of sulphuretted hydrogen remained, and no deposit whatever of sulphur was produced.

The solution of the disinfecting powder in water had a distinct alkaline reaction, and contained, as ascertained by direct experiment, in addition to sulphite of lime and sulphite of magnesia, some quick lime.

Lime-water, *i.e.* a solution of quick lime in water, I find possesses the property of removing sulphuretted hydrogen from its solutions to a larger extent than a solution of M'Dougall's powder; whilst a solution of pure sulphite of lime and magnesia apparently does not possess the power of removing sulphuretted hydrogen from its solution. At any rate, even a concentrated solution of sulphite of lime or sulphite of magnesia, added in large excess to a solution of sulphuretted hydrogen, produces no deposit of sulphur, and has no immediate effect upon this gas.

Having proved experimentally that it is not the sulphite of lime or magnesia in M'Dougall's disinfecting powder, but in all probability the free-lime contained in it, which instantly removes sulphuretted hydrogen from its solutions in water, I will next describe some experiments which I have made in conjunction with Mr. Coleman, our farm-manager, with a view of testing the disinfecting properties of this powder.

The fact that refuse gas-lime contains sulphurous acid in combination with lime, as well as free lime, induced me to compare the effects of M'Dougall's powder with dried and finely powdered gas-lime, to which a small quantity of gas-tar was added. By incorporating some gas-tar with the refuse lime of gas-works, previously dried and powdered, a product is obtained which smells very similar to M'Dougall's powder, and resembles the latter closely in its general appearance; and also so far in composition, as it contains likewise sulphite of lime, free lime, and carbolic acid. The proportion of caustic lime in this prepared gas-lime, however, was much more considerable than in M'Dougall's powder, which no doubt accounts for the fact that this sample of prepared gas-lime greatly excelled the newly-invented powder in deodorizing properties.

It appeared to me also desirable to mix slaked lime with a little gas-tar, and to try this mixture simultaneously with the two other powders in the stable.

With these three powders the following experiments were made:—

1*st Set of Experiments.*

Three loose boxes were cleared out and respectively sprinkled with M'Dougall's powder, prepared gas-lime and tar, and with slaked lime and tar.

All animal smell was instantly removed in each of the three boxes, but there remained a faint but perceptible smell of ammonia in the first box, sprinkled with M'Dougall's powder. In the second box, sprinkled with gas-lime, the smell of ammonia was still more distinct; and in the third box, sprinkled with slaked lime, the smell of ammonia was most marked.

It thus appears from these experiments that whilst all three powders removed instantly the peculiar animal smell which prevails in stables, none possessed the power of fixing free ammonia.

In the experiment with M'Dougall's powder the smell of ammonia was masked by the tarry products contained in this powder to an extent which rendered it difficult to an inexperienced person to recognise by the smell alone the presence of free ammonia. On the other hand, the smell of ammonia in the third loose box was decidedly stronger after sprinkling the floor with slaked lime and tar than before the experiment. As M'Dougall's powder contains only little caustic lime, the prepared lime a good deal more, and the slaked lime most caustic lime, it is evident that the differences in this respect are mainly due to the relative quantities of caustic lime present in the three experimental powders. The experiment with slaked lime, moreover, shows that the excrementitious matters on the floor of stables contain ammoniacal salts, from which ammonia is liberated by caustic lime.

2nd Set of Experiments.

Some of M'Dougall's powder was next added to fresh farmyard manure. The peculiar animal smell of the latter was rapidly removed, but ammonia—it is true, in small quantities, but still in a perceptible degree—liberated at the same time.

An equal portion of fresh farmyard manure was treated with prepared gas-lime, and a third portion of fresh dung with slaked lime and gas-tar.

The two last-named powders rapidly destroyed the disagreeable animal smell of the dung, and, like M'Dougall's powder, liberated some ammonia.

Similar experiments were tried with three equal portions of well rotten dung with similar results. In each case ammonia was given off in small quantities, especially in the experiment in which slaked lime was added to rotten dung.

In order to leave no doubt on the fact brought out by our experiments on fresh and rotten dung, namely, that M'Dougall's powder, instead of fixing ammonia, actually liberated ammonia from its combinations, the following experiments were made:—

A portion of rotten dung was put into a wide-mouthed bottle, in the neck of which a moistened red litmus paper was inserted. At the same time an equal quantity of rotten dung was put into a second bottle, and some of M'Dougall's powder was well mixed with the dung. The animal smell, as before, was completely removed. In the neck of the second bottle a red litmus paper was inserted. In the course of a few minutes the litmus paper in contact with the air surrounding the deodorized dung was distinctly turned blue, whilst the paper in the first bottle retained its original red colour, thus proving clearly that the dung which contains no free ammonia, when deodorized with M'Dougall's powder, gives off ammonia in a perceptible degree.

I have shown in numerous experiments that the amount of ammonia which may be obtained by treating farmyard manure with quick lime is but small; unmixed with any other animal emanations, when gradually liberated by a powder which, like M'Dougall's, contains only little caustic lime, and masked by the smell of tar, the ammonia in dung is hardly perceptible by the smell. And as many people refer the smell of dung to ammonia, forgetting that the peculiar putrescent smell of dung is principally due to other animal exhalations, I can readily understand the mistaken idea which no doubt many entertain who have practically tested the effects of this disinfecting powder upon dung. But let them try the effect of M'Dougall's powder upon a solution of sal-ammoniac or sulphate of ammonia, and they will find, without difficulty, that it liberates from these inodorous salts the pungent-smelling ammonia. Or, by mixing a moderate quantity of the powder with a manure which, like guano, contains a large proportion of ammoniacal salts, it may be shown that M'Dougall's powder contains a constituent, the chemical effect of which manifests itself by the copious discharge of ammonia.

3rd Set of Experiments.

In a third series of experiments I have studied the disinfecting properties of M'Dougall's powder in relation to liquid manure.

With a view of ascertaining what share the sulphite of magnesia and sulphite of lime had in the deodorizing effect upon liquid manure, and what share the free lime contained in the powder, I prepared a pure and concentrated solution of sulphite of lime and sulphite of magnesia, the effects of which were tried upon liquid manure.

For other experiments I used a solution of gas-lime, prepared as described above, and I also tried the effects of slaked lime mixed with some coal-tar.

Finally, I saturated the free lime in M'Dougall's powder, by passing into it sulphurous acid as long as it was absorbed, and removed the excess of this gas by drying the powder at a very moderate heat.

With these various materials, the following experiments were instituted:—

1. Added to 6 ounces of liquid manure 2 ounces of a strong solution of sulphite of magnesia and sulphite of lime. No apparent effect was produced. Added 2 more ounces of the same solution. The smell remained unchanged.

By keeping this mixture of liquid manure with sulphite of magnesia and lime, for three weeks in a bottle, the original disagreeable smell of the liquid manure remained unaltered, thus showing that pure sulphites have not the power of removing the bad smell from putrescent liquids.

2. 50 grains of M'Dougall's powder were finely pounded in a mortar, and gradually mixed with 5 ounces of liquid manure. The bad smell of the latter disappeared instantly. An addition of 5 ounces more of liquid manure; the liquid became sweet to the smell after a few minutes. 10 additional ounces were next mixed with the disinfected liquid, and thus altogether 20 ounces of liquid manure were mixed with 50 grains of M'Dougall's powder.

After some time the bad smell disappeared altogether, but, at the same time, ammonia was set free, as shown by litmus paper suspended in the neck of the bottle.

3. The same experiment was tried, with the substitution for M'Dougall's powder of 50 grains of prepared gas-lime.

The result was similar to that obtained in the second experiment; the only perceptible difference being that, by using gas-lime, the liquid manure, which had originally a dark greenish brown colour, was rendered more transparent and lighter coloured than by using M'Dougall's powder.

4. Another experiment was tried with 20 ounces of liquid manure and 50 grains of slaked lime, mixed with some gas-tar.

The putrescent smell was instantly removed, and the liquid became bright and colourless like water. Ammonia was given off.

5. ¼ lb. of M'Dougall's powder was treated with 20 ounces of distilled water, and filtered.

The clear liquid was coloured yellow, smelt like the powder, and had a weak alkaline reaction.

4 ounces of this solution were mixed with 4 ounces of liquid manure; the bad smell disappeared after some time. 4 ounces more of liquid manure were added; the smell was not entirely removed.

Kept in a bottle for 2 days, the liquid was not entirely deodorized.

6. ¼ lb. of prepared gas-lime was treated with 20 ounces of distilled water. The clear liquid filtered from the insoluble matter was yellow-coloured, and smelt similar to the solution of M'Dougall's powder. It possessed a stronger alkaline reaction than the solution of M'Dougall's powder.

By mixing 8 ounces of liquid manure with 4 ounces of this solution of gas-lime a considerable deposit was produced, the liquid became much clearer and brighter, and lost all disagreeable smell.

7. 6 ounces of liquid manure were mixed with 20 grains of M'Dougall's disinfecting powder.

The colour of the liquid became lighter, ammonia was liberated, and the peculiar disagreeable odour of liquid manure completely removed after some time.

8. 6 ounces of liquid manure were mixed with 20 grains of M'Dougall's powder, previously saturated with sulphurous acid.

The colour of the liquid remained unaltered, and the smell remained as bad as before the addition of the powder.

If the deodorizing effects of the disinfecting powder were due to the sulphite of magnesia contained in it, the deodorizing effect of the powder when saturated with sulphurous acid, it is plain, should have become more marked; but the contrary was the case. Indeed, by neutralizing the free alkaline constituents in the powder its deodorizing power was destroyed.

9. It is but fair to state that Mr. M'Dougall recommends the addition of a soluble phosphate to liquids containing much free ammonia. He mentions liquid manure and sewage as two liquids which do not contain sufficient phosphoric acid in a soluble form to unite with all the ammonia contained in these liquids and the magnesia of the disinfecting powder. Following his advice, I added to liquid manure phosphate of soda, in various proportions, and used small and large doses of the disinfecting powder. In every instance M'Dougall's powder failed to fix the ammonia in liquid manure, notwithstanding the presence of abundance of soluble phosphates.

It thus appears from these various experiments:—

1. That M'Dougall's powder is unfit to fix any ammonia in dung.

2. That its deodorizing effects are not due to the sulphite of magnesia or sulphite of lime, but to the alkaline constituents which it contains.

3. That, instead of fixing ammonia, it liberates, like all alkaline matters, ammonia from its combinations.

It is well known, however, that animal excrementitious matters, when deodorized by lime, after some time give off again a disagreeable odour; and it is very likely that sulphite of magnesia and sulphite of lime, on account of their great affinity for oxygen, will prevent this evil by stopping the further decomposition of animal matters deodorized by lime. Considered in a purely sanitary point of view, M'Dougall's powder may therefore possess advantages over quick lime as a disinfectant. Still it is difficult to conceive how such a farther decomposition can be arrested practically by the use of this powder, for it appears to me that this can only be realized by the employment of so large a quantity of powder as to render the process altogether too expensive.

Drainings of Dung-heaps.—Nobody can deny that farmyard manure is seldom kept in the most efficient manner. In many places in England, especially in Devonshire and in some parts of Gloucestershire, it is a common practice to place manure-heaps by the roadside, often on sloping ground, and to keep these loosely-erected heaps for a considerable length of time before carting the dung on the field. On other farms, the manure is allowed to remain loosely scattered about in uncovered yards for months before it is removed. Heavy showers of rain falling on manure kept in such a manner, by washing out the soluble fertilizing constituents of dung, necessarily greatly deteriorate its value. It is well known that the more or less dark-coloured liquids which flow from badly-kept dung-heaps in rainy weather possess high fertilizing properties. According to the rain which falls at the time of collecting these drainings, according to the character of the manure, and similar modifying circumstances, the composition of the drainings from dung-heaps is necessarily subject to great variations. The general character of these liquids, however, is the same in dilute and in concentrated drainings. Several samples of dung-drainings were recently examined by me, and, from their analyses, it will be seen that they contain a variety of fertilizing constituents which it is most desirable to retain in dung-heaps.

The first liquid examined was collected from a dung-heap composed of well-rotten horse-dung, manure from fattening beasts, and the dung from sheep-pens. Both the horse-dung and dung from fattening beasts were made in boxes. The liquid which ran from this dung-heap was collected in rainy weather, and contained, no doubt, in addition to the liquid portion of the dung, a good deal of rain.

The colour of this liquid was dark brown; it contained no free sulphuretted hydrogen, nor any free ammonia. Its reaction was neutral to test-paper, but on boiling it became alkaline, ammonia being given off freely. Besides ammonia, boiling expelled a very considerable quantity of carbonic acid, which is contained in drainings of dung-heaps, partly in mechanical solution, but chiefly in the form of bi-carbonates ; these, on boiling, are decomposed into neutral carbonates, and into carbonic acid, which escapes.

On addition of hydrochloric acid the liquid strongly effervesced and gave off a most disgusting stench. Notwithstanding the disagreeable odour produced, on adding hydrochloric acid to these drainings of a dung-heap, there was no sulphuretted hydrogen in the mixed gases which escaped. The acidulated liquid being heated deposited in abundance a dark brown flaky substance, which was afterwards identified as a mixture of humic and ulmic acids. The deposition of these organic acids in the shape of a brown flaky mass had the effect of leaving the supernatant liquid merely pale yellow. It is thus plain that the dark brown colour of drainings of dung-heaps is due to compounds of humic and ulmic acids. These compounds are easily decomposed by mineral acids, and as the dark-coloured organic acids, which separate, in a free state are nearly insoluble in water, the original dark brown liquid is decolourized.

Humic and ulmic acid are both products of the decay of carbonaceous organic matters, and their abundance in the drainings of dung-heaps is easily explained by the decomposition of the straw and the non-nitrogenized constituents of excrementitious matters. In combination with potash, soda, and ammonia, humic and ulmic acids form dark-coloured, readily-soluble salts; whilst with lime, magnesia, and earthy and metallic bases the same organic acids form compounds insoluble in water.

The dark brown colour of the drainings therefore is an indirect proof of the existence in them of potash, soda, or ammonia. The subsequent examination indeed has afforded the direct proof that drainings of dung-heaps contain all three alkalies, combined at least in part with organic acids, which being found in large quantities in humus may be called by the generic name of humus-acids.

Chemists are well acquainted with the fact that with the degree of heat to which chemical agents are exposed their affinities one towards the other are changed. Thus, for instance, at the ordinary temperature of the atmosphere, or at the heat of boiling water, sulphuric acid is capable of separating phosphoric acid from bone-earth, and forming with the lime of the latter sulphate of lime or gypsum. But when a mixture of sulphate of lime and phosphoric acid is heated to redness, the affinities between lime and phosphoric and sulphuric acid are changed. A reverse action to that which takes place at a comparatively low temperature manifests itself, and, provided the temperature is sufficiently elevated and enough phosphoric acid present, all sulphuric acid is driven out from the gypsum, and phosphoric acid takes its place.

Similar chemical reactions, dependent on changes of temperature, are continually taking place in dung-heaps in an active state of fermentation, as well as called into play by heating drainings of dung-heaps.

I have kept for days a reddened litmus-paper inserted into the neck of a bottle, in which such drainings were placed, without perceiving the slightest change in the colour of the paper, thus proving distinctly that these drainings do not contain a trace of free ammonia. But when the temperature of the drainings is slightly elevated ammonia is given off at once, and continues to escape as long as the liquid is kept boiling, and a good deal of water is left in the vessel in which the liquid is boiled. For this reason it is necessary in determinations of free ammonia in this and similar liquids containing humus-acids, to continue the process of distillation until the liquid is nearly evaporated to dryness. In boiling the drainings of dung-heaps the volatilization of ammonia is accompanied by the deposition of flakes of humic and ulmic acids, as well as carbonate of lime, held in solution by carbonic acid, which in boiling is likewise expelled.

It thus appears that although the affinity of humus acids for ammonia is sufficiently strong completely to prevent its escape at the ordinary temperature, it suffers a change at a slightly elevated temperature, in consequence of which ammonia escapes. Drainings of dung-heaps contain in solution bi-carbonate of lime, which, at the ordinary temperature of the air, has no effect upon humate and ulmate of ammonia; on heating, the bi-carbonate of lime loses carbonic acid, and becomes neutral carbonate of lime, a combination which is capable of decomposing humates and ulmates of ammonia. The ulmic and humic acid of the latter uniting with the lime, with which they form insoluble compounds, leave the ammonia in a free state, and on boiling of liquid it gradually evaporates with the watery vapours.

The examination of the chemical constitution of the drainings of dung-heaps thus leads at once to the explanation of the reason why hot dung has a pungent smell, caused by the escape of ammonia, and why even rotten dung when cold does not give off any free ammonia. In relation to the amount of ammonia farmyard manure always contains a great excess of these humus acids, hence the free ammonia proceeding from the interior portions of dung-heaps, which are in an active state of fermentation, is arrested by the humus substances contained in the cold external layers of dung-heaps. In contact with air any undecomposed straw is gradually changed into these excellent fixers of ammonia, and thus a natural provision is made in dung-heaps to prevent the loss of ammonia.

Drainings of dung-heaps present us with another interesting chemical particular, which at first sight appears quite anomalous, but which finds a ready explanation in the peculiar composition of these drainings and the properties of humus and ulmic acid. Drainings of dung-heaps, namely, present us with a liquid which, though perfectly neutral to test-paper, may be mixed with a certain quantity of acid without becoming in the slightest degree acid. This will appear from the following experiment:—7000 grains of perfectly clear, dark-brown coloured and neutral drainings were mixed with 50 drops of concentrated hydrochloric acid; the liquid strongly effervesced, gave off a horrid smell, and deposited a considerable quantity of a brown, flaky substance. The supernatant liquid was much paler, and produced no change on litmus paper.

A single drop of concentrated hydrochloric acid added to 7000 grains of distilled water was readily detected by turning blue litmus paper distinctly red, thus proving that the test-paper was sufficiently delicate to detect the presence of a very small quantity of free acid.

A further addition of 50 drops of concentrated hydrochloric acid to the same drainings produced a decided acid reaction, and caused the separation of a little more flakulent matter.

The whole of the brown flaky substance was collected in a weighed filter, dried at 212° Fahr., and weighed, and found to amount to 12·55 grains.

An imperial gallon of these drainings accordingly contained 125·5 grs. of humic and ulmic acids.

If it be remembered that these organic acids are insoluble in water, and are contained in the drainings in combination with alkalies, the curious circumstance that an acid may be added to neutral drainings without producing an acid reaction will be readily understood. The first quantity of hydrochloric acid had the effect of uniting with the alkalies, and it thus became neutralized, whilst the organic humus acids previously in union with the alkalies of the drainings were separated, and, being insoluble in water, of course could not affect litmus paper.

I have determined also in the same drainings the amount of carbonic acid which is expelled by simply boiling this liquid, and found in one imperial gallon of drainings 88·20 grains of carbonic acid, which is thus loosely united with the liquid.

The amount of free ammonia (ammonia expelled on boiling the liquid) in these drainings was determined in the manner described above; and after the free ammonia was removed, quick lime was added to the remainder of the concentrated liquid for the purpose of separating any ammonia present in the form of salts, which are not decomposed simply by boiling.

In this way the following results were obtained:—

One imperial gallon of drainings contained 36·25 grains of free ammonia and 3·11 grains of ammonia in the form of salts, not decomposed simply on boiling, but by continued boiling with quick lime.

Evaporated to dryness, 7000 grains furnished 62·51 grains of solid matters, dried at 212° Fahr.; or one imperial gallon was found to contain 625·10 grains of solid matters. On heating to redness, 62·51 grains left 36·89 grains of ash. This ash was submitted to a detailed analysis, and calculated for one imperial gallon of the drainings.

According to the analytical results obtained in these different determinations, an imperial gallon of these drainings contained—

	Volatile and combustible constituents	395·66		
Viz.	Ammonia driven out on boiling	36·25	Together. 39·36	
	Ammonia in the state of salts decomposed by quick lime	3·11		
	Ulmic and humic acid		125·50	
	Carbonic acid, expelled on boiling		88·20	
	Other organic matters (containing 3·59 of nitrogen)		142·60	
				395·66
	Mineral matters (ash)	368·98		
Viz.	Soluble silica		1·50	
	Phosphate of lime, with a little phosphate of iron		15·31	
	Carbonate of lime		34·91	
	,, magnesia		25·66	
	Sulphate of lime		4·36	
	Chloride of sodium		45·70	
	,, potassium		70·50	
	Carbonate of potash		170·54	
				368·98
	Total per gallon			764·64

These analytical results suggest the following remarks:—

1. It will be seen that these drainings contain a good deal of ammonia, which should not be allowed to run to waste.

2. They also contain phosphate of lime, a constituent not present in the urine of animals. The fermentation of the dung-heap thus brings a portion of the phosphates contained in manure into a soluble state, and enables them to be washed out by any watery liquid that comes in contact with them.

3. Drainings of dung-heaps are rich in alkaline salts, especially in the more valuable salts of potash.

4. By allowing the washings of dung-heaps to run to waste, not only ammonia is lost, but also much soluble organic matter, salts of potash and other inorganic substances, which enter into the composition of our crops, and which are necessary to their growth.

II. *Drainings from another Dung-heap.*

These drainings were not so dark-coloured as the preceding ones. Like the former liquid, it was neutral, but gave off ammonia on boiling and on addition of quick lime.

Hydrochloric acid produced a dark-brown coloured flaky deposit, leaving the liquid only pale yellow.

The amount of the precipitated humus acids was much smaller than in the preceding liquid.

For want of a sufficient quantity of liquid, only the amount of solid matter contained in it could be determined.

An imperial gallon on evaporation furnished 353·36 grains of solid matter, dried at 212° Fahr.

III. *Drainings from a third Dung-heap.*

A dung-heap, composed chiefly of mixed fresh horse, cow's or pig's dung, furnished the material for the third analysis of drainings.

This liquid was much darker than the two preceding liquids, possessed an offensive smell, although it contained no sulphuretted hydrogen. It was neutral to test-paper, consequently did not contain any free or carbonate of ammonia. On heating, ammonia escaped, apparently, however, in much smaller quantities than from the preceding drainings.

This liquid was collected at a time when no rain had fallen for several weeks, which circumstance accounts for its greater concentration. It was submitted to the same course of analysis as the first drainings.

7000 grs. evaporated to dryness produced 135·774 grs. of dry matters; and this quantity, on burning in a platinum dish, furnished 62·58 grs. of mineral matters. A separate portion was used for the determination of the amount of ammonia present in the form of salts; and another portion of liquid, acidulated with a little hydrochloric acid evaporated to dryness, was employed for the determination of the whole amount of nitrogen.

By deducting the amount of nitrogen found in the ammoniacal salts from the total amount of nitrogen obtained by combustion of the solid matter with soda-lime, the proportion of nitrogen contained in the organic substances of these drainings was ascertained.

The following Table represents the composition of the solid substances found in one imperial gallon of drainings from fresh manure:—

Composition of Solid Matters in one Gallon of Drainings from Fresh Farmyard Manure.

Ready-formed ammonia (principally present as humate and ulmate of ammonia)	15·13
* Organic matters	716·81
* * Inorganic matters (ash)	625·80
Total amount of solid matter in one gallon of drainings	1357·74
Containing nitrogen	31·08
Equal to ammonia	37·73
* * 625·80 of ash consisted of:—	
Silica	9·51
Phosphates of lime and iron	72·65
Carbonate of lime	59·58
Sulphate of lime	14·27
Carbonate of magnesia	9·95
" potash	297·38
Chloride of potassium	60·64
" sodium	101·82

It will be observed that these drainings contain about double the amount of solid matter which was found in the liquid from the first heap. The composition of this solid matter compared with that of the solid matter in the liquid from the first heap, moreover, presents us with some particulars to which it may be advisable briefly to allude.

In the first place I would remark that notwithstanding the greater concentration of the third liquid, as compared with the first, the proportion of ammonia present in the form of ammoniacal salts is less than one-half; for whilst the first drainings contained in the gallon 39 grs. of ready-formed ammonia in round numbers, the third drainings contained only 15 grs. per gallon.

It thus appears that drainings from manure-heaps in an advanced stage of decomposition contained, as may be naturally expected, a larger proportion of ready-formed ammonia than the liquid which flows from heaps composed of fresh dung. It is further worthy of notice that the first drainings contained nearly all the nitrogen in the form of ammoniacal salts, whilst the drainings from fresh dung contained the larger proportion of this element in the form of soluble organic substances. The most important constituent of farmyard manure, *i. e.*; nitrogen, thus is liable to be wasted in the drainings, whether they proceed from rotten or fresh manure, for in either case it passes off in a soluble state of combination.

Whilst speaking of the nitrogen in the drainings of dungheaps I ought to mention that in both the liquids examined in detail I have detected readily the presence of nitric acid. In the liquid from fresh manure there were apparently mere traces of nitrates, but in that from rotten dung the proportion of nitric acid was so considerable that I hoped to be able to determine it quantitatively. But I found the large amount of soluble organic matter to interfere sadly with the nitric acid determination; and, unable to supply for the present correct results, I merely mention the fact that these liquids contained nitrates, and trust to be able to supply this deficiency in these analyses at a future period.

In the next place I would observe that the proportion of organic and inorganic matters bear to each other a different relation in the first and in the third liquid.

In the liquid from rotten dung the proportion of mineral matter exceeds that of organic substances, and in the third liquid the reverse is the case. We learn from this that soluble organic matters are very liable to become decomposed; and it is not unlikely that all putrescent organic matters before assuming a gaseous state are first changed into soluble matters.

In the first stage of decomposition, *i. e.*, during the active fermentation of dung, the constituents of farmyard manure are rendered more and more soluble; hence, up to a certain point the amount of soluble organic matters increases in manures. But when active fermentation in manure heaps becomes gradually less and less energetic, and finally ceases, the remaining fermented manure is still liable to great and important changes, for it is subject to that slow but steady oxidation, or slow combustion, which has been termed, appropriately, by Liebig, Eremacausis. To this process of slow oxidation all organic substances are more or less subject. It is a gradual combustion, which terminates with their final destruction.

Hence the larger proportion of organic matter in the liquid from the manure heap formed of fresh dung, in an active state of fermentation, and the smaller proportion of organic matter in the drainings of the first heap, in which the dung had passed the first stage of decomposition, and been exposed for a considerable period to the subsequent process of cremacausis, or slow combustion.

The formation of nitric acid from putrefying organic matters has long been observed, but the exact conditions under which it proceeds are by no means satisfactorily established, and much room is left to further extended investigations.

The mineral substances in the drainings from fresh dung are the same as those from rotten. Like the ash of the latter, the liquid from fresh dung-heaps contains soluble phosphates, soluble silica, and is rich in alkaline salts, especially in carbonate of potash, of which there are nearly 300 grs. in a gallon of the liquid.

Sufficient evidence is thus presented in the analyses of these liquids, that, as the drainings of both fresh and rotten dungheaps are allowed to flow into the next ditch, concentrated solutions of the most valuable constituents of dung are carelessly wasted.

With a view of preventing such a serious loss, I have suggested the propriety of carting the manure on the fields, whenever practicable, in a fresh state, and of spreading it at once. It may be objected that the application of manure in a fresh state, equivalent to winter manuring, and especially the spreading of dung, will lead to waste, inasmuch as the rain which falls during the winter and spring has much more chance of washing out fertilizing substances from dung than by applying it at the time of sowing. This objection would indeed be a valid one, if we were not acquainted with the fact that all soils containing a moderate proportion of clay possess the property of retaining the more valuable constituents of manure; but, this being the case, the objection on these grounds cannot be admitted. With more force, however, it may be made with reference to light sandy soils, and it is indeed upon such soils that manure is best applied in spring.

I would remind the reader of the interesting and important observations of Mr. Thompson with respect to the property of soils of absorbing manuring matters,* and beg to refer him to the highly important investigations of Professor Way on the same subject. The papers of Professor Way on this subject are full of interest; they embody highly important results, and constitute most valuable contributions to our agricultural literature. A careful perusal of these papers will afford strong evidence that soils not merely possess the power of absorbing and retaining gaseous ammonia, but that they also have the property of separating this fertilizer, as well as potash and other manuring matters, from their soluble combinations.

Professor Way principally operated with simple salts, and it may therefore be urged, with some plausibility, that, in the case of a highly complex mixture of soluble substances, such as that presented in the liquid portion of manure, changes may take place in the soil which lead to a waste of manure, when applied long before the crop is sown which it is intended to benefit. Thus it may be urged that it by no means follows that because a soil absorbs ammonia when a solution of sulphate of ammonia is passed through it, the same absorption will take place when an ammoniacal salt, mixed with some dozen of other substances, is passed through it.

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* Journal of the Royal Agricultural Society, vol. xi. p. 68.

Fully impressed with the force of such an argument, I was anxious to determine, by direct experiments, the changes which liquids like the drainings of dung-heaps and liquid manure undergo when brought into contact with soils, and to ascertain at the same time to what extent soils of known composition possessed the power of absorbing manuring matters from such complex liquids. It is hardly necessary to observe that the results to which the experiments to be described presently have led, apply not merely to the liquids experimented with, but extend to compound manuring matters in general and to farmyard manure in particular, for the drainings of dung-heaps may, indeed, be regarded as the very essence of dung. The deductions which can be legitimately drawn from my experiments, therefore, apply in a special manner to farmyard manure.

In order to ascertain to what extent various soils possessed the power of absorbing manuring constituents from the drainings of dung-heaps, I determined to employ a limited quantity of soil and a large excess of liquid. To this end, 2 parts by weight of liquid were well mixed with 1 part by weight of soil, and left in contact with the latter for 24 hours, after which the clear liquid was drawn off and passed through a filter.

EXPERIMENTS TO ASCERTAIN THE EXTENT OF ABSORBING PROPERTIES OF SOILS OF KNOWN COMPOSITION.

1. *Experiment made with the Drainings of Dung-heaps composed of rotten Dung.*—The drainings employed in this experiment were the same which contained in the imperial gallon 664·64 grains of solid matters, the detailed composition of which is given above. The composition of the soil used in the experiment is given below.

The surface-soil contained a good deal of organic matter, a fair proportion of clay, little sand, and a moderate proportion of carbonate of lime in the form of small fragments of limestone. It was a stiffish soil, belonging to the clay-marls. Its subsoil was richer in clay and of a more compact texture and less friable character than the surface-soil. The mechanical analyses of soil and subsoil gave the following results :—

	Surface-soil.	Subsoil.
Moisture when analysed	5·36	3·66
Organic matter and water of combination ..	25·86	8·79
Lime	14·30	26·03
Clay	34·84	56·76
Sand	19·64	4·76
	100·00	100·00

In the chemical analysis of this soil the following results were obtained :—

	Surface-soil.	Subsoil.
Moisture when analysed	5·36	3·66
Organic matter and water of combination ..	25·86	8·79
Oxides of iron and alumina	13·88	10·13
Carbonate of lime	14·30	26·03
Sulphate of lime	·56	Not determined.
Phosphoric acid and chlorine	traces	
Carbonate of magnesia	1·04	1·67
Potash	·07	
Soda	·18	
Insoluble siliceous matter	38·75	49·73
	100·00	100·00

2000 grains of this soil and 2000 grains of subsoil were mixed with 4000 grains of the liquid from rotten dung. After 24 hours the clear liquid was carefully drawn off and filtered. Its original dark brown colour was changed into a pale yellow colour. This soil thus possessed in a high degree the property of decolourizing dark-coloured liquids like the washings of dung-heaps.

1200 grains of the filtered liquid, passed through soil, were distilled in a retort nearly to dryness, and the ammonia which was given off carefully collected in an apparatus containing hydrochloric acid, and so constructed as to secure the perfect absorption of ammonia.

The amount of chloride of ammonium obtained on evaporation of the acid liquid in the receiving-vessel was ·62 grains. This gives for 1 imperial gallon of liquid passed through soil 11·49 grains of ammonia.

Originally the drainings contained, per gallon	39·36
After filtration through soil they contained, per gallon	11·49
Absorbed by 70,000 grains of soil	27·87 amm.

1000 grs. of this soil thus absorbed ·396 of ammonia.

On evaporation of another portion of the same liquid passed through soil, 1 imperial gallon of filtered drainings was found to contain :—

164·88 of organic matter.
210·20 of inorganic matter.

Before filtration through soil, the imperial gallon contained :—

268·10 grains of solid organic substances.
368·98 of mineral matters.

A considerable quantity of both organic and mineral matters thus was removed from the liquid in contact with the soil.

b. A similar experiment was made by diluting 4000 grains of the same drainings with 4000 grains of distilled water, and leaving this more dilute liquid in contact for 24 hours with 2000 grains of the same soil and 2000 of subsoil.

The filtered liquid contained in the gallon :—

Ammonia	6·91
Organic matters	118·50
Mineral matters	147·36
Total amount of solid matters in gallon ..	272·77

The 147·36 of mineral matters (ash) consisted of—

Silica	2·38
Phosphates of lime and iron	1·54
Carbonate of lime	79·72
,, magnesia	6·17
Sulphate of lime	7·92
Chloride of sodium	18·90
,, potassium	26·44
Carbonate of potash	4·29

Originally the liquid employed in this experiment contained 19·68 grains of ammonia to the gallon. After passing through half its weight of soil it contained only 6·91 grains of ammonia. Consequently 12·77 were retained by 35,000 grains of soil, and 1000 grains of soil absorbed ·365 grains of ammonia.

This result, it will be seen, agrees closely with the first experiment, in which undiluted drainings were used, and ascertained that 1000 grains of the same soil absorbed ·396 grains of ammonia.

In both instances it was thus found that rather more than two-thirds of the amount of ammonia present in these drainings in the form of ammoniacal salts were retained by a very limited quantity of soil.

I have purposely used a large amount of liquid in comparison with that of soil. If, under such conditions, the soil is capable of retaining two-thirds of the whole amount of ammonia present in a liquid like the one examined, it is not too much to expect that no ammonia whatever will be lost in practice by carting manure on the fields in autumn and spreading it at once. The quantity of soluble ammoniacal matters in a heavy dressing of the best dung does not amount to many pounds, and such a quantity, in relation to the weight of the soil ready to take up ammonia from the manure, is so insignificant that the most scrupulous may rest satisfied that in a soil containing even a small proportion of clay no ammonia will be lost by dressing the fields in autumn.

Other no less important changes than those referring to the absorption of ammonia will strike the reader to have taken place in these drainings left in contact with the soil.

For better comparison's sake, I will give the composition of the drainings before and after passing through soil, and then make a few additional remarks which are suggested by such a comparison.

Composition of Drainings from Rotten Dung.

1 imperial gallon contains—

	Before Filtration through Soil.	After Filtration through Soil.
Ammonia (in the form of ammoniacal salts)	19·68	6·91
Organic matters	134·05	118·50
Silica	·75	2·38
Phosphates of lime and iron	7·90	1·54
Carbonate of lime	17·46	79·72
Sulphate of lime	2·18	7·92
Carbonate of magnesia	12·83	6·17
Chloride of sodium	22·85	18·90
,, potassium	35·25	26·44
Carbonate of potash	85·27	4·29
	338·22	272·77

It will be observed that this liquid, in passing through the soil, has undergone a striking change. Leaving unnoticed several minor alterations in the composition of the original liquid, I would direct special attention to the very small proportion of carbonate of potash left in the drainings after contact with this soil. It will be seen that, out of 85 grains of potash contained in the original liquid, no less than 81 grains have been retained by the soil. This is a result of the greatest importance, inasmuch as it shows that the soil possesses, in a remarkable degree, the power of removing from highly-mixed manuring substances not only ammonia from ammoniacal salts, but also the no less important soluble potash compounds. According to this result, 1000 grains of soil absorb no less than 2·313 grains of carbonate of potash. But, in addition to carbonate of potash, a considerable quantity of chloride of potassium is retained in this soil by passing the washings from rotten dung through it: for it will be observed that nearly 9 grains of this salt, or, in exact numbers, 8·81, were retained in the soil. The avidity of the soil for soluble salts of potash is the more remarkable, as it offers a striking contrast to the apparent indifference of this soil to absorb soda from its soluble combinations; for it will be seen that the liquid, after filtration through the soil, contains only about 4 grains less of common salt in the gallon than before filtration.

In a purely chemical point of view, soda salts are closely allied to salts of potash, and yet there is a marked difference observable in the power of this soil, at least, to absorb the one or the other alkali.

As regards the practical effect which salts of soda and potash are capable of displaying with reference to the nutrition of plants, the former are not to be compared to the latter in point of efficacy. It was believed at one time that soda was capable of replacing potash in the ashes of our crops, but this opinion was not based on trustworthy evidence. On the contrary, the best and most extensive series of ash analyses of our crops show that whilst the amount of potash, within certain limits, is constant in the ashes of plants, that of soda, especially of chloride of sodium, is liable to great fluctuations, arising, no doubt, from local conditions of the soil.

The fact that soils are capable of absorbing potash from soluble manuring matters, whilst no special care is manifested by them to retain the equally soluble soda salts, appears to me to account, to some extent at least, for the comparative constancy of the amount of potash in the ashes of our crops, as well as for the fluctuation of the amount of soda in the same.

The power of soils to retain potash in large proportions must have the effect of converting the salts of potash in the manure applied to the land into compounds which, though not altogether insoluble in water, are yet sufficiently difficult of solution to permit only a limited and fixed quantity to enter into the vegetable organism in a given period. The case is different with salts of soda; for as soils do not appear to retain them in any high degree, and plants have no selecting power, but absorb by endosmosis whatever is presented to the spongioles of their roots in a state of perfect solution, it is evident that more soda will enter into the plants when grown on a soil naturally abounding in this alkali or heavily dressed with common salt, than when grown upon a soil poorer in soda.

We have here, at the same time, an interesting illustration of the fact that the soil is the great workshop in which food is prepared for plants, and that we can only then hope to attain unto a more perfect knowledge of the nutrition of plants and the best means of administering to their special wants when we shall have studied, in all their details, the remarkable changes which we know, through the investigations of Mr. Thompson and Professor Way, take place in soils when manuring substances are brought into contact with them. The subject is full of practical interest, but also surrounded by great difficulties, which, it appears to me, can only be overcome when the investigation is taken up in a truly scientific spirit, without reference to the direct application which, in due course, no doubt, well-established chemical principles will receive in agriculture. It is the undue anxiety to obtain at once what is popularly called a practical result, the grasping after results which at once may be translated into so many bushels of corn, which is a great hindrance to the more rapid advancement of agricultural science; and it is to be hoped, for the sake of the true interests of the really practical man, that the voice of those capable of understanding and appreciating purely scientific results will be sufficiently powerful to keep in check the too great anxiety for immediate results.

In the next place, I beg to direct attention to the absorption by the soil of the phosphates contained in drainings. If it is borne in mind that the soil and subsoil with which the liquid was brought into contact contained a large excess of carbonate of lime, it is not more than would be naturally expected, if we should see the soluble phosphates of the original drainings converted by the carbonate of lime into insoluble compounds.

Having already remarked upon the power of this soil to retain ammonia, I beg in conclusion to point out the large quantity of carbonate of lime in the filtered liquid as worthy of notice. This large amount of carbonate of lime is easily explained by the presence of much lime in the soil. Before filtration the liquid contained only about 17½ grains of carbonate of lime, and after filtration as much as nearly 80 grains. Thus whilst potash and ammonia are absorbed by the soil, lime is dissolved and passes into the liquid, which is filtered through the soil. Not only is the quantity of carbonate of lime considerably increased in the filtered drainings, but that of sulphate of lime in a minor degree also.

It is highly satisfactory to me to find the observations of Professor Way with respect to the relative power of soils to retain ammonia, potash, soda, and lime, confirmed in my experiments with a liquid containing a number of fertilising agents required by our crops.

The composition of a liquid like the washings from dung-heaps, when passed through soils, necessarily must be influenced by the composition of the soils employed in the experiment. The results here given and the remarks just made therefore hold good only with soils of a similar composition to the one used in this experiment.

Before describing the next filtration experiments, I may state that I have thought it a matter of some interest to examine what amount of solid organic and inorganic matter a given quantity of pure water would dissolve from the soil, the composition of which has been stated above. Accordingly, one part by weight of subsoil and one part of surface-soil were mixed with four parts by weight of distilled water, and the whole, being occasionally stirred up, left to subside for twenty-four hours, after which time the water was filtered from the soil and carefully analysed.

An imperial gallon of this water was found to contain 84·88 grains of dry residue (dried at 220° F.), consisting of—

Organic matter, and a little water of combination	48·00
Carbonate of lime	26·84
Sulphate of lime	5·73
Phosphate of lime, with a little oxide of iron	·65
Carbonate of magnesia	·50
Chloride of sodium	1·25
Potash	·99
Silica	·92
	84·88

The amount of organic matter in this water is very great; it arises from the great excess of decomposing organic remains in the soil, and imparted to the water a yellow colour and disagreeable smell, not unlike the smell of water in which flax is steeped. It will be further observed that even pure rain-water is capable of rendering soluble a considerable quantity of all those mineral constituents which are found in the ashes of our crops, and therefore are necessary to their growth.

2. *Filtration experiment made with the drainings of a dung-heap composed of fresh-mixed farmyard manure.*—Having ascertained in the previous filtration experiments that a soil containing a good deal of clay and lime is capable of removing from compound manuring substances all the more valuable fertilising constituents, I was anxious to determine to what extent soils deficient in both clay and lime possessed the property of retaining fertilising substances from drainings of dung-heaps. The composition of the liquid used for this experiment is given above; it is the same liquid collected from a fresh dung-heap which in a gallon contained 1357·74 grains of solid matter.

The soil selected for experiment was a light, sandy, red-coloured, very porous soil, containing, as will be seen by the following analysis, only little clay and still less lime, but a good deal of organic matter. It was submitted to a minute and careful mechanical and chemical analysis, and furnished the results embodied in the subjoined tables:—

1. *Mechanical Analysis.*

Moisture	3·45
Organic matter and water of combination	13·94
Coarse white quartz sand	47·00
Fine red sand and a little clay deposited from water on standing 5 minutes	19·82
Coarse clay deposited on standing 10 minutes	2·82
Fine clay deposited from water on standing for 1 hour	6·30
Finest clay kept in suspension in water after standing longer than 1 hour	6·67
	100·00

It appears from these results that nearly half the weight of this soil consists of pure white coarse quartz-sand, which can be readily separated by washing. The deposit which settled from water after five minutes' standing consists chiefly of fine red sand mixed with very little clay. The remainder is clay in a very finely subdivided state, besides humus and some water of combination. The result of the mechanical examination thus shows that the proximate constituents of this soil are present in an advanced state of decomposition. In the following tabular statement the minute chemical composition of the same soil is given :—

2. *Chemical Analysis.*

Moisture	3·45	
* Organic matter and water of combination	13·94	
Carbonate of lime	·31	Containing together ·39 of lime.
Sulphate of lime	·53	
(Containing SO_3 ·31)		
Alumina	14·74	
Oxide of iron	5·87	
Magnesia	·18	
Potash (in a state of silicate)	·25	
Chloride of sodium	·11	
Phosphoric acid, combined with iron and alumina (equal to bone-earth ·131)	·061	
Soluble silica (soluble in dilute potash)	7·42	
Insoluble siliceous matters (almost entirely white sand)	53·32	
	100·181	

* Containing nitrogen	·192
Equal to ammonia	·228

5000 grains of this soil were mixed with 5000 grains of liquid from fresh manure heap, and 5000 grains of distilled water. After twenty-four hours the clear liquid was filtered from the soil, and found to be somewhat lighter-coloured than before ; but, in comparison with the decolourising properties of the clay-soil used in the experiment with the drainings from rotten dung, its effect upon the dark-coloured organic compounds in the liquid appeared to be weak.

A portion of the filtered liquid was used for the determination of the ammonia contained in it in the form of volatile salts, or, at any rate, in the form of salts which yield ammonia on boiling their watery solution. Another portion was evaporated to dryness, and the amount of nitrogen in the dry residue determined. The rest of the liquid was used for the determination of solid matter and ash.

Leaving unnoticed the details of these various determinations, I shall state at once the composition of the drainings passed through this light sandy soil. I may observe, however, that the ammonia and nitrogen, as well as the total amount of solid matter and ash in it, were determined twice, and closely agreeing results were obtained. An imperial gallon of liquid from fresh manure passed through red sandy soil contained :—

Ready formed ammonia (chiefly as ulmate and humate of ammonia)	7·13
* Organic matter	301·70
* * Inorganic matters (ash)	245·70
Total amount of solid matter p. gal. of liquid	554·53
Containing nitrogen	12·60
Equal to ammonia	15·30

The ash (245 grs.) consisted of—

Silica	15·08
Phosphates of lime and iron	33·14
Carbonate of lime	21·22
Sulphate of lime	trace
Carbonate of magnesia	2·36
,, potash	85·93
Chloride of potassium	39·49
,, sodium	48·48

It appears distinctly from these results that this soil possessed the power of absorbing manuring matters in a much smaller degree than the stiffer soil used in the preceding experiment. This agrees well with previous observations, in which it was found that soils in which sand greatly preponderates exhibit these useful absorbing properties in the least, and others in which clay preponderates, in the highest degree. The soil used in the last experiment, it is true, contains a fair proportion of alumina, but this alumina exists principally in a free state, or at all events it is so loosely united with silica that it can be easily separated from this combination by dilute acids. The absorbing properties of soils, it thus appears, do not depend so much on the alumina contained in soils in a free state, but, as shown already by Professor Way, rather on peculiar combinations, into the composition of which alumina enters. It is more than probable likewise that the different agricultural clays contain double silicates, to which Professor Way refers the absorbing properties of soils, in very variable proportions, and that consequently the agricultural capabilities of soils, so far as they are dependent upon these important properties, cannot merely be ascertained by determining the proportion of clay which they contain. In short, the mere analysis of soils is not calculated to give us a fair idea of their true characters ; nor does it appear to me to afford sufficient indications of what is really wanting in a soil in order to make it yield up heavy crops.

The nature of the changes which these drainings from fresh farmyard manure underwent in contact with the soil, the analysis of which has just been given, will appear by glancing at the subjoined diagram, in which the composition of these drainings is stated before and after filtration through soil. An imperial gallon of liquid contained—

	Before Filtration	After Filtration
	through Soil.	
Ready formed ammonia	7·67	7·13
* Organic matters	358·40	301·70
** Inorganic matters (ash)	312·90	245·70
Total amount of solid matter per gallon ..	678·97	554·53
Containing nitrogen	15·54	12·60
Equal to ammonia	18·86	15 30
Silica	4·75	15·08
Phosphates of lime and iron	36·32	33·14
Carbonate of lime	29·79	21·22
Sulphate of lime	7·14	trace
Carbonate of magnesia	4·98	2·36
" potash	148·69	85·93
Chloride of potassium	30·32	39·49
" sodium	50·91	48·48
** Total of ash	312·90	245·70

The amount of ready-formed ammonia retained by this soil, it will be seen, is very trifling indeed; nor is the proportion of nitrogen which is retained in the soil in the form of nitrogenised organic matters very great. We are thus presented here with an instance, showing clearly that there are soils which do not possess the power of absorbing ammonia in any marked degree. In the case of such soils as the one used in this experiment, I think it would be hazardous to apply manure in autumn. I may also mention a curious circumstance in connection with this soil. I am informed that guano and ammoniacal manures do not seem to do much good on this soil, whilst the application of nitre is followed with marked effect.

The most decided change in the composition of this liquid is observable in the proportion of potash which is contained in the filtered liquid; for, as in the case of the former soil, a considerable quantity of this alkali has been absorbed by the sandy soil. On the other hand, there is only a trifling amount less chloride of sodium in the liquid after than before filtration, thus affording another proof that the power of soils to absorb potash is much greater than to retain soda.

It will likewise be observed that, instead of yielding carbonate of lime to the liquid which was brought into contact with the light soil, some carbonate of lime and all the sulphate of lime were actually retained. This soil, it will be remembered, is deficient in lime. Perhaps it may not even contain sufficient to supply the wants of some crops, and seems to be endowed with the property of absorbing lime from manuring matters, affording thereby an interesting instance how special provision is made in soils for the absorption of those constituents which are naturally deficient in them, and which are required in considerable quantities for the healthy and luxuriant growth of our crops.

In the preceding experiment just the opposite took place; for it will be remembered that the drainings, after passing through the calcareous clay soil, contained a great deal more of lime than before filtration. Similar differences will be observed with respect to other constituents originally present in the liquid and retained in the stiff and in the sandy soil in very different proportions. I abstain from noticing any minor changes in the composition of the filtered liquid, nor shall I indulge in any speculations respecting the compounds in the soil which have contributed to these changes and the new combinations in the soil which may have resulted from them. Our present knowledge on the subject is far too imperfect to warrant us to theorise profitably on these matters; I therefore prefer to send forth for the present my analytical results without any further comment, and conclude by expressing the hope that I may be permitted to continue similar inquiries into the physiology of soils, and do not doubt that great and important practical benefits will in due course be derived from increased knowledge of the properties of soils and the changes manuring matters undergo when in contact with them.

Royal Agricultural College, Cirencester,
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ON THE USE OF

LIME, MARL, AND SHELL-SAND

IN

AGRICULTURE.

AN INQUIRY UNDERTAKEN AT THE REQUEST OF THE BATH AND WEST OF ENGLAND AGRICULTURAL SOCIETY.

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ON THE

USE OF LIME, MARL, AND SHELL-SAND.

THE use of lime in agriculture dates from a very remote period, and its utility as one of the cheapest and most effective means for raising the fertility of many soils is generally acknowledged by all who take an interest in good farming. At the same time it is conceded, even by the best friends of this useful mineral manure, that the application of lime and marl is often abused, or at any rate that the money periodically spent in liming might be more judiciously applied by diminishing the usual application of lime, and expending the money thus saved in the purchase of artificial manures.

The effects of the first application of lime or marl on newly broken-up land that has been long out of cultivation are truly marvellous, and for a number of years the increased fertility of the land can be maintained undiminished. But it is well known that no soil, however fertile it may be originally, can be maintained in good heart by the use of lime alone. Experience, indeed, has shown that the constant application of lime to the land, on the expense of ordinary manuring, sooner or later will reduce the fertility of the land, at first greatly increased by lime, until it ceases to produce remunerative crops and enters into the condition in which it is said to have been exhausted by lime, or to have been overlimed.

Some soils are much more readily exhausted by repeated applications of lime than others. There are many soils in the West of England which appear to require scarcely anything else but lime in order to make them yield abundant crops. This circumstance perhaps explains the fact that probably in no part of this country lime is so much esteemed and so generally applied to the land as in the West of England. Again, there are soils which are not improved at all by lime, and whole districts in which lime or marl are never used by good farmers. The character of the soil thus materially affects the use of lime in agriculture. Furthermore, it is a well-known fact that the form in which lime is used influences the result which it is expected to produce. And lastly, we would observe that the effects of lime on vegetation are greatly modified according to the use of good or bad lime. The quality of lime, of course, is dependent upon that of the limestone from which the former is made.

Continued attention to the functions which lime exercises in relation to our cultivated crops, and the examination of several limestones, marls, samples of shell-sand, as well as a good many soils occurring in the district over which the operations of the Bath and West of England Society extends, have enabled me to draw up the following Report, which I trust will be generally useful as a guide to those who require information respecting the use of lime in agriculture; and to be of more particular interest to many of the members of the Bath and West of England Agricultural Society.

I propose to speak, in the first place, of the forms in which lime is used in agriculture, and under this head to refer especially to the composition of a good many limestones, marls, and varieties of shell-sand that occur in the West, and are extensively used, chiefly for agricultural and to a minor extent for other purposes. In the next place, it will be my duty briefly to allude to the functions of lime upon the soil and vegetation, for a proper appreciation of the first principles involved in this subject is absolutely necessary in order that the farmer may derive the full advantage which lime is capable of affording. Under the third and last general head I shall have to offer some remarks on the application of lime, marl, and shell-sand to the soils in the West of England, and shall then more specially notice the composition of soils in different localities within the circle of the Society's operations, and shall illustrate by some examples which actually came under my notice some of the general principles that ought to regulate the application of lime to the land.

I. On the forms in which Lime is used in Agriculture.

Lime is used in agriculture generally in one of the following forms:—

1. Burnt and slaked lime.
2. Chalk.
3. Marl.
4. Shell and coral sand.

The characters and composition of these different forms in which lime is applied to the land will be described in the order here given.

Burnt, or quicklime, as every one knows, does not occur as a natural mineral, but is produced on burning limestone in a kiln. The quantities of quicklime depend in a great measure on the composition of the stone from which it is obtained.

1. *On the Composition of several kinds of Limestone found in the West of England, and on Quick and Slaked Lime.*

The bulk of all limestone consists of carbonate of lime, *i. e.* a combination of carbonic acid with lime. Pure white marble consists almost entirely of this combination, and in some of the best descriptions of ordinary limestone the proportion of carbonate of lime amounts, as we shall see presently, to 94 or even 96 per cent. Usually, however, the proportion of carbonate of lime is smaller, since carbonate of magnesia, oxides of iron, some alumina, and more or less silicious matters, and a few other mineral matters that need not be mentioned here in detail, enter into the composition of ordinary limestones.

The colour, degree of hardness, and general appearance of the various kinds of limestones depend in a great measure on the relative proportions in which the constituents just named occur in them. The differences which prevail in the various kinds of limestones, however, are not entirely due to variations in composition, but they can be traced likewise to purely physical causes which have been in operation when the solid limestones were formed. Frequently the composition of different limestones presents us with but slight variations, whilst their texture, degree of hardness, and adaptation for practical purposes exhibit great contrasts. According to the prevailing physical and chemical properties, limestones may be conveniently classed as follows:—

a. Building stones.
b. Hydraulic limestones.
c. Agricultural limestones.

a. Limestones used for building.—Some of our best building-stones occur in the West of England, as, for instance, the celebrated Bath stone and similar oolitic limestones which occur in the neighbourhood of Bath and Bristol. Good building-stones are hard and uniform in texture, and capable of resisting atmospheric influences in a higher degree than ordinary limestones, which, on account of the want of this essential qualification, are not generally used for building purposes. An excellent oolitic building-stone is the Dundry stone, which is quarried near Bristol. A specimen of this stone, analysed by me, yielded the following results:—

Water, driven off at 212° Fahr.	·230
Water of combination	·110
Carbonate of lime	96·146
Sulphate of lime	·153
Magnesia	·470
Protoxide of iron	·540
Alumina	·120
Soda	·044
Potash	·296
Silica	1·350
	99·459

The church of St. Mary Redcliffe, Bristol, is built of this stone; the tower is of the twelfth, the body of the church of the fifteenth century. Mr. Godwin, the restorer of this beautiful church, informs me that he considers the Dundry stone quite as good as Caen stone, which for some time was employed in the restoration of this church, but which is now superseded by the Dundry stone, of which the church was originally built.

As it may not be uninteresting to compare with the preceding analyses that of Caen stone, I may be allowed to mention here an analysis of that stone and also two others of oolitic limestones used for building. One of the latter represents the composition of the oolitic limestone from Downside, Brackley Combe, near Bristol; the other that of the oolitic limestone, Combe Down, Bath. The three subjoined analyses were made by Messrs. Ransome and Cooper:—

Composition of Oolitic Limestone, Caen, Normandy.

Water	1·91
Silica	13·71
Protoxide of iron	·73
Carbonate of lime	82·58
Magnesia	·48
	99·41

This stone is used for internal work in the new Houses of Parliament, also in part of Westminster Abbey and in Canterbury Cathedral. It is very fine-grained and well adapted for delicate carvings.

Composition of Oolitic Limestone from Downside, Brockley Combe, near Bristol.

Water	·47
Silica	4·64
Peroxide of iron	·27
Carbonate of manganese	·55
,, ,, iron	·34
,, ,, lime	92·58
,, ,, magnesia	·25
	99·10

Composition of Oolitic Limestone, Combe Downs, Bath.

Water	·74
Silica	·85
Protoxide of iron	1·04
Alumina	·61
Carbonate of lime	95·74
,, ,, soda	·71
Magnesia	·23
Chloride of sodium	·05
	99·97

This stone was used in the restoration of Henry the Seventh's Chapel, Westminster Abbey, but appears readily to decay, and is decidedly inferior to Dundry stone, although it differs but little from the latter in composition.

b. Hydraulic Limestones.—A hydraulic limestone is a stone which, on burning, furnishes lime that sets under water. The physical characters of hydraulic limestones vary exceedingly; their colour generally is dark blue or brown, more rarely yellow, and, generally speaking, they are hard and compact. This description of limestone is always an impure form in which carbonate of lime occurs in nature, and generally, though not always, the most impure limestones produce the best hydraulic lime or cement on burning. The impurities are chiefly magnesia, sand, clay, silicate of lime, and alkaline silicates. Hydraulic limestones are not confined to a particular geological formation, but they abound in the lias formation. Lias lime, therefore, is commonly regarded as a bad agricultural lime, and for this reason seldom used by farmers if another description of lime can be procured at a reasonable price. Some silurian limestones also form good cements after burning.

In order to convey to the reader an idea of the composition of a good hydraulic limestone, I give the analysis of a limestone which occurs in the neighbourhood of Totnes. The specimen which I analysed was forwarded to me by Mr. Watson, of Dorsly, near Totnes, who informs me that it was taken from

Habertonford quarry, situated just at the end of the trap-rock district. When used for building walls it forms a mass as hard as rock, and it sets as a cement when used for forming ponds, for which purpose it is largely employed.

Composition of Hydraulic Limestone from Habertonford Quarry, near Totnes.

	Dried at 212° Fahr.
Water of combination	1·51
Oxides of iron and alumina	1·59
Carbonate of lime	83·86
Sulphate of lime	·10
Magnesia (in the state of silicate)	·63
Insoluble silicious matter (clay and sand)	12·06
Alkalies (in the state of silicates)	·25
	100·00

A much inferior cement, or, properly speaking, a bad lime, is produced on burning a lias-limestone which occurs at Stapleton, near Bristol. A specimen of this stone gave, on analysis, the following results:—

Water of combination, and a little moisture ..	2·12
Oxides of iron and alumina	2·06
Carbonate of lime	84·64
,, ,, magnesia	·69
Insoluble silicious matter (clay and sand)	10·49
	100·00

Other lias limestone from the West of England will be described presently under agricultural limestones.

To give an example of a silurian limestone, which partakes of the characters of a hydraulic lime after burning, the following analysis, to which I submitted a limestone from Pembrokeshire, may be stated:—

Composition of Silurian Limestone from Clynderwen, Pembrokeshire.

Moisture, driven off at 212° Fahr.	·18
Water of combination	·52
Oxides of iron and alumina	·91
Containing phosphoric acid	(·022)
Carbonate of lime	81·70
Sulphate of lime	·10
Carbonate of magnesia	·79
Insoluble silicious matter	15·86
	100·06

It will be seen that all three limestones are very impure, but although the amount of carbonate of lime is larger in the Habertonford lime than in the two others, it produces a better cement, thus showing that it is not merely the presence of certain impurities, but also the state of combination in which they occur, which renders one limestone better adapted for the making of cement than another.

c. Agricultural Limestones.—For agricultural purposes all limestones are applicable which contain above 60 per cent. of lime and are free from impurities, the presence of which in limestones, often much richer in lime, has the effect of yielding a lime, after burning, that sets under water.

The comparative value of different limestones varies exceedingly, since some kinds produce, on burning, products that slake with difficulty, and are, in comparison with others, poor in lime; whilst some when burned in the kiln readily slake and furnish a voluminous minutely-subdivided powder rich in lime. These differences are due to natural variations in the composition of limestones from different geological formations, as well as to variations in the composition of limestones of the different beds of one and the same formation. Generally speaking, the higher the percentage of carbonate of lime, and the smaller the amount of foreign matters, which a limestone naturally contains, the better it is adapted for burning. However, the physical character, no less than the chemical composition, of limestones, has to be regarded in estimating their fitness for burning. The hard, compact, crystalline kinds generally produce a better lime—other circumstances being equal—than softer, more friable, and lighter specimens. There are, indeed, some limestones, rich in carbonate of lime, which, on account of their slight cohesive power and porosity, cannot be economically employed for the making of quicklime. But, on the whole, the composition of limestones affords excellent indications as to their fitness for burning into quicklime. I shall, therefore, consider in detail the composition of several specimens of limestones from various localities in the West of England.

The limestones which I had an opportunity of examining geologically are distinguished as Carboniferous, or mountain limestone; Lias limestone; Silurian limestone; Caradoc sandstone; Oolitic limestone.

Mountain limestone occurs in great perfection in South Wales and in Devonshire. In the last-mentioned county it often forms isolated hills of very limited extent, and as the soils in the neighbourhood are peculiarly destitute of lime, these mountain limestone hills are considered a great boon to the agricultural community.

Mountain limestone also is found in Somersetshire, where it and lias lime are much employed for agricultural purposes.

The colour of mountain limestone is various: some beds are light-grey, others yellow, blue, dark-grey, almost black. The dark-coloured specimens are often very dense, crystalline, hard, and not unlike basalt. Many beds are full of shells, others almost destitute of fossil remains. In short, the aspect and physical characters of mountain limestones, no less than their composition, vary considerably, as will be seen by inspecting the subjoined analyses. In the first place, I shall notice the composition of an excellent light-coloured, compact mountain limestone from South Wales, which in the following tabulated results is grouped together with a limestone from Dartbridge, near Totnes, on account of the similarity in composition which both exhibit.

Composition of Mountain Limestone from South Wales, No. I.; *and Limestone from Dartbridge Quarry, Totnes*, No. II.

	No. I.	No. II.
Water	·286	·49
Oxides of iron and alumina	·390	·93
Carbonate of lime	96·350	95·57
„ „ magnesia	2·289	·85
Insoluble silicious matter	·858	2·05
	100·173	99·85

In both stones the percentage of carbonate of lime is high; both are compact, crystalline, and give, on burning, good lime. No. 1, especially, is an excellent limestone, for the quicklime produced from it swells up very much on slaking, and hardly contains any silicious impurities.

It is often the case that two quarries, not far removed from each other, yield limestones very different in appearance and in value. By comparing the analysis of the limestones from Dartbridge Quarry, situated in a slate district, with that of Habertonford Quarry, and mentioned under Hydraulic limestones, the reader will at once be struck with the great variations which the stones from these two quarries exhibit. Differences equally great will be observed on comparing the Dartbridge limestone with the following analysis of a limestone from Petehole Quarry, situated in a heavy clay district in the neighbourhood of Totnes:—

Composition of Limestone from Petehole Quarry, near Totnes.

Organic matter (graphite), and a little water of combination	1·98
Oxides of iron and alumina	2·50
Carbonate of lime	71·11
Lime in a state of silicate	1·33
Sulphate of lime	1·14
Magnesia in a state of silicate	·99
Insoluble silicious matter	20·95
	100·00

Mr. Watson, of Dorsley, who kindly forwarded to me these three limestones occurring in the neighbourhood of Totnes, informs me that Dartbridge Quarry is situated 8 miles from Petehole Quarry and 12 miles from Habertonford Quarry, and Petehole Quarry is situated 4 miles from Habertonford Quarry.

Like the Habertonford limestones, that from Petehole Quarry contains a large quantity of insoluble silicious matter and sand. The lime which enters into its composition does not all occur as carbonate, but some of it is in combination with sulphuric acid, as well as with silicic acid. The proportion of sulphate of lime in this limestone is much larger than usual. It also contains organic matter, in the shape of graphite,—a constituent which rarely enters into the composition of limestones. This stone appears to be a limestone changed from its original constitution by subsequent volcanic action and admixture of the products of violent subterranean commotion.

I have not learned whether or not the Petehole limestone makes good lime, but am inclined to think that it will not. At any rate, it is evident that this stone, which contains only 71 per cent. of carbonate of lime, cannot produce a lime as valuable for agricultural purposes as the limestone from Dartbridge Quarry, in which stone no less than 95 per cent. of carbonate of lime occurs.

In the next Table I have arranged the results of two specimens of Lias limestone from Aberthaw, Glamorganshire.

Composition of Lias Limestones from Aberthaw, Glamorganshire.

	1st Specimen.	2nd Specimen.
Moisture	·260	·666
Water of combination	·290	
Oxides of iron and alumina	·483	1·333
Phosphoric acid	·167	
Carbonate of lime	89·870	89·332
Sulphate of lime	·110	not determined.
Carbonate of magnesia	·880	2·336
Insoluble silicious matter	8·120	6·333
	103·180	100·00

Both analyses were made with stones from the same quarry. It will be seen that No. 2 contains more magnesia and less insoluble silicious matter than No. 1, and that both contain about the same quantity of carbonate of lime. The quicklime obtained from it is rich in lime, but, like most Lias limes, it does not swell much on slaking, and is better adapted for cement-making than for quicklime. Still, in the absence of a better lime, it is usefully employed for agricultural purposes. Lias lime, when used for agricultural purposes, I may observe, does not readily slake spontaneously, like good mountain-lime, and often requires to be mixed at once with water in order to become reduced to powder.

Silurian limestones, as well as limestones belonging to the Caradoc sandstone, occur in Glamorganshire and Pembrokeshire. An analysis of a Silurian limestone has been given already; I will now place on record the analysis of a limestone which occurs in Pembrokeshire, and which by geologists would be termed Caradoc sandstone:—

Composition of Caradoc Sandstone, Pembrokeshire.

Water of combination	·13
Oxides of iron and alumina	2·66
Carbonate of lime	81·55
" " strontia	3·77
" " magnesia	1·04
Sand and some insoluble silicious matter	11·02
	100·17

It is worthy of remark that stones called in common life sandstones, may, like the specimen of Caradoc sandstone, contain a high percentage of carbonate of lime, and be well adapted for burning into quicklime. This is actually the case with the Caradoc sandstone; it produces indeed in burning a valuable lime, since it slakes readily and yields what is technically called a tolerably fat lime.

It will be seen that the analysis shows about 11 per cent. of sand and insoluble silicious matter, which is more than the proportion of insoluble matters in the preceding Lias limestones. Notwithstanding this larger amount of insoluble silicious matter in the Caradoc sandstone, it yields a better lime than the Lias limestone, which circumstance is explained by the fact that the insoluble matter in the latter occurs principally as clay, whilst in the former it exists chiefly as sand.

Apart from the practical interest that attaches to this analysis, it is interesting in a mineralogical point of view, inasmuch as it exhibits a considerable quantity of carbonate of strontia, a constituent which so far as I know has not been noticed before in Caradoc sandstone.

In the preceding analyses the amount of carbonate of lime and that of the ordinary impurities, such as magnesia, oxide of iron, sand and clay, which accompany the former in agricultural limestones, has been determined; but with one exception no notice has been taken of the small proportions of phosphoric and sulphuric acid, which it is well known occur occasionally in limestones.

As phosphoric acid is a valuable fertilising constituent, it appeared to me not unlikely that the agricultural value of different kinds of lime might be influenced by the relative proportions of phosphoric and sulphuric acid which they contain. In order to ascertain if the best agricultural limestones really contain more phosphoric acid than others less valued by the farmer, I procured several kinds of limestones, and submitted them to a refined process of analysis, in which especial care was taken to ascertain accurately the amount of phosphoric acid.

The results of this examination are embodied in the subjoined Table:—

Composition of Carboniferous, or Mountain Limestone, from Williamson, Pembrokeshire (No. I.); *Mountain Limestone from Ashburton, Devonshire* (No. II.); *and Silurian Limestone from Llandewi, Pembrokeshire* (No. III.).

	No. I.	No. II.	No. III.
Moisture	·050	·200	·120
Water of combination	·170		·230
Oxides of iron and alumina	·193	·718	·683
Phosphoric acid	·057	·012	·077
Equal to bone-earth	(·123)	(·026)	(·166)
Sulphate of lime	·080	·100	·050
Magnesia	·400	1·490	·150
Insoluble silicious matter	·170	1·760	13·720
Carbonate of lime	99·080	95·490	84·740
	100·200	99·770	99·810

On comparing these analytical results with each other it will be seen:—

1. That the proportion of phosphoric acid in the less pure Silurian limestone from Llandewi is somewhat greater than in the much purer limestones from Williamson and Ashburton, and that in all three limestones the quantity of phosphoric acid is very small.

2. That the proportion of sulphate of lime or gypsum likewise is very inconsiderable in all three specimens analysed.

3. That No. III. contains nearly 14 per cent. of insoluble silicious matter, whilst No. I. contains a mere trace, and No. II. not quite 2 per cent.

4. That the proportion of pure carbonate of lime is very large in the limestone from Williamson, somewhat smaller in the Ashburton limestone, and considerably smaller in the Llandewi stone.

5. That No. I. altogether contains only 1 per cent. of foreign matters, whilst in No. II. there are 4½ per cent. and in No. III. about 15 per cent. of foreign matters.

6. That the amount of magnesia found in either of these three limestones is inconsiderable.

It follows from these analytical results that the Williamson limestone, notwithstanding the somewat smaller amount of phosphoric acid in comparison with No. III., is by far the best, and has to be considered as one of the most valuable agricultural limestones that can be found anywhere. This limestone indeed contains nearly as much pure carbonate of lime as the Carrara marble, the composition of which is stated by Wittstein, who analysed it, as follows:—

Composition of Carrara Marble.

Carbonate of lime	99·236
" " magnesia	·284
Oxide of iron	·251
Silica	none
	99·771

On burning, the limestone from Williamson yields a splendid white lime, which readily slakes spontaneously on exposure to the air, and falls to a light powder as fine as flour.

The Ashburton limestone, though not quite as good as the limestone from Williamson, is an excellent agricultural limestone. It burns well, and also falls to a fine white and light powder. This Silurian limestone, on the contrary, like the other Silurian limestone the analysis of which has been stated already, and indeed like most Silurian limestones, does not produce a very good lime.

The limestone from Llandewi, I am informed by Mr. Morgan of Haverford-West, who supplied me with most specimens of Welsh limestones, makes a red-coloured lime, which by some farmers, on account of its somewhat cheaper price, is preferred to the beautifully white and extremely light lime from Williamson. I believe, however, that it is bad economy to save a few shillings in the purchase of an inferior lime, if such a splendid lime as the Williamson lime can be easily obtained at a trifling higher price.

Oolitic limestones.—These are very common in Gloucestershire and part of Somersetshire. The best lime of the oolitic limestone series is produced from the Great Oolite or Bath stone.

Limestones belonging to the Inferior Oolite rock are invariably of less value for lime-burning than the Great Oolite rocks. Cornbrash, Forest Marble limestone, and Stonesfield slate, a variety of slaty limestone, I believe are seldom, if ever, used for the making of quicklime.

I shall first notice the composition of Great Oolite and Inferior Oolite limestone, and then give in a separate Table the composition of the other oolitic limestone rocks.

Composition of Great (No. I.) *and Inferior Oolite Limestone* (Nos. II. and III.).

	No. I.	No. II.	No. III.
Carbonate of lime	95·346	89·20	85·339
Sulphate of lime	·204	·09	Water. 2·300
Phosphoric acid	·124	·06	not determined.
(Equal to bone-earth)	(·260)	(·14)	.. ..
Magnesia	·739	·34	1·028
Oxides of iron and alumina	1·422	4·14	3·833
Soluble silica	1·016	2.75	7·565
Insoluble silicious matter	·533	3·27	
	99·384	99·85	100·065

No. I. is a good limestone, equally useful as a building stone and for burning.

No. II. cannot be used for building, but being hard does well for road mending; less valuable it is to the lime-burner.

Both these stones are from the neighbourhood of Cirencester.

No. III. occurs in the neighbourhood of Combe, near Sherborne, and resembles in its general features the specimen of Inferior Oolite limestone from the neighbourhood of Cirencester.

Composition of Cornbrash (No. I.); *Stonefield Slate* (No. II.); *and Forest Marble Limestone* (No. III.).

	No. I.	No. II.	No. III.
Carbonate of lime	89·195	84·264	81·242
Sulphate of lime	·241	·649	·737
Phosphoric acid	·177	·177	·032
(Equal to bone-earth)	(·364)	(·244)	(·072)
Magnesia	·771	·454	·372
Oxide of iron and alumina	2·978	1·809	1·420
Soluble silica	1·231	·582	1·210
Insoluble silicious matters	4·827	11·558	15·240
	99·420	99·433	100·210

Cornbrash limestone, it will be seen, contains most lime, and likewise an appreciable quantity of phosphoric acid; but its texture is such that it cannot be conveniently used as a building stone, nor does it do well for lime-burning. The soils resting on Cornbrash, and formed by its degradation and decomposition, are noted for their corn-growing qualities: hence the derivation of the name Cornbrash.

Stonefield slate and Forest Marble limestones are both very impure forms of carbonate of lime. Stonefield slate on account of its slaty structure is used as roofing slate; and some of the beds of forest marble, which separate into thin slates, furnish slabs for barn-floors and pigsties.

On the Value of Limestones for Agricultural purposes.—It has been assumed that a limestone is the more valuable for burning the more lime and the less magnesia it contains. Magnesia is often considered prejudicial to vegetation, and for this reason limestones containing much magnesia are deemed unfit for burning. It is true many magnesian limestones on burning produce poor lime that slakes with difficulty, and does not swell much on slaking, and such lime of course cannot act so beneficially upon vegetation as other varieties, which fall to a fine floury powder and are richer in pure lime. But it does not appear to me logical to infer from the different results which good and bad limes produce upon vegetation that magnesia is injurious to vegetation. Direct experiments which have been made with caustic magnesia indeed have shown that there is no foundation for the alleged injurious effects of caustic magnesia, which is supposed by many practical and scientific men to burn up vegetation. It appears also that this erroneous view respecting the action of magnesia upon plants arises from the purely accidental circumstance that bad limes often contain much magnesia. Space prevents me from discussing in this place at length the erroneous opinion of those who regard magnesia as a deteriorating element in the estimation of the value of an agricultural limestone. I content myself by expressing my conviction that 2 or 3, or even 10 per cent. of magnesia, will not materially affect the value of the limestone, if it furnishes a lime which slakes well and falls to a fine voluminous powder rich in lime. It should be borne in mind, however, that slaked lime is used in agriculture for the sake of the lime, and not for the magnesia which it contains. Magnesian limestones often contain 20 or even 30 per cent. of carbonate of magnesia, and do not yield quicklime so rich in pure lime as limestones containing naturally more carbonate of lime.

There is another mistake which is frequently made, namely, the mistake of connecting the agricultural value of limestones with the greater or smaller amount of shells and other fossil remains which different specimens present to the eye. It is believed that the more shelly or coralline a limestone is, the better the lime which it is likely to produce. This supposition rests on the assumption that corals, shells, and other fossil remains in limestones contain much phosphoric acid. Neither the alleged fact, that shelly limestones produce better lime than stones comparatively free from fossil remains, is proved, nor does the statement which has been made in explanation of this assumption rest on analytical evidence.

Many exceedingly shelly limestones which I have had an opportunity of examining, notwithstanding their shelly texture, are totally unfit for burning; and some of the worst limes in the neighbourhood of Cirencester are made of the most shelly limestones. I have moreover taken the trouble of examining for phosphoric acids several limestones full of fossil shells, as well as some fossil remains extracted from the oolitic limestones in our neighbourhood, and find neither the shelly limestones richer in phosphoric acid than non-fossiliferous limestones, nor a larger amount of phosphoric acid in the shells than in the matrix in which they are embedded. By far the most valuable property of a limestone is its power to burn in the kiln, so as to produce a solid stone that admits of being removed from the kiln without too much waste, and that in slaking swells greatly, producing a light floury powder. Generally speaking, limestones rich in carbonate of lime possess this valuable property in a high degree; and within certain limits, the amount of pure carbonate of lime in a limestone is a measure of its agricultural value. In a minor degree the proportions of phosphoric and sulphuric acid affect the value of limestones for agricultural purposes; but generally the amount of these fertilising constituents is too inconsiderable to deserve any notice. Should there be much phosphoric acid in a limestone, it is, of course, all the more valuable; and, on the other hand, if there is much sand or oxide of iron, alumina, and other foreign impurities in a limestone, it will yield a quicklime which is deteriorated in value in a corresponding degree.

On the changes Lime undergoes in burning and slaking.—The chief constituent of all limestones, it will be remembered, is carbonate of lime, *i. e.* a combination of lime with carbonic acid. When burned in the kiln the carbonic acid is driven out by the heat, and the lime, mixed with the foreign matter of the limestone, remains behind as caustic, burned, or quicklime. One ton of good limestone, on an average, yields in round numbers nearly 11 cwt. of quicklime or lime-shells. The weight of quicklime per bushel varies greatly with the kind of limestone, and the heat to which it has been exposed; when burnt very high it becomes more compact than at a more moderate heat, and then, of course, is heavier per bushel. Too great a heat should be avoided, especially if the limestone contains much clay or other silicious matters, since such limestones are apt, when burned too highly, to yield a lime which does not readily slake. Such lime is said to be over-burned.

On exposure to a moist atmosphere burned lime slowly attracts water; or by pouring upon it a certain quantity of water, it absorbs the latter at once, heats, and in either case falls to a fine powder. The process is known as slaking, and the product is slaked lime.

The most economical and approved mode of reducing quicklime to fine powder is spontaneous slaking in covered heaps. The lime is laid up in heaps, and covered with grass sods, earth, or the clearings of ditches, and then left for three or four weeks, or until it has completely fallen to powder. Covering with sods and earth excludes to a great extent heavy showers or long-continued rain, whereby the quicklime is apt, at least in part, to run into mortar. Should this take place, notwithstanding the precaution of keeping the heaps covered with earth or grass sods, it is advisable to mix the mortary portion of the heap with the rest, or, better still, with some fresh quicklime, before distributing it over the field.

Some kinds of lime, especially inferior limes, do not slake spontaneously, and require to be watered in order to fall to powder. Slaked in either way, lime greatly increases in bulk—the more the better it is. Good limes generally increase 3 to 3½ times, and seldom as much as 4 times; whilst bad limes, particularly those rich in earthy matter, increase rarely more than twice in bulk, and often less.

Slaked lime contains water in an invisible form, or chemically combined water, and is called by chemists hydrate of lime. 100 parts of lime-hydrate, or dry slaked lime, when pure, contain —

Lime	76
Water	24

Quicklime differs materially in its physical and chemical properties from the stone from which it is obtained. Whilst limestone is hard and dense, and nearly insoluble in pure water, quicklime falls readily to a fine powder, which is soluble in about 770 parts of water. Quicklime has a hot, alkaline taste, and causes, amongst other effects, the resolution of vegetable and animal matters into simple, volatile, or soluble combinations. The changes limestones undergo in burning are thus partly of a mechanical, partly of a chemical kind. The mechanical changes enable the farmer to reduce the lime by slaking into an extremely fine powder, which can be readily and thinly spread upon, or intimately mixed with, the soil. The chemical change consists chiefly in the expulsion of carbonic acid, and the conversion of the mild into caustic lime.

Slaked lime, when exposed for some time to the atmosphere, gradually absorbs carbonic acid, and returns in part to a mild condition, or becomes partly carbonate of lime again. Still, however long lime may have been exposed to the influence of the atmosphere, it never becomes entirely reconverted into carbonate.

With a view of ascertaining to what extent slaked lime, which had been exposed for some months to the atmosphere, had become reconverted into carbonate of lime, I analysed a portion of such lime. The slaked and exposed lime was made from the same limestone (from Williamson) of which an analysis has been given already. The results of this examination are as follows:—

Composition of Quicklime spontaneously slaked by exposure to air.

Moisture, driven off at 212° Fahr.	·78
Oxide of iron and alumina	·29
Silica	·14
Magnesia	·14
Sulphate of lime	·11
Carbonate of lime	15·11
Lime-hydrate	83·43
	100·00

It will be seen that lime slaked spontaneously contains an appreciable quantity of carbonate of lime. The amount of carbonate in slaked lime of course is not constant, but varies with the time during which lime has been exposed to the atmosphere. This lime, like the stone from which it is made, is an exceedingly pure and valuable material, which can scarcely be surpassed by any other lime.

This will be a fitting place to put on record an analysis which I lately made of gas-lime, *i. e.* the refuse lime from gas-works. The lime in the gas-purifier principally answers the purpose of removing from the crude gas, as it issues from the retorts, sulphuretted hydrogen and carbonic acid. The slaked lime consequently becomes more or less changed into carbonate of lime and into sulphuret of calcium, a combination of sulphur with calcium, the metallic base of lime. At the same time some tarry matter, a little ammonia, and other volatile substances, pass into the gas-purifiers, and are in part retained by the lime in a mechanical way.

When gas-lime is first exposed to the atmosphere it gives off a very bad smell, which arises principally from the sulphur compounds in this substance; after some time the bad smell diminishes, and at last becomes almost imperceptible. This shows that the sulphurous compounds in gas-lime undergo changes on keeping, which may be stated briefly to consist in the gradual oxidation of sulphuret of calcium, which, passing through the formation of sulphite of calcium, terminates in the production of sulphate of lime or gypsum. Gas-lime kept for some time thus always contains some gypsum.

From these remarks it will be gathered that gas-lime contains the following ingredients: carbonate of lime, lime hydrate, sulphuret of calcium (mere traces), sulphite of lime, sulphate of lime, small quantities of tarry matters, a little ammonia, water, and, of course, all the impurities which are contained originally in the quicklime employed in the gas-works.

The relative proportions of the chief constituents of gas-lime will be recognised by throwing a glance at the subjoined Table, which gives the composition of gas-lime when dried at 212° Fahr.:—

Composition of refuse Gas-lime.

Water of combination and a little organic matter.. ..	7·24
Oxides of iron and alumina	2·49
Sulphate of lime	4·64
Sulphite of lime	15·19
Carbonate of lime	49·40
Caustic lime	18·23
Magnesia and alkalies	2·53
Insoluble silicious matter..	·28
	100·00

It need hardly be stated that the composition of gas-lime, for obvious reasons, must be subject to great variations. In fresh gas-lime the proportion of water amounts from 30 to 40 per cent.

Gas-lime, it will be seen, contains a good deal of sulphite of lime, *i. e.* a combination of lime with sulphurous acid. This combination is readily decomposed even by carbonic acid; and as sulphurous acid, which is readily liberated by the carbonic acid in the soil, is injurious to vegetation, gas-lime should not be applied to the land in too fresh a state, for in such a state it is decidedly mischievous even when used in moderate quantities. The safest plan of using gas-lime appears to me to employ it in the shape of a compost. Mixed with refuse matters, whether of animal or vegetable origin, gas-lime, on keeping for five, or better for six, months, becomes transformed into a very useful fertiliser for all soils naturally poor in lime. In fact, gas-lime may be used with equal advantage as quicklime in making lime-compost heaps.

2. *Chalk.*—The localities in the West where chalk occurs are confined to part of Dorsetshire, Wiltshire, and Somersetshire; its agricultural use is naturally confined to the immediate neighbourhood where it is found.

Chalk is a soft kind of carbonate of lime, which often constitutes extensive beds, separated usually by geologists into the upper and lower chalk beds. Neither the upper nor the lower chalk is pure carbonate of lime, but both invariably contain more or less silica, often in the shape of minute silica shells of infusorial animals, besides oxides of iron and alumina, magnesia, and traces of phosphoric and sulphuric acids as potash or soda. In some beds of chalk, oxide of iron occurs in only a minute quantity, whilst in others its quantity is appreciable; hence the white colour of the former and the yellowish colour of the latter.

It is a curious fact that sometimes farmers find it answer their purpose to sink deep pits in localities that are situated on the chalk formation, and to apply the lower chalk to the surface-soil, already containing abundance of chalk. Irrational as this may appear at first sight, this practice finds a ready explanation and defence in modern chemical researches, for these tell us that the lower chalk beds often contain so large a proportion of phosphate of lime that even bones or superphosphate, when used as manures on soils formed by the direct disintegration of lower chalk beds, are without efficacy; whilst on land formed by the decomposition of the upper chalk beds, bones or superphosphate, or even the chalk from lower beds, produce the same striking effect, especially on root-crops, which usually attends the use of phosphatic manures.

There are soils in Somersetshire, I am informed, in the neighbourhood of Ilminster, where superphosphate of lime is of no use whatever; and as here the lower chalk formation prevails, it would be very interesting to ascertain whether those soils on which superphosphate shows no effect contain more than a sufficient quantity of phosphoric acid to answer all the purposes for which superphosphate is employed in agriculture. It must not be supposed, however, that all beds in the chalk formation become richer the deeper they are situated, nor that the beds which are described by geologists as belonging to the lower chalk are necessarily richer in phosphoric acid than those nearer the surface or the upper chalk beds. This will appear clearly from the subjoined Table, in which are arranged the results of analyses of several varieties of chalk, from different beds of the chalk formation. These analyses, made by Professor Way, at the same time may serve to illustrate the composition of different varieties of chalk:—

Analysis of Chalks.

	Lower Chalk.	Lower portion of Chalk with Flints.	Upper Soft White or Free Chalk.	Second Specimen of Upper Chalk.
Clay and sand, insoluble in acid	2·04	·66	1·46	·87
Silicic acid, soluble in acid	trace	.. ..	.. ..	.. ..
Carbonic acid	42·14	42·98	41·48	42·57
Sulphuric acid	·31	trace	none	·09
Phosphoric acid	·07	·08	·04	·08
Chlorine	none	none	none	·08
Lime	54·37	55·24	55·72	55·18
Magnesia	·25	·10	·06	·30
Potash	·08	·06	·17	·22
Soda	·19	·14	·02	·21
Protoxide and peroxide of iron	·55	·74	1·05	·40
Alumina	trace	.. ..	.. ..	.. ..
	100·00	100·00	100·00	100·00

According to these results, good chalk contains from 95 to 98 per cent. of pure carbonate of lime; but neither the samples of the lower chalk nor the upper chalk beds which were analysed contained much phosphoric acid. I cannot help thinking that money is often spent uselessly in the chalk districts in sinking pits and bringing to the surface-soil a variety of chalk which may be harder or somewhat different in colour, but otherwise does not materially differ from the chalk of the upper beds. It is true, phosphate of lime is more abundant in the beds of the lower chalk than in those of the upper chalk, but it is also true that there are beds as poor in phosphates in the lower as those in the upper chalk. Unless, therefore, a bed considerably richer in phosphates is reached in sinking a chalk-pit, labour and money are likely to be thrown away. The analysis of the chalk which it is intended to bring to the surface, with especial reference to the phosphoric acid contained in it, at once would decide the question whether it is desirable to go to the expense of sinking a deep chalk-pit or not.

3. *Marl.*—A third form in which lime is applied to the land is that of marl. The term marl is used often in rather a loose sense, and applied sometimes indiscriminately to all mineral matters which are dug up and put on the land in large quantities. Hence, mineral manures possessing properties widely differing from each other pass by the name of marl; and agricultural writers have to distinguish a great variety of marls: such as clay marls, shell marl, sandy marl, chalk marl, peaty marls, stony marls, dry and wet marls.

I shall not attempt to describe here the properties and application of the different kinds of marls which are used in agriculture, but shall confine myself to a brief account of a few marls which are used in the West of England, and which I had an opportunity of examining. I am aware that there are many marls used for manuring purposes in Devonshire and Somersetshire, as well as in Cornwall and South Wales, which I have not examined. Numerous applications for marls used for agricultural purposes were met with no response, and I had consequently no opportunity to analyse several kinds of marls which I should have liked to examine. However, to confess the truth, I am almost glad that I have not to report on the agricultural value of many specimens of marls, for I am afraid I could not have done justice to the subject in the limited time allowed to me for examining into the various calcareous manures that are found in the West of England, and for reporting on their uses in agriculture.

"The Marls of the West of England, and their uses in agriculture," is a subject quite comprehensive enough by itself, and, when undertaken in a proper manner, will give an analytical chemist plenty of work for a number of months.

The first marl on which I have to report was forwarded to me by Mr. Symes, of Combe, near Sherborne. This marl on analysis was found to contain in 100 parts :—

Moisture and organic matter	5·41
Oxides of iron and alumina	6·94
Carbonate of lime	10·55
,, ,, magnesia	1·44
Phosphoric acid	trace
Insoluble silicious matters (chiefly fine sand)	74·86
Alkalies and loss	·80
	100·00

It will be observed that this is a sandy marl, *i. e.* a mixture of some clay with carbonate of lime and much sand. On light soils deficient in lime this marl would produce a beneficial effect, but since it contains so large a proportion of sand and but little lime I doubt the propriety of using it if it has to be carted any distance. At the best it is but a poor sandy marl, which can only do good when used in very large quantities upon light soils quite deficient in lime, or upon heavy land, which is benefited by almost any mechanical ameliorator.

In the next Table I have grouped together the analyses, made some time ago, of three marls found in the West of England.

No. I. is a clay marl from Bridgewater.

No. II. a chalk marl, or malm as it is locally called in Wiltshire.

No. III. another chalk marl from Gloucestershire.

	No. I.	No. II.	No. III.
Water and a little organic matter	3·38	..	..
Finely divided silica (soluble in caustic potash)	17·94	16·710	0·26
Insoluble silicious matter (fine clay)	54·89	6·090	..
Oxides of iron	8·82	·780	2·86
Alumina	6·67		
Lime	1·44	40·757	52·33
Magnesia	0·92	·825	0·31
Potash	1·48	traces	traces
Soda	1·08	traces	traces
Phosphoric acid	0·51	·242	traces
Sulphuric acid	traces	1·546	..
Chlorine	traces	traces	traces
Carbonic acid and loss	2·87	33·050	44·70
	100·00	100·000	100·46

Marl properly speaking signifies a mixture of clay, carbonate of lime, and sand, with or without organic matter, containing not less than 5 or 6 per cent. of carbonate of lime.

It will be observed therefore that No. I. can hardly be called a marl.

There are many similar minerals, which are called by practical men clay marl, since they are used with marked benefit on some soils.

The so-called clay marl from Bridgewater appears to be an alluvial clay. It occurs in reddish brown lumps, readily breaks down on exposure to the atmosphere, and possesses considerable fertilizing qualities. It will be seen that this mineral fertilizer contains a considerable quantity of phosphoric acid and soluble potash, but is very poor in lime. The fine clay which enters into its composition, moreover contains a great deal of potash in an insoluble state, from which, however, it is gradually liberated on exposure to the atmosphere.

There can be no doubt that the fertilizing effects which this clay marl produces are due to the large amount of soluble potash as well as to the phosphoric acid which it contains, and not to the lime. The use of this clay marl will not supersede the application of lime, or of a marl rich in carbonate of lime.

This marl thus presents us with the curious fact that the very best thing that can be mixed with this marl is lime, and that wherever lime is really wanted, as is the case in many soils near Bridgewater, the clay marl occurring in the neighbourhood of this town does not answer the purpose for which lime is usually employed in agriculture.

No. II. occurs in gray lumps at the foot of the Wiltshire Downs. It is largely used by the Wiltshire farmers, both on pasture and arable land.

The proportion of phosphoric acid in this marl is not large, but still it helps to add to its fertilizing effects, which are due principally to the large quantity of carbonate of lime, and perhaps also to the finely divided or soluble silica, which also occurs in abundance in it.

Still larger than in No. II. is the proportion of carbonate of lime in the chalk marl from Gloucester, which is by far the least valuable of these three marls.

Chalk marls on the whole are good fertilizers for all soils deficient in lime, and some produce very beneficial results even when applied to soils containing superabundance of lime. It appears thus clearly that lime in the latter instances cannot be the cause of the fertilizing properties of some kinds of chalk marls. Careful analytical researches indeed have traced the fertilizing effects of some chalk marls chiefly to the phosphoric acid which they contain in the form of phosphate of lime. Phosphatic nodules occur frequently in Wiltshire marls and in some places in Somersetshire. The occurrence of these phosphatic nodules, which in appearance can hardly be distinguished from ordinary chalk marls, is indicative of good soils. In localities on the greensand or lower chalk formation, farmers should have a special look-out for phosphatic nodules, inasmuch as their notice may probably lead to the discovery of Coprolite beds. Unfortunately many phosphatic nodules cannot be distinguished by their physical characters from common chalk marl, and the tests for phosphate of lime are too complicated to enable any one not well acquainted with analytical chemistry to detect with precision the presence of phosphoric acid.

4. *Shell or sea sand.*—Shell-sand is calcareous sand which consists of the fragments of broken shells, corals, silicious sands, débris of granite, and small quantities of animal matter and soluble alkaline salts. It differs much in colour and fineness, &c., as well as in chemical composition, and consequently also in quality. Extensive deposits of shell-sand are found in many parts of the Devonshire and Cornish coasts, for instance at Bude, Barracaine, Northcote Mouth, Hartland Quay, and especially at Padstow. There is an immense deposit of indefinite depth in the estuary of Padstow, from whence it is transported in large quantities to great distances inland. It has been estimated that 4,000,000 of cubic feet are annually employed for agricultural purposes in Cornwall alone, in which county shell-sand is held in high estimation, since it is peculiarly well adapted as a manure for the soils of Cornwall. These soils are generally either stiff clays or poor sands; they result chiefly from the disintegration of the granitic and schistose rocks that abound in Cornwall, and are very deficient in lime; hence the utility of shell-sand, which owes its fertilizing qualities principally to the carbonate of lime which it contains.

Most of the samples of Cornish and Devonshire shell-sand which I examined were supplied to me by my friend and pupil Mr. E. Hockin, of Bude, who also kindly made several shell-sand analyses for me. The results of Mr. Hockin's analytical examinations are embodied in the subjoined tabular statement:—

Composition of Sea-sand (Shell-sand) from Devon and Cornwall.

	Bude.	Comb Martin.	Hartland.	Northcote Mouth.	Summerliege.
Water and organic matter	3·668	6·468	6·420	8·525	2·267
Silicious sand	37·144	68·635	58·322	25·025	29·910
Oxide of iron and alumina	3·397	8·784	4·350	1·768	3·492
Carbonate of lime	53·123	14·138	29·840	62·467	63·067
Magnesia and alkaline salts	2·668	1·975	1·068	2·215	1·264
	100·000	100·000	100·000	100·000	100·000

Before offering any remarks on these analyses, I give the composition of another sample of shell-sand from Bude, which was collected a year after the first sample. The following analysis of Bude sand therefore is calculated to show the variations in composition to which this sand is subject at different times. Grouped together with this analysis is another, made in my laboratory, of a sea-sand from Sandymouth, Cornwall.

Composition of a second sample of Shell-sand from Bude (No. I.), *and Sea-sand from Sandymouth, Cornwall* (No. II.)

	No. I	No. II.
Water and a little organic matter	2·52	3·51
Oxides of iron and alumina	8·50	3·48
Carbonate of lime	52·59	43·27
,, ,, magnesia	·98	1·70
Silicious sand	35·33	48·29
Chloride of sodium (common salt)	·38	not determined
	100·30	100·25

On comparing these analytical results with each other it will appear:—

1. That the proportions of carbonate of lime in the analysed samples of sea-sand from different localities vary exceedingly. Thus, whilst the sand from Comb Martin contained only 14 per cent., that from Northcote Mouth and that from Summerliege contained 62½ and 63 per cent. respectively.

2. That the samples richest in lime contain least silicious sand, and those poorest in lime the most silicious matter.

3. That the proportion of oxide of iron likewise varies considerably in the sands from different places, which circumstance no doubt explains at least to some extent the various colours of the different kinds of sea-sand analysed by me.

4. That the proportion of soluble alkaline salts in all samples is very trifling.

5. That the specimen of sea-sand from Comb Martin examined in my laboratory is too poor in lime to be profitably carried away any distance.

6. That the sea-sands from Northcote Mouth and Summerliege possess nearly the same agricultural value, and are the best varieties of the samples of sand the composition of which is stated above.

7. That Bude sea-sand varies but little as regards the proportion of carbonate of lime which different samples drawn at long intervals contain.

8. That Bude sand contains rather more than one half its weight of carbonate of lime, and the shell-sand from Sandymouth

nearly 50 per cent., and that therefore both will prove useful fertilizers upon soils deficient in lime.

9. That the shell-sands from Comb Martin and Hartland Quay are inferior kinds of sea-sand, especially the former, since it contains only 14 per cent. of carbonate of lime.

I may observe that I have carefully examined the shell-sand from Bude for phosphoric acid, but have not succeeded in detecting the least trace of phosphoric acid in this species of shell-sand.

This negative result, however, must not be taken as a proof that shell-sand is invariably destitute of phosphoric acid. This is not the case, for I have experienced no difficulty in recognising distinctly the presence of phosphoric acid in several other kinds of shell-sand, but with the exception of the sea-sand from Padstow the proportions of this acid were too small to admit of a quantitive determination.

In the far-famed shell-sand from Padstow, on the other hand, I found an appreciable quantity of phosphate of lime, as well as a considerable quantity of sulphate of lime, both which constituents it need hardly be mentioned add considerably to the fertilizing properties of this species of shell-sand.

A careful analysis of a sample of shell-sand kindly supplied to me by Mr. Bryant of Padstow yielded the following results :—

Composition of Shell-sand from Padstow.

Water and a little organic matter	1·233
Oxides of iron and alumina	1·686
Phosphoric acid	·228
(equal to bone-earth)	(·491)
Carbonate of lime	80·080
„ „ magnesia	3·176
Sulphate of lime	1·049
Chloride of sodium (common salt)	·314
Insoluble silicious sand	12·127
	99·811

This analysis fully establishes the superiority of the Padstow sand over many other Cornish and Devonshire shell-sands, and shows that 1 ton of one kind of sand may be worth to the farmer as much and more than 4 or 5 tons of another locality.

The amount of phosphoric acid in the Padstow shell-sand analysed in my laboratory corresponds to about ½ per cent. of bone-earth; and considering the large quantities of shell-sand that are often laid on the land, besides much carbonate of lime, an amount of bone-material will be added to it which cannot fail beneficially to affect the crops raised on soils that have received a good dressing of Padstow shell-sand.

II. Functions of Lime upon the Soil and Vegetation.

Having described the physical and chemical properties of several kinds of limestones, marls, sea-sand, and other calcareous mineral substances, occurring in the West of England, I shall now proceed to refer to the functions which lime is supposed to exercise upon the land and upon vegetation.

Unless the agriculturist entertain correct views with regard to the theory of the action of lime, he is as likely as not to misapply it and to meet with disappointment. For this reason it may not be out of place to allude briefly to the functions of lime.

There are especially four functions requiring particular notice:

1. *Lime exercises a mechanical effect upon the land to which it is applied.*

Stiff, heavy clay land by its addition is rendered more porous, friable, and consequently better adapted for cultivation. Sandy, light soils, on the other hand, when limed, are consolidated, and thus improved in their physical condition.

2. *Lime supplies food to plants.*

All naturally fertile soils contain a notable proportion of lime, while in those which are naturally unproductive the quantity of lime is comparatively small. It is on soils of the latter description that lime is added with much benefit; and we may therefore safely conclude that it is really indispensable to the fertility of the soil.

All our cultivated plants on burning furnish ashes, containing more or less lime. It thus appears that it is a necessary food of plants without which they cannot come to perfection; and as plants have not the power within themselves to generate lime, we can readily understand the benefits which result from its application to soils naturally deficient in it or impoverished by long-continued cropping.

The quantity of lime actually removed from the soil by different crops varies considerably. Some plants require a much larger amount than others. Thus it has been found that in the produce of an acre of land of the following crops there is contained of lime:—

			Lime in the Grain.	Lime in the Straw or Roots.	Total.
			lbs.	lbs.	lbs.
Wheat	25	bushels	1	12	13
Barley	40	„	1½	15½	17
Oats	50	„	3	19	22
Rye	26	„	1½	15½	17
Beans	25	„	2½	34	36½
Turnips	20	tons	46	72	118
Potatoes	8	„	8	31	39
Red clover	2	„	..	77	77
Rye grass	2	„	..	30	30

The different quantities of lime which are removed by those crops partly, no doubt, explain why lime favours the growth of some crops more than others, and partly also why it is necessary to renew the process of liming from time to time.

3. *Lime exercises a beneficial effect upon the organic matters in the soil.*

Organic matters are present in all soils in larger or smaller quantities: and under good cultivation their proportion increases in ordinary circumstances every year. Now although organic substances on the whole are beneficial to vegetation, they will cease to be so when they have accumulated in too large a proportion. Lime, on account of its caustic properties, greatly facilitates the destruction of organic matters, and thus prevents their accumulation to an injurious extent. Hence lime is frequently added to compost heaps with a view to hasten the decomposition of both vegetable and animal matters, and it has been found to answer that purpose exceedingly well. Lime no doubt exercises an analogous effect upon the organic matters in the soil. During the decomposition of the organic substances, carbonic acid is produced in abundance, and also a small quantity of nitric acid. Both carbonic and nitric acid are highly conducive to the luxuriant growth of plants; and their production, under the influence of lime, consequently accounts in some degree for the beneficial effects of liming.

The roots, leaves, and other vegetable remains of former crops, in a comparatively fresh or undecomposed state, it is well known, scarcely produce any fertilizing effect upon vegetation, but they become excellent fertilizers when their organic tissue has been more or less destroyed by the process of decay or putrefaction. They then become converted from an inert to an active state, and in this state exercise a beneficial effect upon vegetation. Now lime possesses the power of hastening the change of inert vegetable matter into active fertilizing substances, and will therefore prove especially useful on soils abounding in organic matter.

Its alkaline properties moreover render lime peculiarly applicable for neutralizing any free acid existent in the soil. The prejudicial effects of sour humus on vegetation, as exhibited in the produce of boggy or peaty land, are well known to practical men, and also the benefit which results from an abundant supply of caustic lime to such land. Lime not only combines with the organic acids constituting the sour humus and thus sweetens the soil, but it also hastens the decomposition of the organic matters which give rise to the formation of sour humus, and thus removes also the cause of its injurious effects.

Whilst speaking of the action of lime on organic matters, we would not forget to mention that all organic substances contain inorganic or mineral constituents in an intimate state of combination. From this close union the mineral matters, however, cannot be removed by water, even when they are as easily soluble as potash or soda. As long as the organic tissue of the roots, leaves, and other vegetable matters in the soil remain unaltered, potash, soda, sulphuric and phosphoric acid, and other fertilizing mineral matters which are united with them, will remain unavailable to the use of plants. But in the measure in which the decomposition of the organic substances proceeds, the inorganic are liberated and can then be applied to the benefit of the growing plants. And as lime hastens the decomposition of all organic matters, its beneficial effects upon vegetation partly, no doubt, are attributable to the liberation of inorganic or mineral fertilizing substances, which it promotes in a great measure.

4. *Lime exercises a beneficial effect upon the inorganic matters in the soil.*

Although the effects of lime are most conspicuous on soils rich in organic matters, it is not inactive on land deficient in such matters. Lime not only facilitates the decomposition of organic substances, but effects also important changes in the mineral constitution of soils. In particular we would mention its effects upon many silicates. By causing their decomposition in the soil, lime sets free potash and soda, two substances highly conducive to the luxuriant growth of many plants.

In many soils, but especially in clay land, we find portions of granite and other minerals from which clay has been originally produced. These minerals are the chief sources from which the necessary amount of alkalies, required by plants, is furnished. But as their decomposition proceeds slowly, a long time must pass before potash and soda can be set free. Lime materially hastens this decomposition, and can be compared in this particular action to the effects which prolonged fallow produces upon land.

If it only acted beneficially in converting inert vegetable substances into actual fertilizers, the beneficial effect upon clays that are nearly destitute of organic substances would be perfectly unintelligible. This action, however, fully accounts for the effects of lime upon clay land.

We thus see that the action of lime on vegetation depends on more than one cause; and that consequently its effects in that respect will be influenced by the various circumstances under which it is applied to the land.

At the same time, the four different functions which we have mentioned as belonging to lime, point out to us the uses of lime in agriculture, and the benefits which are likely to result from its application.

On the exhausting Effects of Lime.

The use of lime, like that of many other good things, is often turned into abuse, and the failures which have resulted from the injudicious application of lime have brought this valuable fertilizer into disrepute with some, who ascribe to it an exhausting effect.

It is the opinion of some practical men that liming will render ordinary manuring unnecessary, and the acting upon this principle in many instances has done much injury. This, however, is a great mistake. The fact is, lime applied by itself is incapable of supplying all the wants of the growing plant, and is therefore not calculated to supersede the use of farmyard-manure. If, notwithstanding the non-application of any other manure than lime, good crops have been raised, this fact proves simply that the land has been in excellent condition. We can, however, confidently predict that sooner or later the produce will gradually sink, and at last the soil will cease to bear remunerative crops. This is indeed so well known to practical men, that many consider the use of lime prejudicial to the permanent productiveness of the soil. When, however, care is taken to apply manure in sufficient quantity to limed land, no fear ought to be entertained that lime will exhibit any exhausting effects. We have seen that lime, by rendering the hidden mineral treasures of the soil available to the immediate use of plants, especially by liberating potash and soda from the insoluble combinations in which these two alkalies exist, greatly increases the luxuriant growth of plants. It has been shown, also, that it converts inert vegetable substances into actual fertilizers, but that lime itself has not the power of supplying all the substances which, through its instrumentality, are rendered available to plants. It follows therefore, as a necessary consequence, that they will grow languidly as soon as the supply of these fertilizing materials in the soil falls short. Hence arises the necessity of supplying them in the form of farmyard manure. If we wish to grow abundant crops we must supply the materials necessary for their existence, and the more liberally these are presented to the young plant the more likely are we to succeed.

Lime certainly possesses the great advantage of rendering available the inert fertilizing matters in the soil, and has also the effect of bringing farmyard manure into a rapid action, but it cannot itself supply the materials upon which it works. The use of lime thus stimulates to a vastly increased produce, which must draw largely on the resources of the soil. Now, as lime restores only a small quantity of those substances which plants require, it is most unreasonable to expect that the fertility of the land will be maintained by lime alone.

To keep land in good condition, we must, as a general rule, add as much of everything as we carry off in the produce. The judicious farmer, therefore, will apply all the materials which are demanded by the increased produce in larger quantities than by a scanty crop; and this he does by liberally adding manure to the land, and not merely by using lime as a substitute for manure. If manure is liberally added to limed land, no exhaustion need to be feared.

On the other hand, the neglect of this principle, which ought to be kept in view by every one cultivating land, must be attended with a more speedy exhaustion than when no lime is used; for we cannot constantly take out of the land a number of fertilizing substances, and add only one material, without impoverishing it.

On the Crops most benefited by Liming.

We have stated above that all cultivated plants require lime as an essential article of food, without which they cannot come to perfection, and it is therefore evident that it will increase the produce of all crops on soils naturally deficient in this substance. But as lime exercises several important functions in relation to the vegetable processes, we may expect that its application to some crops will be characterised by a more marked effect than to others. Practical experience confirms this supposition, for it is well known that liming not only improves the quantity and quality of some crops in an especial manner, but that it alters as well the natural produce of the land, by killing some kinds of plants and favouring the growth of others.

The crops which are especially benefited by liming are: clover, rye-grass, and natural grasses; sainfoin, peas, beans, and vetches; turnips.

The effects of lime upon clover and rye-grass are strikingly beneficial; and for this reason perhaps on no description of crops is lime applied so advantageously as upon white clover and artificial grasses. It causes white clover and rye-grass to thicken, and to produce a closer sole every succeeding year the land remains in pasture, and thus contributes greatly to enlarged crops.* Not only is the quantity of the clover crop increased, but its quality is also materially improved. Clover and rye-grass, when grown on limed land, are far more juicy and nutritious than when grown on unlimed land.

On many soils it is indeed impossible to cultivate, economi-

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* Lime, when applied as a top-dressing upon dry lands that have not even been cultivated, on Exmoor, has the magical effect of producing white clover in quantity, without its being sown.—R. S.

cally, clover or rye-grass without a heavy dose of lime ; and land which previously to liming was quite unfit for the cultivation of these crops, after the addition of a good dose of lime, has given a heavy produce of superior quality.

On limed land, moreover, clover is less exposed to the failure which is known under the term of clover-sickness. Although we would not in every instance ascribe the cause of land becoming clover-sick to its deficiency in lime, I have no hesitation in asserting that in many cases the failure of clover can be traced to the want of lime in the soil upon which it is attempted to be grown.

On natural grasses, especially on benty grass, the best farmyard manure often produces little improvement until a dressing of lime has been applied.*

In arable farming, where the land remains in pasture two or three years, the liberal use of lime is attended with the greatest benefits. Lime destroys the coarser grasses and favours the growth of a sweeter and more nutritious herbage. The superior quality of limed pastures has long been known to practical men ; and this superiority is fully accounted for by the effects of lime in changing the natural produce of the land.

Old pastures are best limed in the beginning of the winter ; the lime will then be washed into the soil, and come in reach of the roots before the new growth starts.

Lime kills moss, heath, feather grass (*holcus mallis*), *soft meadow grass* (*holcus lanatus*), and other plants. characteristic of peaty land, and is therefore a valuable means for improving peaty or mossy meadows.

Peas, beans, and vetches grow much more luxuriantly in limed than in unlimed land, and yield a larger crop of grain as well as of straw. Peas grown on newly limed land are excellent boilers, and more pleasant to the taste than when grown on unlimed land. By the application of a heavy dose of lime to clay land on which peas or beans did not succeed the produce has been doubled in many instances.

Sainfoin and Lucerne are also materially benefited by a dose of lime, as they are plants which like peas and beans require a larger proportion of it than most other plants.

Lime also exercises a highly favourable effect upon turnips, inasmuch as it improves both the quantity and quality of this crop. It is most efficient when applied in the compost form, and when the land is already rich in organic matters, and should be laid on when the ground is prepared for the reception of the seed.

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* This result has been singularly verified on an Exmoor farm, the action of farmyard manure being found threefold *after* a dressing of lime.—R. S.

In land naturally deficient in lime turnips will refuse to grow, or, if they grow, will produce a scanty and irremunerative crop. Unlimed land, moreover, is liable to give rise to the disease, in turnips, called "fingers and toes." This is so well known to practical men, that lime is considered by many a specific remedy against this disease, and the appearance of the disease itself in turnips as an indication of the propriety of reliming the land. Professor Johnston also states it as his opinion—"That the cure of this disease appears to be the application of a large dose of lime to the stubble-land in the autumn, after it has been turned up by the plough."

Turnips grown upon peaty land, it is well known to practical feeders, are hardly worth being consumed by fattening stock.

On the other hand, those grown on the rich turnip soils of the Lothians are very nutritious. These soils, being formed by the disintegration and decomposition of trap and other similar rocks, often contain a considerable amount of lime, and we may therefore infer that lime exercises a direct influence in the production of a large amount of nutritious substances.

Potatoes when grown upon heavy land or wet clay soils are improved both in quantity and in quality by the application of lime. On heavy wet land potatoes, it is well known, are generally waxy, and the addition of lime to such land has the effect of making them more mealy and agreeable to the taste. On light soils the use of lime is said to diminish this crop.

Upon corn crops lime also acts beneficially. On clay land especially it greatly increases the produce in grain and straw. Whilst it has the effect of hardening the straw of wheat, at the same time it produces a finer and heavier grain, yielding more flour. The improvement which lime is capable of effecting upon grain crops is more marked on stiff than on light soils; and greater on barley than on wheat or oats.

Barley, of all the corn crops, is most benefited by the use of lime, and oats appear to derive the least benefit from its application. Still I have no doubt that, on clay soils, oats will be much improved by lime. On light gravelly soils oats suffer by the too abundant use of lime, and it ought therefore to be applied in small doses, just sufficient to keep the land in proper condition for the cultivation of turnips and grass.

III. On the application of Lime, Marl, and Shell-sand, with special reference to the Soils in the West of England.

On the Quantity of Lime usually added to Arable Land in the West of England and in other Districts where Land is limed.

It is a point of much practical importance to the farmer to know in what quantities he should apply lime to the land.

General rules, however, cannot be laid down in this particular any more than in many other agricultural practices, since many circumstances—as, for instance, the character of the land, the nature of the crop intended to be raised, the previous application of lime, the price and convenience at which lime can be procured—must necessarily exercise a great influence on the quantity of lime most profitable to the land.

Where lime is cheap and the soils very deficient in it, as in many parts of Somersetshire and Devonshire, the quantity of lime added to the land is naturally larger than in other districts where the expense of hauling lime is very considerable, or upon soils which, although benefited by lime, do not yield so large an increase of produce as others.

I shall have to notice presently the composition of several soils in Somersetshire and Devonshire which are naturally deficient in lime, and which but for the want of this element would be extremely fertile. On land of that description, I believe, according to many leases the tenant is obliged to put on his land 10 hogsheads of lime for every breaking crop. This is the usual quantity of lime which the landlord requires his tenant to put on the land on the Brandon hills, and about the same quantity is used in some parts of Devonshire. Often, however, only 8 hogsheads are used every five years, to which practice no objection is made by a good landlord if the tenant can show that he has purchased artificial manures for the money saved in applying less lime to the land than required by the lease.

In most districts of South Wales, where lime can be readily procured, 4 loads of lime of 25 bushels each for every breaking crop are considered a good dressing for light land, and 6 to 8 loads for heavy land. Often, however, lime is used in larger quantities, to the injury of the land, upon which at first it exercises a wonderfully beneficial effect, the effect becoming less perceptible and finally ceasing altogether if the application of larger doses of lime is repeated too frequently.

As it may be of some interest to farmers in the West to know what quantities of lime are added to the land in other counties where liming has been successfully practised, I subjoin a Table, in which are considered the proportions usually added on some of the best cultivated districts :—

Quantity of Lime applied per imperial acre in different districts.

	Bushels.		Years.		Bushels in a Year.	When applied.
Roxburgh	200	every	19	or	10½	To the fallows.
Ayr (Kyle)	40	,,	5	,,	8	To the fallows or lea.
Carse of Stirling ..	50	,,	6	,,	9	Do. do. do.
South Durham ..	90	,,	12	,,	8½	Do. do. do.
Worcester	70	,,	6 or 8	,,	10	Before grasses and tares.

It thus appears that in these counties 8 to 10 bushels a year are pretty uniformly applied. On very stiff soils or on peaty land a larger dose no doubt can be used with advantage, but on light soils it is advisable to use it in smaller doses.

Some farmers prefer using large doses at once, whilst others maintain that repeated dressings with smaller doses are attended with the greatest amount of practical benefit.

There can be little doubt that, on soils abounding in vegetable matters or wholly destitute of lime, a large quantity will be required at once to change their mechanical and chemical constitution; and the propriety of liming the land heavily at first is thereby indicated.

But, when land has been brought by cultivation into good condition, the safest plan to maintain it in fertility will be to supply lime at shorter intervals with smaller doses, at the rate of about 8 bushels a year.

Repeated liming with small doses at larger or shorter intervals, indeed, is necessary to keep the land in its maximum state of productiveness. The reasons for the practice are obvious.

In the first place, the well-known tendency of lime to sink deeper and deeper into the soil, from year to year, removes the lime from the surface into the subsoil, and thus takes it out of the reach of the roots of plants. This tendency to sink is greater in light and porous soils than in heavy; but even in very stiff land lime gradually sinks and passes into the subsoil. Hence the necessity of applying it as near as possible to the surface.

Secondly, heavy rains wash it down into the lower strata, and dissolve also considerable portions of it. It is on account of this dissolving action that badly drained soils require to be more frequently limed than those which are well drained.

In the third place, it will be remembered that all our cultivated crops remove a certain proportion of lime from the soil; and as some crops take up a much larger quantity than others, the course of cropping must necessarily influence the period at which liming ought to be repeated.

On the Application of Lime to different kinds of Soils, and the Composition of Soils benefited by Liming.

It has been noticed already that the efficacy of lime as a fertilizer is influenced greatly by the character of the soil to which it is added; and as soils vary greatly in their chemical characters, it appeared to me a useful inquiry to ascertain the composition of some soils occurring in the West, upon which lime is usually employed. Mr. Cotterell at Bath very kindly assisted me in this inquiry by procuring for me a good many soils from various parts of Somersetshire and Devonshire. These and other soils from Wales and Cornwall were specially analysed with reference to the present inquiry on the use of lime in agriculture.

A very minute analysis, in which every constituent is ascertained, however small its quantity, was considered to lead to no useful result; I therefore confined myself to the careful determination of the chief constituents of soils, and was thereby enabled to examine a much larger number of soils than I could have undertaken had each been submitted to a minute analysis.

The soils upon which lime is used successfully in the West are clay soils, peaty and marshy soils, and light sandy soils; and since the effect of lime is somewhat different upon each of these three kinds of soils, I shall notice some particulars respecting the use of lime upon each of these three classes of soils separately.

On the Application of Lime on Clay Soils and the Composition of Clay Land much benefited by Liming.

There are many clay soils in Somersetshire and Devonshire which are much benefited by the application of lime, since they are greatly deficient in it. Thus all the clay soils in the districts where the old red sandstone rocks prevail are much benefited by liming; indeed there are few stiff clay soils which will not be greatly improved by the liberal use of lime. Thus on the stiff clays near Honiton lime is very usefully employed; and as soils like those from Hembury Fort, near Honiton, of which an analysis is appended, are naturally rich in all the mineral elements required by our cultivated crops, no fear need be entertained that repeated dressings of lime will permanently injure the land.

Composition of two Stiff Clay Soils from Hembury Fort, near Honiton.

a. Mechanical Analysis.

	No. 1.	No. 2.
Moisture	2.68	3·34
Organic matter and water of combination	5·22	4·15
Lime	2·42	2·71
Fine sand	32·55	22·19
Clay	57·13	67·61
	100·00	100·00

b. Chemical Analysis.

	No. 1.	No. 2.
Moisture	2·68	3·34
Organic matter and water of combination	5·22	4·15
Oxides of iron and alumina	7·61	11·52
Carbonate of lime	2·42	2·71
Magnesia and alkalies	1·74	1·36
Insoluble silicious matter (chiefly clay)	80·33	76·92
	100·00	100·00

The first of these soils is a stiff red soil, which contains a few flints, but is otherwise free from stones. It dries up to a hard mass like bricks, and is full of white particles, showing that this soil has been liberally limed.

The second soil resembles the first very much in its general characters, and also exhibits white particles of lime. It is evident that these soils are naturally poor in lime, and therefore much improved by liming.

The red clay soils, situated on the old red sandstone formation round Torquay, also are much benefited by lime, for naturally these soils contain but little lime, and the lime mentioned in the subjoined analysis of a soil from the estate of Mr. Brunel, near Torquay, arises chiefly from the artificial supply of this element.

Composition of Red Clay Soil from the neighbourhood of Torquay.

Moisture	5·700
Organic matter and water of combination ..	6·820
Oxides of iron and alumina	8·920
Carbonate of lime	2·580
Magnesia	·249
Potash and soda	·471
Soluble silica	·880
Insoluble silicious matter	74·380
	100·000

More friable red coloured clay soils, containing more sand than the preceding but naturally very deficient in lime, abound in the neighbourhood of Wellington and Bridgewater, as well as in many other localities in Somersetshire and Devonshire. In order to present at a glance the chemical characters of these kinds of soils, I have arranged in a tabular form a number of analyses of soils which I had an opportunity of examining:—

Composition of Soils from Bridgewater (No. I.), *Wellington* (No. II.), *and Totnes* (Nos. III. and IV.).

a. Mechanical Analysis.

	No. I.	No. II.	No. III.	No. IV.
Moisture	1·15	1·27	14·90	11·68
Organic matter and water of combination	8·45	4·36	6·48	8·58
Lime	2·47	·92	·74	2·98
Sand	43·50	58·08	53·70	58·90
Clay	44·43	35·37	24·18	17·86
	100·00	100·00	100·00	100·00

b. Chemical Analysis.

	No. I.	No. II.	No. III.	No. IV
Moisture	1·15	·	14·90	11·68
Organic matter and water of combination	8·45	·	6·48	8·58
Oxides of iron and alumina	8·47	·	22·65	24·11
Carbonate of lime	2·47	·	·74	2·98
Magnesia and alkalies	1·04	·	1·01	1·45
Insoluble silicious matter..	77·62	·	54·22	51·20
	100·00	·	100·00	100·00

The first of these soils is reddish coloured, tolerably friable soil, from the farm of Mr. Poole, near Bridgewater. It contains particles of lime, showing that it has been limed at some time or other.

No. 2, a red-coloured soil from the neighbourhood of Wellington, is very similar to the Bridgewater soil, and bears a bad character as a wheat-growing soil; however, I believe unjustly so. It is very poor in lime, and will no doubt be benefited by liming.

The two last mentioned soils were sent to me by Mr. Watson of Dorsely, near Totnes, who describes No. III. as a soil from a field in good fertile condition, and No. IV. a soil from an adjoining field of precisely similar character, but not in such good heart, having been more cropped of late years. Mr. Watson further observes in his letter to me, "the soil is good for corn and roots, but yet does not grow as much corn in proportion to the bulk of straw as I fancy it should: probably climate may prevent it. I have found superphosphate, guano, and bones, and also oil-cake manure, all to have good effects. I have doubts, however, on the question of the application of lime, and it is on this point more particularly that I now beg your attention." I give this extract of Mr. Watson's letter, because it is well calculated to throw light on the use of lime on soils similar to those in the neighbourhood of Totnes.

It will be observed that the soil which is described as one in rather exhausted condition contains nearly 3 per cent. of lime, and No. III., described as a good fertile soil, only ¾ per cent. Surprised at the result of my analyses, and fearing the boxes in which the soils were sent had been mislabelled, I wrote to Mr. Watson again on the subject, and learned from him that No. IV. was well limed in 1843 and again in 1851, but No. III. had not been limed since 1840.

These are interesting facts, for they show us in the first place that a soil may be in a good fertile condition, though it may contain but ¾ per cent. of lime, and secondly that Mr. Watson's supposition respecting the use of lime was well founded, for No.

IV. contains more than sufficient of lime to answer all the requirements of the crops of a rotation, and the further addition of fresh lime therefore could not do any good (so far as the supply of constituents of plants is concerned). Indeed it may be questioned whether the repeated liberal doses of lime have not hastened the exhaustion of this soil in grain-producing constituents. This circumstance led me to determine the quantity of phosphoric acid, which I found to amount in this soil to only ·147 per cent.

There can thus be no doubt but that superphosphate and other phosphate manures will much improve this and similar soils, and I cannot help thinking that there are many soils in Devonshire, Somersetshire, Cornwall, and South Wales, upon which a portion of the money now spent in the purchase of lime or shell-sand might be much more economically laid out in the purchase of artificial manures, especially those rich in phosphates; or in the purchase of oil-cake, the consumption of which on the farm would tend to produce a much more valuable manure than is found at present on many farms, especially in Wales and some parts of Devonshire.

The rocks on which Mr. Watson's soils rest have also been analysed by me, and as their composition may be of some interest, I subjoin a Table which contains the results of analyses of three rocks from Dorsely.

No. I. is a specimen of the rock immediately under the soil. It is a brown-coloured rock.

No. II. is a specimen of the rock subjacent to No. I. Colour of rock bluish-grey, occurring at a depth of from 2 to 6 feet.

No. III. shows the intermixture of No. I. and II.

	No. I. Brown Rock.	No. II. Blue Rock.	No. III.
Water of combination	6·274	4·360	3·02
Oxides of iron and alumina	27·854	26·452	28·02
Phosphoric acid	·250	·508	·29
Carbonate of lime	1·234	10·040	8·04
Magnesia	3·008	*2·008	*1·96
Insoluble silicious matter	61·274	56·580	58·67
	100·538	100·000	100·00

Comparing these results with each other, it will be observed that the brown rock contains very little lime, and just half the amount of phosphoric acid which is contained in the blue rock on which the brown rock rests, whilst there is no less than 10 per cent. of carbonate of lime in No. II. The rock No. III. contains 8 per cent. of lime and less phosphoric acid than No.

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* Determined by loss.

II., but more than No. I. The brown rock in all probability is formed from the blue rock; and it is to be regretted that the soil does not rest upon this rock, for a decomposition of this rock would furnish a very fertile soil.

The geological disposition of the rocks in South Devon is extremely interesting, and it is to be hoped that practical geologists like Mr. Whitley, of Truro, chemists and practical observers, will combine together in their labours, which then no doubt will bring to light facts valuable to the occupier of the land.

Again, on the clays of the granite and clay-slate, lime is of the greatest utility. These two formations prevail in Wales and Cornwall, and hence the soils in those parts often stand in need of lime. This will appear by throwing a glance at the subjoined Table, in which the composition of four soils from South Wales is given:—

Composition of four Soils from Wales.

	No. I.	No. II.	No. III.	No. IV.
Moisture	3·93	4·94	5·93	4·57
Organic matter and water of combination	5·23	7·65	7·53	9·30
Oxide of iron and alumina	6·37	13·11	7·28	10·15
Carbonate of lime	8·07	·93	1·10	1·30
Insoluble silicious matters (clay and sand)	75·47	73·18	77·81	73·29
Magnesia and alkalies (principally magnesia)	·93	·19	·35	1·39
	100·00	100·00	100·00	100·00

No. I. is a soil from Penally, 2 miles from Tenby; it contains fragments of slate and is full of bits of lime. It has evidently been limed in enormous quantities, for it requires about 400 bushels of burned lime per acre to add 2 per cent. of lime to a soil of only 6 inches in depth, and naturally the Penally soil hardly contains any lime. I am informed that this soil produces only middling crops, and that a large dose is required to produce any effect upon it.

The wonder to me is that lime does produce any effect at all. Chemically, *i. e.* as a manure, it certainly cannot act on land limed to such an extent, and it is plain that lime can only act beneficially in a mechanical way, which will explain at once why large doses are necessary to produce any effect.

No. II. is a very heavy soil from Tallybont farm, in Lawhaden parish, near Narbeth. It is described to me as a good soil.

No. III. is a soil from Greenway farm, near Narbeth. It is a lighter soil than No. I., and is described to me as a very good soil, which rents at about 3*l.* an acre. It is said to require but little lime, and to produce excellent pasture.

No. IV. is a poor soil from Tegfynydd in the parish of Llanfalteg, county of Carmarthen.

This soil has been limed in 1853 with 5 tons of lime to the acre, and produced, in 1854, 20 bushels of wheat, in 1855 a crop of barley, in 1856 oats; in the winter of 1856 it was covered with about 5 tons of manure per acre, and was growing in 1857 clover and oats.

I abstain from making any remarks on these data, which to the intelligent agriculturist speak volumes.

On the Application of Lime to Peaty Soils on Land long out of Cultivation.

Practical men are all agreed that new land, or long pastured land, should be heavily limed when brought into arable cultivation. On such land lime should be applied in no less quantities than 150 bushels per acre; and when it can be had at a cheap rate it may even be used with advantage at the rate of 250 to 300 bushels per acre.

Having pointed out the peculiar disorganizing action of quick-lime on vegetable matter, greatly abounding in such land, it will not be necessary again to enter into a lengthened discussion of the causes of the beneficial effects which lime is capable of producing under these circumstances. Suffice it to say that it converts the abundance of vegetable substances in such soils into food for plants, improving at the same time the physical condition greatly.

Peaty soils especially will be greatly improved by a heavy dressing of quick-lime; and it is on such land that lime must be used in large doses to produce at once a decidedly beneficial effect.*

In peat land the proportion of organic matters often amounts to from 50 to 60 per cent., and it is therefore evident that much lime is required to effect the decomposition of so large a quantity. It may be laid down as a general rule for our guidance, that the greater the proportion of vegetable matter in the soil the more safely lime can be employed in large doses.

Land that has lain long in grass, when broken up is generally full of couch, larvæ of insects, and worms. A good dose of quick-lime will be found most useful in destroying these nuisances and converting them into food for plants.

On inferior pasture land a dressing with lime and salt has the effect of producing a finer herbage, and may therefore be used

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* Such is the immediate effect of a heavy dressing of lime upon cultivated peat soils, that it is found practically useless without it to plant them with corn crops, as the crops become lodged, and in many cases rotted upon the land; while succulent crops are very profitable.—R. S.

with advantage for keeping down the coarser grasses and inducing the growth of a more delicate and nutritious herbage.

In illustration of the uses of lime on pasture land I append the analyses of three pasture soils :—

Composition of Soil from Shepton Mallet (No. I.) ; *Claverton* (No II.) ; *and from Kingston Seymour, Congressbury* (No. III.).

a. MECHANICAL ANALYSIS.

	No. I.	No. II.	No. III.
Moisture	3·54	..	2·31
Organic matter and water of combination	18·96	16·80	9·52
Lime	2·18	·75	1·59
Sand	23·53	32·66	35·51
Clay	51·79	49·79	51·07
	100·00	100·00	100·00

b. CHEMICAL ANALYSIS.

	No. I.	No. II.	No. III.
Moisture	3·54	..	2·31
Organic matter and water of combination	18·96	16·80	9·52
Oxides of iron and alumina	13·05	16·08	12·90
Carbonate of lime	2·18	·75	1·59
Insoluble silicious matter	61·75	64·36	72·60
Carbonate of magnesia	..	1·56	..
Magnesia and alkalies	·52	alkalies ·45	1·08
	100·00	100·00	100·00

The soil from Shepton Mallet, it will be observed, contains a great deal of vegetable matter, present principally in the shape of undecayed and partially decomposed roots. This is a stiff dark-coloured clay soil, which dries up into hard lumps.

In the soil from Claverton there is also a considerable quantity of organic matter and clay, and comparatively speaking little sand. Like the preceding soil, it is of a stiff nature, and contains very little lime.

The third analysis represents the composition of marshy land from Kingston Seymour. It is a marshy, dark-coloured, almost black soil, which is free from stones, and dries up to hard masses like brickbats. The dark colour is due to the presence of imperfectly decomposed vegetable remains. All three soils, but more especially the one from Claverton, would be greatly benefited by heavy dressings of lime.

In the marsh land the proportion of lime is smaller than in the two other soils, and yet its colour is much darker. This appears to me to indicate that the land is badly drained, and that the effect of lime probably will not be so marked upon this soil as on others of a similar composition.

In badly drained soils organic matter rapidly increases; the land becomes more and more marshy or peaty. This defect can only be successfully remedied by thorough drainage, and by subsequently applying lime or marl if necessary. Lime used before the land is well drained can only lead to disappointment, for lime does not destroy readily an excess of organic matter if the air is excluded, as is the case in imperfectly drained soils.

On the Application of Lime to Light Soils deficient in Lime.

Light land, no less than heavy, is often much benefited by marling or liming. In fact, all soils, whether light or heavy, are rendered more fertile by the use of lime, if they are deficient in this substance, so essential to the healthy growth of plants. Sandy soils are often very poor in lime as well as in clay and in organic matters; they are open, readily admit air, and allow the rain that falls upon them rapidly to carry into the subsoil, not only soluble matters, but also finely divided powdery matters, such as slaked lime. Every farmer knows that lime has a tendency to sink in the ground, and that this tendency is greater in light than in heavy soils. For this reason it is more advisable to lay on lime sparingly on light land, and to renew the application of lime at shorter intervals, than to put at once a heavy dressing and to allow a longer period to intervene before the application of lime is renewed.

On sandy soils deficient in lime turnips and swedes are very apt to become "fingered and toed." There is nothing which so effectually cures this evil as a dressing of about 2 tons of lime and as much long dung as can be spared, applied in February when the land is ploughed for the turnip crop, and the subsequent application of 1½ cwt. of superphosphate, which it is best to drill with the liquid-manure drill, on sowing the turnip crop; or 2 cwt. of superphosphate and 1 to 1½ guano, if farmyard-manure cannot be spared in sufficient quantity to give the land a good dressing. On the whole, 2 to 3 tons of lime per acre may be regarded as a good dressing for light sandy soils, and this quantity, generally speaking, should not be exceeded.

Where marl, or chalk, or shell-sand can be readily procured, it is advisable to use these fertilizers in preference to quicklime upon light sandy soils. Good marl, especially, produces excellent effects upon sandy soils, where it supplies not only lime but also clay, in which sandy soils are always deficient. Morever, in the shape of marl, lime is not so readily carried into the subsoil as when used as slaked lime.

These general remarks on the use of lime upon light land are further illustrated by the subjoined analyses of three soils found in the West of England:—

Composition of Soils from Yatton (No. I.) ; *from Combe, near Sherborne* (No. II.) ; *and Soil from Montacute* (No. III.).

a. MECHANICAL ANALYSIS.

	No. I.	No. II.	No. III.
Moisture	2·47	·	3·65
Organic matter and water of combination	4·10	·	5·78
Lime	1·92	·	1·48
Sand	75·45	·	53·30
Clay	16·06	·	35·79
	100·00	·	100·00

b. CHEMICAL ANALYSIS.

	No. I.	No. II.	No. III.
Moisture	2·47	5·50	3·65
Organic matter and water of combination	4·10		5·78
Oxides of iron and alumina	5·58	2·83	8·01
Carbonate of lime	1·92	·40	1·48
Magnesia and alkalies	·73	·77	1·28
Insoluble silicious matters..	85·20	90·50	79·80
	100·00	100·00	100·00

The soil from Yatton is a sandy dead-looking soil, showing here and there white particles of lime or chalk. It is tolerably free from stones; the stones are as hard as flint, and some are reddish-coloured like jasper. This soil probably has been limed at one time or the other, and, although it may not want to be limed immediately, it may be safely predicted that it is one of those light soils that require a periodical dressing of lime.

In the soil from Combe, near Sherborne, hardly any lime occurs, and no less than about 90 per cent. of silicious sand. It is self-evident that marl or lime will much improve such a soil; but since this soil is also deficient in other fertilizing constituents, farmyard-manure, or a mixture of guano, superphosphate, and salt, should be used as well as lime or marl if the soil is to yield good crops. Lime used by itself upon such soils, which are but little better than blown sand, answers no useful purpose.

A much better soil than that of Yatton or Combe is the soil from Montacute. This is a lightish loamy soil, which ought to grow good turnips, as it is readily pulverised. It exhibits white particles of lime, which has in all probability been applied to it in the shape of slaked lime, chalk, or marl. Periodical liming appears to be requisite to keep this soil in a productive condition, since naturally the land is poor in lime.

There is but one other observation which I would make before giving a few instances of soils upon which lime is actually used, but upon which its use cannot be recommended. It is this :—Never depend upon the use of lime alone on light land ; the first application or two of lime may produce a marvellous change ; but if no other manures are employed at the same time, the land will become sooner exhausted than would have been the case had no lime been used at all.

On the Composition of Soils not benefited by Lime.

Generally it may be stated that all soils containing more than 4 per cent. of lime are not benefited by lime. If a soil, therefore, naturally contains 10 or 20 per cent. of carbonate of lime, we need not wonder that lime does not produce any good effect. It must not be inferred from this observation that I think all soils containing less than 4 per cent. of lime require lime. I am quite aware that this is not the case, and have become acquainted with excellent soils containing only 1½ or 2 per cent. of lime, and which are never limed, and yet maintain their fertility. For all I know, there may be others which, although they contain rather more than 4 per cent. of lime, may still be improved by the use of lime. Experience alone can here be our guide, and, as far as my experience goes, I have found that lime does no good upon soils containing more than 4 per cent. of lime, and that, generally speaking, the application of lime to land need not be renewed if the proportion of lime in the land still amounts to 1¾ to 2 per cent. But I have now to give the composition of four soils upon which I believe lime is largely used:—

Composition of Soils from Longsutton (No. I.); *from Mendip* (No. II.); *and two Soils from Street, Glastonbury* (No. III., *a*, *b*).

a. Mechanical Analysis.

	No. I.	No. II.	No. III. *a*.	No. III. *b*.
Moisture	6·33	3·28	7·61	4·30
Organic matter and water of combination	7·59	7·16	15·82	5·50
Lime	22·66	20·22	11·95	13·09
Sand	30·70	46·72	21·53	28·66
Clay	32·72	22·62	43·09	48·45
	100·00	100·00	100·00	100·00

b. Chemical Analysis.

	No. I.	No. II.	No. III. *a*.	No. III. *b*.
Moisture	6·33	3·28	7·61	4·30
Organic matter and water of combination	7·59	7·16	15·82	5·50
Oxide of iron and alumina	11·84	7·19	12·81	15·66
Carbonate of lime	22·66	20·22	11·95	13·09
Insoluble silicious matter	49·65	57·68	50·79	49·95
Magnesia and alkalies	1·93	4·47	1·02	1·50
	100·00	100·00	100·00	100·00

The soils from Mendip and Longsutton, according to the characters of their constituents, are marly loams; the two others stiff calcareous clays.

The Longsutton soil contains many white soft particles of lime, showing that it has been limed at no very remote period. I also readily detected in it grey light-coloured stones, which strongly effervesced with acid, and were evidently limestones, probably lias or inferior oolite limestone.

The soil from Mendip, a red-coloured soil likewise, appeared to have been recently limed, for it is full of white particles and lumps of slaked lime. The stones found in this soil were partly red sandstones, partly greyish crystalline limestones, and a few bits of crystalline calcspar ; both the sandstones and the limestones effervesced strongly with acid.

One of the soils from Street, Glastonbury (that marked *a*), is a stiff dark-coloured soil, full of vegetable matter, and containing also small stones and shells, which strongly effervesced with acid.

The second soil from Street, marked *b*, does not contain much organic matter, but a good many small stones, which by their effervescence with acid are proved to be limestones.

Mr. Clark, who sent these soils, observes that the dark-coloured soil is from a pasture that is tert (that is tart or sour), and scours the cattle after Midsummer before frost sets in ; the red-coloured soil, on the other hand, produces sound pasture ; when cultivated it was formerly extensively limed.

It has been supposed that the deficiency of lime in pasture land was a cause of the production of sour herbage, or herbage that scours cattle. As I have not paid particular attention to this subject, I cannot pretend to say much about it ; but this is quite certain, that there is land, as in the case before us, which contains as much as 12 per cent. of lime and yet produces grass that scours cattle. The growth of sour grass and the soil from Street cannot be connected with the proportion of lime it contains. The dark-coloured appearance and the large quantity of organic matter in this soil appears to me to indicate imperfect drainage, and to this circumstance probably the production of sour herbage is due. We have here another instance showing that there may be an excess of organic matter in a soil although it contain much lime.

These four analyses are particularly interesting in showing the utility of examining soils for lime before going to the expense of applying lime to the land, for they present us with no less than four instances in which the money laid out in the purchase of lime has been spent to no good purpose. And this leads me briefly to allude to the mode of ascertaining whether a soil is likely or not to be benefited by lime. Put a small quantity of soil in a tumbler, and pour upon it first a little water and then a good deal of spirits of salt or muriatic acid ; if this addition produces a strong effervescence, there is no need of applying lime to the land; if no effervescence is produced, in all probability liming or marling will be useful. However, this simple test cannot always be depended upon, and it is therefore much safer to have the proportion of lime determined in the soil, which at no great expense can be done by any analytical chemist.

On the Application of Shell-sand to some Cornish Soils.

In conclusion, a few remarks on the use of shell-sand in relation to some Cornish soils lately examined by me may not be amiss, since they apply no doubt to many other soils of Cornwall and Devonshire, upon which shell-sand is largely employed as a manure.

It has been stated already that immense quantities of shell-sand are annually used for agricultural purposes on the coast of Cornwall and Devonshire. A great diversity of opinion appears to prevail amongst practical men as to the economy with which sea or shell-sand is used by the farmer. Some allege that the effect of sand on the crops is very marked; others that hardly any effect is seen to follow the application of shell-sand to the land.

There can be no doubt that in some instances shell-sand does no good, but at the same time it must be admitted that in the majority of cases shell-sand is a useful manure for most soils resting on the clay-slate or granite formations along the Devonshire and Cornish coast, for these soils are generally very poor in lime. The use of shell-sand, however, like that of many other good things, has been much abused. It is too often forgotten that repeated heavy dressings of sea-sand cannot produce so good effects as the first application, since shell-sand owes its fertilizing qualities almost exclusively to the lime it contains, and it ought to be remembered that no single manuring element can permanently maintain the land in good heart. It is, indeed, plain that the effects which usually follow the first application of sea-sand must cease when the quantity of lime incorporated uniformly with the surface-soil is so large that the spongeoles of the roots can readily find more than sufficient lime to meet all the requirements of the growing plant.

The examination of some soils from the neighbourhood of Bude has furnished to me, I think, decided proofs that there are many soils in Cornwall which are much benefited by a dressing with shell-sand, and also that shell-sand is often applied to land upon which it is not needed, and upon which money would be far more beneficially spent in the purchase of artificial manures or of artificial food.

The following Table exhibits the composition of five soils from the neighbourhood of Bude. They were sent to me by Mr. Hockin :—

Composition of five Soils from the neighbourhood of Bude, Cornwall.

	No. I.	No. II.	No. III.	No. IV.	No. V.
Moisture	1·68	4·217	..	1·10	..
Organic matter and water of combination	5·87	12·163	7·90	5·77	14·84
Oxides of iron and alumina ..	7·23	7·730	8·75	10·62	7·35
Carbonate of lime	4·23	1·258	11·25	4·87	·95
Magnesia and alkaline salts (determined by loss)	·05	·282	·98	·27	·47
Insoluble silicious matter ..	80·26	74·350	71·12	77·37	76·39
	100·00	100·000	100·00	100·00	100·00

Soil No. I. came from Newhouse, near Bude, and is an average sample of the clay of the district; depth of soil about 12 inches below yellow clay. This field has not been sanded for the last five years, and as it still contains nearly 5 per cent. of carbonate of lime, a further dressing of sea-sand would be of no use except as a mechanical ameliorator.

Soil No. II. is a soil from a field on Halls. This field has been a furze-brake for the last 30 years, until 1855, and consequently cannot have been sanded for that time. About 30 years ago, Mr. Hockin informs me, it was in wheat and was probably sanded. The soil is light and on a porous rock, in some parts stony; depth of soil from 4 to 8 inches. There is much less carbonate of lime in this soil than in the preceding, and I have no hesitation in saying that a good dressing of shell-sand would now do good to this soil.

No. III. is from a field at Well. This is a light soil, has been most liberally sanded every two or three years for *many* years. Naturally the light soils in this district are almost destitute of lime, and a simple inspection will show that the carbonate of lime shown in the above analysis is all due to the shell-sand added to the land, evidently in enormous quantities, at one time or the other. On land treated like No. III. it may be safely asserted the further application of shell-sand must turn out a complete failure.

No. IV. is a soil from Broomhill Field, Berry Park. This field, I am informed, is a fair specimen of the soil in this district; it rests on a porous rock, and is in a good state of cultivation. Depth of soil about 8 inches; has not been sanded for the last 10 years.

It will be seen that this soil still contains nearly 5 per cent. of carbonate of lime. On this soil likewise a further application of shell-sand would not be attended with any benefit. The analysis of this soil is interesting, inasmuch as it shows that shell-sand may remain for a long time in the soil, and that therefore good dressings with shell-sand need not be repeated at short intervals.

The last-mentioned soil is from a pasture meadow which 50 years ago obtained a prize as an irrigated meadow. The quantity of lime in this soil, taken at a depth of 5 inches from the surface, is small. Probably the surface-soil contains more.

These instances, referring to the use of shell-sand in Cornwall, I think are instructive. They explain why in some cases no effect whatever is produced by the use of shell-sand, whilst in others even a moderate dressing benefits the crop to which it is applied; and why sometimes shell-sand only produces a good result when it is used in very large quantities, in which case it acts mechanically, and not chemically, upon the soil. In short, the same principles which regulate the application of lime to the soil ought also to guide the farmer in using shell-sand. How far practical men act upon principle it is not for me to decide, but this is quite certain, that instances in which much money is periodically wasted in the purchase and application of lime, marl, or shell-sand, are far more numerous than is generally believed.

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ON

PARING AND BURNING.

BY

DR. AUGUSTUS VOELCKER.

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ON PARING AND BURNING.

PERHAPS few agricultural operations, even long after they have been practised with marked success in a district, can be said to be so firmly established as to meet with universal approval. There will, on the contrary, always be men who, in the face of long and extended experience, will doubt the economy of certain agricultural operations, or deny their accordance with sound principles, or their consistency with modern improvements.

Paring and burning, a practice carried out with much benefit in various parts of England, and in none with better results than on the Cotswold hills, has shared this general fate of many other agricultural practices. Like deep drainage, subsoiling, autumn-ploughing, deep cultivation, the application of artificial manures, and other high-farming operations, paring and burning has been the subject of lengthened discussion in our agricultural periodicals. On the one hand we possess the testimony of trustworthy and acknowledged good farmers, who all speak very favourably of this mode of raising produce; on the other hand, there are not wanting men of intelligence who advise agriculturists not to adopt paring and burning as a regular farm routine; and some men who go to the length of condemning this practice unconditionally, as being wasteful and inconsistent with scientific principles and good practice. We cannot feel surprised at such great diversity of opinion if we bear in mind how difficult it is with most men to discard preconceived theoretical views; how little, comparatively speaking, is known of the *rationale* of even common farm practices; how much more easy it is to give vent to speculations than to establish a single fact; and how few men are capable of explaining in intelligible language the more direct cause or causes of their success, and of the failure experienced by others. Again, it is an undeniable fact that fixed rules cannot be laid down in agriculture, of which it can be reasonably expected that they will lead invariably to the same results; for it is self-evident that the very same operation which in one locality perhaps has doubled the produce, may in another district remain unattended with any benefit, or, under unfavourable circumstances, may even do harm instead of good. We must, therefore, be prepared to meet with discussions on agricultural matters, and to expect, it may be, plans, proved by long personal experience, to be called in question, or even to be condemned or ridiculed.

In the absence of scientific principles—and agriculture will always more partake of the characters of a practice than of those of science—agricultural discussions, carried on in a candid and generous spirit, must be doing much good. They often ventilate the question under discussion in all directions, and tend by degrees to the establishment of principles useful to intelligent men. Uniformity of opinion leads to stagnation, and this, in the world of intellect, is as baneful as it is in the physical world, whatever the relations may be in which stagnation may be considered. Thus the discussions which appear from time to time in our agricultural periodicals on paring and burning are not so unprofitable as they may perhaps seem at first sight. For my own part, I feel indebted to them for several hints, which have much assisted me in the examination of the question: "Is paring and burning, as a regular farm practice, founded on correct principles or not?"

The object of the following pages is to record some experimental investigations made on this subject, and to adduce reasons, founded upon analytical evidence and well-established agricultural experience, in support of my conviction that paring and burning on some kinds of soils is not only a profitable operation, but that it is, under certain circumstances, by far the most rational plan of cultivation which can be adopted, in our present state of knowledge, for raising upon some kinds of land the largest amount of produce with the least expenditure of money.

OBJECTIONS AGAINST PARING AND BURNING.

Various objections have been raised against paring and burning, amongst which the following three are the principal:—

1. This practice has been condemned by some writers on the subject, because it destroys the organic matters in the soil, and thus causes a waste in a most important class of fertilising constituents.

2. Others less speculative, and therefore ready to acknowledge the benefits arising from paring and burning, notwithstanding object to it because they maintain that, although two or three good crops can be grown after paring and burning, this operation will leave the land afterwards in such an exhausted condition that the cost of bringing it again into a profitable state of cultivation will be found greater than the temporary benefit derived from paring and burning.

3. It is objected to on the ground of expense, and maintained that it is more profitable to lay out money in the purchase of guano, superphosphate, or other artificial manures, than to spend it in paring and burning.

Let us examine these three objections:—

1st. With regard to the first objection, it will be observed that it is taken for granted that organic matters are soil-constituents, which under all circumstances exercise a beneficial effect on the growth of plants, for which reason it is deemed most important by those who hold this view to preserve them as much as possible in the soil.

It cannot be denied that organic matters are desirable in *most* soils. The fact that well-cultivated and productive soils (like many rich wheat loams, and most garden soils) invariably contain much organic matter, has led many agriculturists to connect intimately the larger or smaller proportion of organic matter in different soils with their relative productiveness. Not many years ago it was customary with most agricultural writers to estimate the relative state of fertility of different soils by determining the amount of humus, *i. e.* decomposed organic matters in each. This, however, is clearly contrary to reason and well-ascertained facts; for there are soils which, like peaty lands, or the soil of poor pastures, contain a very high percentage of organic matter, and yet are quite sterile. On the other hand, there are soils which, like many very fertile clays, hardly contain any humus, and yet are highly productive. These inconsistencies have compelled the adherents of the humus theory to assume a number of such terms as dead, inert matter, sweet and sour humus—terms which, in the sense in which they are generally used even now are meaningless, and which for this reason might with much benefit be subjected to the process of burning.

The humus theory has retarded rather than promoted agricultural improvements. Happily it may be regarded at present as fully exploded. Had Liebig done nothing else for agriculture but to give the *coup de grace* to the humus theory, by means of his irresistible argumentative writings, the agricultural community would still be highly indebted to the great German chemist; for as long as this theory found favour with practical men, much to their disadvantage, the importance of the mineral constituents, so necessary for every description of agricultural produce, was altogether overlooked. It was reserved for Liebig to give general recognition to the fact, that the mineral matters which enter into the composition of plants are not merely accidental, but essential, constituents, without which plants cannot live; and to point out in a clear and convincing manner the necessity of the presence in the soil of those mineral matters which are found in the ashes of the plants we intend to cultivate. The influence of Baron Liebig's writings on this subject upon agricultural improvements can hardly be over-estimated. It is not saying too much that Liebig's writings have given a new impulse to agricultural pursuits, and created a new branch of industry, viz. the manufacture of artificial manures. Though unsuccessful in the first attempt to manufacture efficient artificial manures, Liebig has nevertheless opened the way to the manufacture and general application of artificial manures.

The failure of Liebig's mineral manures, to whatever it may have been due, however, does not prove the unsoundness of the principle so clearly announced in Liebig's writings, namely, the principle that plants cannot grow vigorously if the mineral constituents found in their ashes are deficient in the soil or in the manure applied to it. Liebig's position in enforcing this truth is unassailable; nor has it indeed been assailed by any one who can lay claim to the title of a man of science. It is, in reality, not in principle but in practice that Liebig has failed. And this need not excite surprise; for, however true a principle may be in the abstract, such a principle, if applied to a subject upon which it can have no bearing, is evidently misapplied, and likely to lead to errors in practice. Thus it is unquestionably necessary upon a purely sandy soil, containing very little besides silica, to use a manure which includes all the mineral elements found in the ashes of the crop intended to be raised. In this case the abstract principle finds a strict application—hence a corresponding useful practical effect. But if a manure, composed entirely of the ash-constituents of plants, is applied to clay soils, and many other soils, containing an almost inexhaustible supply of those very minerals which are added to it in the shape of a mineral manure, it is plain that the same abstract truth can find no application. The result of such misapplications of a correct principle naturally must be what it has since proved to be in numerous instances—a complete failure. But, as just mentioned, the failure which has in many instances attended the application of purely mineral manures does not show that mineral substances are useless in relation to vegetable life, much less that organic matters after all are more important in relation to the growth of plants than mineral substances. These mineral matters are essential to the very existence of every kind of agricultural produce, and must, therefore, be present in the soil, or in the manure applied to it, or else they will not grow; organic food may be altogether wanting in the soil or the manure, for under favourable circumstances the plant can get it from the atmosphere. Thus in a certain sense mineral matters are the more important.

Whether it is advisable to apply *mineral* or *organic* food to the soil, in cultivating certain crops on land of a particular description, is another and, as far as practice is concerned, an equally important question. Here it may happen, and does happen, in the case of many soils, at least in England, that the artificial or direct *application* of minerals (not the minerals themselves) is of no use whatever. Speaking of the *application* of mineral matters in such a case, most purely mineral manures may justly be considered to be unimportant, or at any rate of doubtful efficacy—much less valuable than organic manures. But it cannot be said, in a general way, that mineral matters are less important than organic manuring elements, nor the reverse.

It is evident at the same time that it is impossible for practical men thoroughly to comprehend how far certain scientific principles are applicable in a particular case if these principles themselves are misunderstood; nor can it be expected that a place will be secured for science in the affections of the practical man if the teachers of science be unacquainted, or but very imperfectly informed, on practical matters. Scientific men too often fall into the grievous error of insisting upon the application of abstract principles under all circumstances.

Chemical principles, though they may not always find a direct application in agriculture, or though, when stated in the abstract, they may require to be greatly modified in practice, are, however, of primary utility to the occupier of land. The want of a clear perception of a scientific truth, and its bearing upon the farm routine, as followed in this or that locality, is a fertile source of endless disputes. In order fully to appreciate the objections of those who, I think, attach, generally speaking, too great an importance to the organic matters in the soil, it appears to me desirable to allude briefly to the functions of humus, *i. e.* organic matters in a state of progressing decomposition. I would, therefore, observe:—

1. Humus is an excellent absorber of moisture, and for this reason of special use in sandy and other naturally dry soils. In illustration of this property, the following partial analyses of two soils may find here an appropriate place. Both soils are from Buckinghamshire. Before proceeding with their analysis, I kept them in a heated room, in a powdered state, until they were perfectly airdry, neither gaining nor losing water when weighed from day to day. In this state they were analysed, and the following results obtained:—

	No. I.	No. II.
Moisture	4·70	22·35
Organic matter and water of combination ..	5·98	22·01
Oxides of iron and alumina	10·51	16·02
Carbonate of lime	1·32	·95
„ magnesia	·85	·43
Phosphoric and sulphuric acid	trace	trace
Alkalies, chlorine, and loss	·47	·56
Insoluble silicious matter (chiefly sand) ..	76·17	37·68
	100·00	100·00

No. I. was a soil in wheat, No. II. soil in permanent pasture.

The wheat soil, it will be seen, contained nearly 6 per cent. of organic matter, and retained, in a moderately-dry atmosphere, about 5 per cent. of moisture, which was only driven off at the temperature of boiling water. The pasture-land contained 22 per cent. of organic matter, and, under the same circumstances in which No. I. retained only 5 per cent. of moisture, was capable of retaining no less than 22 per cent.

2. Humus not only absorbs and retains moisture from the atmosphere, but also ammonia; and this it does in virtue of its porosity, no less than in virtue of the chemical affinity which the humic and ulmic acids found in humus possess for ammonia.

3. The organic remains in soils contain nitrogen, and, on gradual decomposition, give rise to the formation of ammonia, which at once is fixed by the humic acids generated at the same time during the decomposition of the organic matters of the soil.

4. Organic matters, in order to be decomposed, must be brought into contact with atmospheric air, the oxygen of which changes them by degrees into brown and black humus, both of which include various organic combinations, characterised by great avidity for absorbing oxygen from the atmosphere, by which they are finally resolved into carbonic acid. Organic matters thus furnish a continual source of carbonic acid in the soil, and afford thereby organic food to the plant, which food appears to be highly beneficial in the earliest stages of vegetable life, before the green leaf is fully formed, and the more mature plant can avail itself of the carbonic acid of the atmosphere.

5. This process of slow oxidation, or eremacausis, to which all organic matters are subject in contact with the air, is attended with evolution of heat, which heat, of course, is beneficial to the growth of plants.

6. In virtue of the dark colour of humus, soils containing organic matters absorb more readily heat from the sun than others deficient in humus; and for this reason also organic matters appear to favour vegetable growth.

7. The vegetable remains of former crops, besides combustible elements, contain mineral matters: the latter, however, are so firmly united with the organic portion that they cannot be dissolved by water from the fresh organic matters. But in the measure in which the decomposition of the organic matter proceeds, the mineral matters are rendered soluble, and thus humus furnishes also mineral food to the growing plant.

For more than one reason, therefore, organic matters in the soil are capable of exercising a beneficial influence on plants. It may appear therefore highly desirable to preserve them by all means; and their destruction by fire would seem to be opposed to the first principles of good farming. There can be no doubt that, in many instances, paring and burning is inapplicable; but at the same time experience has shown that in other instances the destruction of the organic matter in soils is not attended with any evil consequences. There must exist therefore some cause or causes which afford an explanation of the benefits of a practice which appears contrary to what has been stated in regard to the functions of humus. Now it is quite true that humus absorbs moisture and ammonia from the atmosphere, but is it equally true that all soils stand in need of a good absorber of moisture and ammonia? Are there not some which seldom get even sufficiently dry, and for this reason are considered wet and cold soils? Are there not soils which contain constituents capable, like organic matter, of absorbing moisture and ammonia from the atmosphere and of retaining it? Again, are there not plants which find abundance of organic food in the atmosphere, and for this reason are not dependent for food on the organic matter in the soil? It is evident that, if these questions can be answered in the affirmative, the most serious objections against paring and burning fall to the ground. If, moreover, it can be shown that by the destruction of useful matters we can realize a greater practical advantage than by any other known means, no cause will remain for lamenting their dissipation by fire. In this case their loss is equivalent to money well spent in other farming operations. The examination of many soils, upon which paring and burning is practised with manifest good results, has shown that they contain a large proportion of clay; and as clay possesses in a high degree the power of absorbing moisture and ammonia, it matters little if the organic matters in soils containing much clay are burnt away, for they still retain their power of absorbing atmospheric food for plants. In sandy soils, or light land deficient in clay, it would be decidedly wrong to pare and burn, but in heavy land, and all soils containing a fair proportion of clay, the organic matter may be destroyed without injuring the land, especially if it can be shown, as I hope to be able to show presently, that its destruction is attended with decided advantages.

2ndly. The second objection against paring and burning, namely, that it will produce a few good crops and then leave the land in such an exhausted condition, that the cost of bringing it again into a profitable state of cultivation will be greater than the temporary benefits derived from paring and burning, rests on the assumption that the soil furnishes all the food for the crops which are raised upon it, and that none of the matters taken from the soil are returned to it. This objection would indeed have some force if it were usual to pare and burn for corn crops, and to sell off the farm corn and straw. However, commonly land is pared and burned in preparation for turnips; the roots are then consumed on the land by sheep, and by this means the mineral matters taken up from the soil by the turnip crop are restored to it almost completely in the sheep's excrements. It is well known that turnips derive the bulk of their solid matter from atmospheric food. In passing through the body of sheep a considerable proportion of the organic part of turnips derived from the atmosphere is in the shape of excrements imparted to the soil. This added to the numerous fibres and decaying leaves enriches the land sufficiently in organic remains to meet the requirements of the subsequent corn-crop. No fear therefore need to be entertained that soils become impoverished by paring and burning, if this operation is performed as a preparation for root crops to be consumed on the land.

3rdly. The third objection against paring and burning, raised on the ground of expense, being a purely practical one, might be fairly left for settlement with those more directly interested in this matter. I may observe, however, that I have been at considerable pains to ascertain the opinions of practical men on this subject, and have received reliable evidence that paring and burning, in the judgment of the best farmers on the Cotswold hills, is the most economical means of raising on land of certain descriptions a good crop of turnips; and that it has been followed for ages with the most successful results. Numerous personal inquiries lead me to confirm the opinion expressed by Mr. Caird, who says that the best farmers on the Wold burn the most.

Mr. Caird rests his opinion on the testimony of several practical men; amongst other things he mentions "a field which had been broken up from its natural state exactly fifty years ago; it was then pared and burned, and so started the first crop of turnips, which supported the other crops of the course. The same process had since been seven times repeated; no manure of any kind had ever been applied, except such as arose from the consumption of its own produce on the ground, and the crops in each succeeding rotation had shown no sign of decreasing. The soil, which lies on the lower oolite formation, is very thin, but as it is not more so than when first broken up, its depth must have been maintained by the ploughman, perhaps imperceptibly, bringing up some fresh subsoil after each burning."

It affords me peculiar pleasure to show the perfect agreement of this practice with scientific principles; and I hope likewise to be able to show that the money laid out in paring and burning is much more economically spent than by purchasing guano, superphosphate, or other manures for root-crops.

On the Changes produced on Paring and Burning.

In order to enable the reader fully to understand the advantages resulting from paring and burning, it now devolves upon me to explain briefly the changes which take place in the constituents of the soil submitted to this operation.

These changes are of a twofold character.

The first relates to the action of fire on the organic matters, the second to that of fire on the mineral substances of the soil. Let us consider each separately.

1. *Action of Fire upon the Organic Matter of the Soil.*

All cultivated soils contain organic matter, some in smaller, others in larger proportions, in the shape of decaying or decayed roots, leaves, &c. In badly drained and in naturally stiff soils these organic remains rapidly increase from year to year, whilst under ordinary cultivation such an accumulation of organic matter does not take place on sandy, porous, and well-drained, light soils.

The more clay a soil contains, the more retentive and the stiffer it is; the more impervious the subsoil upon which it rests, the less perfectly air can find access to the interior of the soil and the more rapidly these vegetable remains increase in it. Hence the large proportion of organic matter which is found in land resting on the impervious forest marble clay, a description of clay which I believe would not be unproductive if it were efficiently drained, and altered in its physical characters by other approved mechanical means. Hence also the large amount of vegetable remains in land laid down in permanent pasture, or in soils after one or two years' growth of clover or sainfoin.

In clover-lea or old sainfoin soils there is a great abundance of vegetable matter, arising from the clover roots and decayed leaves, as well as from the weeds, couch, thistles, &c., grown upon it. Generally vegetable matter in sufficient quantity can be raked together to burn a large quantity of soil, without the addition of any other combustible matter. On burning, the organic portion of these vegetable remains is destroyed for the greater part, and the mineral and saline matters contained in every kind of vegetable matter are left behind, mixed with clay and other mineral matters of the soil, more or less changed by the action of the fire.

The general character of the ashes left on burning vegetable matters, freed as much as possible from adhering earth, may be illustrated by two analyses, made some time ago in my laboratory.

I selected for examination two weeds, which infest very generally the calcareous clay soils and brashy land on the Cotswold hills, namely, the stemless thistle (Carduus acaulis) and couch. The first when gathered contained from 25 to 26 per cent. of dry substance and 74 to 75 per cent. of water, and left on burning 9·66 per cent. of ash.

The ash of this thistle submitted to a partial analysis furnished in 100 parts:—

Composition of the Ash of the Stemless Thistle (Carduus acaulis).

Potash and chloride of potassium	27·40
Chloride of sodium	·90
Lime	41·44
Magnesia	4·40
Oxide of iron and alumina	2·01
Phosphoric acid	5·36
Sulphuric acid	2·92
Soluble silica and sand	3·50
Carbonic acid, and loss	12·07
	100·00

Lime it will be seen is the principal constituent of this ash. This may account for the fact that this thistle delights to grow on the calcareous formation of Gloucestershire. In addition to lime, this ash contains a very large proportion of salts of potash, and besides sulphuric acid, soluble silica, and several other less important mineral fertilizing constituents, an amount of phosphoric acid which is by no means inconsiderable. This acid is evidently united chiefly with lime as phosphate of lime.

In preparing the ash of couch, it was found extremely difficult to separate adhering clay; notwithstanding all care the removal of adhering fine soil from the couch was incomplete, as will be seen by a glance at the subjoined analyses.

Couch on burning furnished an ash, coloured slightly red by oxide of iron, derived no doubt chiefly from adhering clay.

100 parts of this couch ash were found to contain by my friend and pupil Mr. Kensington, now assistant to Professor Anderson of Glasgow:—

Composition of the Ash of Couch.

Potash	10·02
Soda	5·69
Chloride of sodium	3·34
Lime	5·58
Magnesia	·04
Oxides of iron and alumina	12·40
Phosphoric acid	9·38
Sulphuric acid	5·33
Soluble silica	24·92
Insoluble silicious matter (chiefly sand) ..	17·50
Carbonic acid, and loss	5·80
	100·00

These constituents probably are united in this couch ash as follows:—

Carbonate of potash	14·10
Potash in a state of silicate	·27
Soda in a state of silicate	5·69
Chloride of sodium	3·34
Oxides of iron and alumina	12·40
united with phosphoric acid	9·38
equal to bone-earth	(20·32)
Sulphate of lime	9·06
Carbonate of lime	3·30
Magnesia in a state of silicate	·04
Soluble silica	24·92
Insoluble silicious matter (sand)	17·50
	100·00

The ash of couch it will be observed differs in several respects from that of the stemless thistle. The latter contained but little silica, whilst soluble silica is the chief constituent of couch. Again, the proportions of lime and potash in the thistle are much larger than in couch, a fact which is interesting on account of both weeds having been collected from soils of a similar character. This is quite consistent with our present information on the particular wants of different families of plants. Thistles are evidently lime and potash plants, and couch appears to require much soluble silica for its growth, a fact which perhaps will explain its occurrence in sandy as well as in calcareous and clay soils. The two last-mentioned soils often, it is true, do not contain any silica in the shape of sand, capable of being mechanically separated from the other soils' constituents, but most clay soils are rich in alkaline silicates, from which plants unquestionably can take up soluble silica much more readily than from sand.

The large proportion of phosphoric acid in couch ash likewise deserves to be specially noticed. United with lime we have no less than 20 per cent. of bone-earth in couch ash, a circumstance which throws some light on the experience of many Gloucestershire farmers, with whom I have conversed on this subject, and by whom I am told that the fouler the land is, the better will be the crop of turnips, grown without any manure upon land simply pared and burned. I remember having walked once over a very foul piece of land full of couch, and was not a little amused by the remark of my agricultural friend who accompanied me: "What fine healthy couch, Sir, and will give me next year, I don't doubt, a splendid crop of roots, although I do not mean to put a single load of manure on this land." Considering the large amount of couch which is sometimes collected from fields and burned along with other vegetable remains, containing phosphoric acid, a very considerable dressing of bone-material must be given to the turnip crop in couch ashes. Indeed I have ascertained that a much larger proportion of bone-earth is brought within reach of the turnip plant in the red ashes obtained on paring and burning than is contained in a heavy dressing of bone-dust. I shall advert again to this point further on, and only observe in this place that phosphate of lime is the most valuable constituent of couch ashes, and that next to it, potash and sulphate of lime exercise beneficial effects upon the growth of root-crops.

The ashes left on burning other weeds and other vegetable matters found in soils, no doubt will present similar differences to those just pointed out in the analyses of the ash of couch and the stemless thistle. However great the differences in the proportions of phosphate of lime, potash, and other fertilizing constituents may be in the various kinds of vegetable remains which are reduced into ashes in paring and burning, every description of vegetable matter produces ashes containing valuable mineral manuring elements. These mineral constituents, before paring and burning, are disseminated throughout a large mass of soil, and therefore of comparatively little value to crops which, like turnips, remain on the land but four or five months, and which are not provided with the food-searching apparatus which is presented to us in the long fibrous roots of wheat, clover, and various other plants. During the winter, these crops, prevented by the cold from making much progress in an upward direction, extend their roots downward, thereby establishing by degrees an apparatus which is ready to supply the growing plant with abundance of mineral food as soon as the warmer season of the year pushes on the young and fairly established plant. This, no doubt, is the reason why the direct supply of mineral substances in most soils produces hardly any effect upon wheat: quite the reverse takes place when root-crops are manured with minerals. It may be shown that a soil contains possibly 1000 times as much phosphate of lime as is contained in the ashes of a heavy crop of roots, for which reason a good dressing with superphosphate or bone-dust in the eye of the speculative chemist may appear wasteful and contrary to every chemical principle; and yet it can be proved that such a dressing must do good to turnips. What does the young turnip gain, if there is plenty of phosphate of lime in the soil and the plant cannot reach it; or what benefit is a superabundance of phosphate of lime spread all over the field, when the turnip crop is stopped in its growth by the cold weather in autumn, before the crop has had time to collect the disseminated phosphates in a sufficient quantity to enable it to form large bulbs? The shorter the period of vegetation the greater the necessity of a superabundant supply of mineral matters in that portion of the soil which is within reach of the plant. Hence the direct supply of bone-dust or superphosphate to a portion of the soil produces such marvellous effects; thoroughly incorporated with the whole mass of soil, it would do much less, if any good. Hence also the great value of the ashes produced on paring and burning. The roots of the plants which furnish these ashes penetrate the soil to a great depth, and having ransacked the soil, so to speak, in every direction, and sifted out of it the phosphate of lime, potash, &c., which constitute but a very small proportion of the whole mass of soil and subsoil, leave these and other important mineral fertilizers, on burning, in a small compass. Incorporated with a portion of the surface soil, they superabundantly enrich it with those fertilizing constituents, which experience has shown to be especially valuable for root-crops.

If the roots, &c., of former crops exercise such a beneficial effect, it may be said, why not let them become gradually decomposed? By doing this, would the farmer not realize all the advantages of a concentration of mineral food in the surface soil, and at the same time be benefited by the organic portion of the vegetable remains of former crops? In reply to this question, it may be stated that couch and the roots of clover, &c., do not readily lose their vitality nor decompose with sufficient rapidity to admit of this plan being carried out in the cultivation of root-crops, for which paring and burning is specially adapted. In fresh roots and other vegetable remains, the saline inorganic constituents, found in their ashes, are so firmly united with organic constituents, that it is impossible to dissolve by means of water any appreciable quantity even of such soluble combinations as alkaline salts. By the decay of vegetable matters, their mineral constituents are gradually rendered soluble, and by the rapid destruction by fire their mineral matters are at once made soluble and rendered available to the immediate use of plants. These saline mineral constituents, in such a soluble state, act as powerful manures; and hence it is that paring and burning produces an immediate effect upon plants which, like all quick-growing plants, require, so to say, ready-made or soluble mineral food.

The excess of undecomposed organic matters in soils, moreover, is decidedly injurious to vegetation. Peaty soils furnish familiar examples of this. Soils upon which paring and burning is practised with the most benefit contain often much and always a fair proportion of clay; they are impervious and compact in texture, and for this reason do not readily admit air. The roots, stems, and other vegetable matters remain, therefore, buried in the ground for years without undergoing decomposition, or that preparation which we have just seen is so necessary to their yielding soluble fertilizing substances to a quick-growing crop. Thus the destruction by fire of the organic remains in heavy soils, far from doing any harm, is the most available and economical means of preventing their undue accumulation. The fire, I would observe, in concluding this part of the subject, destroys insects, their eggs and larvæ, as well as the seeds of weeds, bits of underground stems, which, like the knots of couch, are so apt to vegetate again, and which, therefore, cannot be got rid of so effectually as by burning. In short, nothing cleans land so thoroughly as paring and burning.

2. *Action of Heat on the Inorganic or Mineral Matters of the Soil.*

The heat generated during the combustion of the organic remains affects the mineral or soil constituents, properly so called, at least in part, producing in them changes which are partly of a mechanical, partly of a chemical kind.

In a former contribution to the Royal Agricultural Society's Journal I have described, in detail, the nature of the physical and chemical changes which take place in clay soils on burning. In order to save the general reader the trouble of reference, I will just briefly state some of the results which I obtained in a number of analytical experiments, and beg to refer those specially interested in clay-burning to Vol. XII., page 496, of the Journal of the Royal Agricultural Society, where a paper of mine will be found, entitled, 'On the Causes of the Efficacy of Burnt Clay.'

The mechanical effects of heat on clay are simple and easy to be understood. Heavy stiff clay soils are impervious to water, very tenacious and unctuous, and for these reasons often cold and expensive to work. Burning alters, at least to some extent, these undesirable qualities, and tends to render naturally stiff soils more porous and friable. But although the mechanical effects produced on clay upon burning are highly important, they do not sufficiently explain the full benefits which are obtained on the application of burnt clay or soil to the land. By a series of experiments I showed that in burning clay soils effects similar to those of fallowing are produced; and that many of the constituents of clay, more especially potash, are rendered more soluble by burning. It is to the potash liberated from clays on burning that I am inclined to ascribe the chief benefits resulting from the application of burnt soil as a manure. I further showed that those clay-soils, which contain originally a large proportion of undecomposed silicates of potash and soda, are best suited for burning, whereas soils and clays, resembling in composition pure pipe or porcelain clays, and all soils which contain mere traces of undecomposed alkaline silicates, are unfit for burning. Finally, I showed that the inefficacy of overburnt clay is due partly to the mechanical changes which clay undergoes in overburning, whereby it is rendered hard like stone, and, in consequence of its diminished porosity, becomes less efficient as an absorber of ammonia; partly to the chemical changes, whereby the constituents of clay soils are rendered less soluble than they are even in their natural state. Subsequent analyses of clays in their natural condition, and after burning, have fully confirmed the above-mentioned general results. Amongst others, I may instance a clay which has been sent to me for examination by Charles Lawrence, Esq., accompanied by the following note, which I have no doubt will be read with some degree of interest:—

"Dear Sir,—I now send you a specimen of clay, which underlies a blackish loam of variable thickness, from twelve to eighteen inches and more in depth; and, in reference to an article of yours which I read some time ago, I am desirous of ascertaining, first, whether it is of a description which would pay for burning and spreading over the surface, and, secondly, whether it contains constituents which would render it eligible as a manure to spread over and get it incorporated with light land which gets into a dust in the spring. The field from which this clay comes lies against the railway, and is quite of a different character to any other on my farm. It was a very worthless pasture when it came into my hands, producing only coarse, wiry grasses and weeds. I had it drained, then pared and burnt in the winter of 1847, since which it has produced me a crop of oats, a crop of beans, and three crops of wheat, without manure. The oats and beans were more remarkable for an enormous bulk of straw than grain; but the wheat in each case produced, with abundant straw, forty bushels of grain per acre, though two of the wheat crops were in successive years.

I am, my dear Sir, yours very truly,

Dr. Voelcker. CHARLES LAWRENCE."

This clay, submitted to mechanical analysis, gave the following results:—

Hygroscopic (accidental) water	2·37
Water of combination	5·38
Carbonate of lime	31·38
Fine sand	2·25
Clay	58·62
	100·00

It will be seen that this is a calcareous clay, which, like most clay-soils in the neighbourhood of Cirencester, contains but a very trifling proportion of fine sand.

The detailed analysis of the same clay, being well calculated to illustrate the states of combination in which the constituents of this and similar clays occur, may find here a fitting place:—

Composition of Clay from Chesterton Farm, sent by Charles Lawrence, Esq.

	Hygroscopic water	2·37
	Water of combination and a little organic matter ..	5·38
	Carbonate of lime	31·38
Soluble in dilute acid.	Carbonate of magnesia	2·04
	Oxides of iron and alumina	11·90
	Potash	·35
	Soda	·18
Insoluble in acid.	Alumina	7·43
	Magnesia in a state of silicate	1·52
	Potash in a state of silicate	1·29
	Silica	36·16
		100·00

By far the larger proportion of the potash, it will be observed, exists in this clay in an insoluble condition as silicate of potash, and as it contains much lime, which, as shown in my previous communication, reacts upon the silicate of potash, when clays are burnt at a proper temperature, causing the liberation of potash and the production of silicate of lime, there is no doubt that this clay is well adapted for burning, and in a burnt state likely to do much good to light land. In its natural condition it yielded only ·35 per cent. of potash to very dilute acids, and after burning, rather more than double that quantity, or, in exact numbers, ·77 per cent.

That burning has the effect of rendering other constituents besides potash more soluble in dilute acids, is clearly shown in the subjoined analytical results obtained with this clay in its natural state, and when burnt, at various temperatures. In two separate determinations it gave in its natural state:—

	1st Experiment.	2nd Experiment.
Insoluble matters in dilute acids	56·30	55·17
Soluble ,, ,,	43·70	44·83
containing potash	(·35)	
	100·00	100·00

Heated very moderately it yielded:—

Insoluble matters in dilute acid	50·90	52·31
Soluble ,, ,,	49·10	47·69
containing potash	(·77)	
	100·00	100·00

Exposed to a somewhat stronger, but still by no means a very high temperature, it produced:—

Insoluble matters in dilute acids	46·20
Soluble matters	53·80
	100·00

These experiments thus show plainly that the solubility of clay in dilute acids is regulated by the degree of heat to which it is exposed. A certain degree of heat is necessary to induce a proper chemical reaction; but, as demonstrated by former experiments, an excessive heat should be carefully avoided, inasmuch as it has the effect of rendering burnt clay again less soluble. It is, no doubt, for this reason, and not on account of a little charcoal which is obtained, that practical men recommend stifle burning, for this prevents the heat of the heaps of burning clay getting too intense, and consequently stifle-burnt clay is always very porous, crumbles readily to powder, and is more easily soluble than clay burnt at too high a temperature. In accounting for the advantages of paring and burning, the changes in the inorganic matters of the soil must not be overlooked; for soils which are regularly pared and burned often contain much organic matter, and afford therein fuel for burning a considerable quantity of the soil itself.

On the Soils well adapted for Paring and Burning.

As stated already, it is not all soils that can be pared and burned with advantage. It becomes, therefore, a matter of some importance to decide beforehand which soils may be pared and burned with advantage and which not. It appeared to me, therefore, desirable to examine the characters of some soils, upon which paring and burning is practised with marked beneficial results. To this end I procured some soil from one of the fields on the farm attached to the Royal Agricultural College, and from another in the neighbourhood of Cirencester. The field from which the former was taken was at the time in sainfoin, which had partially failed: this field was afterwards pared and burned, and I had thus an opportunity of analyzing the red ashes procured by the combustion of the vegetable matter in the soil and the action of the heat upon the mineral constituents of the same soil. These two soils differed much in their physical characters, but agreed so far as to be much improved by paring and burning. The soil from the Royal Agricultural College farm, on analysis, furnished the following results:—

Composition of a Soil from the Farm of the Royal Agricultural College.

Moisture	5·981
Organic matter	13·217
Oxides of iron and alumina	12·954
Carbonate of lime	7·578
Sulphate of lime	·431
Carbonate of magnesia	1·414
Phosphoric acid	trace
Potash	·520
Soda	·122
Insoluble silicious matter (chiefly clay)	57·092
Loss	·691
	100·000

The depth of this soil is not more than 5 inches in the deepest places, and in some parts of the field it reaches barely 3½ inches. It is full of stones (limestones), and affords a good example of the thin brashy soils which abound on the Cotswold hills. With the hill farmers, land of that description passes as light land; but it may be observed that it is light merely on account of the prevalence of fragments of limestones, varying from the size of the palm of a hand to that of a bean. The pulverized portion of the soil, separated from the stones, is destitute almost altogether of sand, and constitutes a very stiff impervious clay. Although termed light land, it is well adapted for paring and burning, for in the pulverized portion clay greatly preponderates, and, on account of its impervious character, organic matters rapidly accumulate in it, and furnish combustible elements in a fair proportion.

I have also ascertained its mechanical state of subdivision, by passing a large quantity of air-dry soil through a series of cullenders, and in this way obtained from 37,205 grs., or about 5½ lbs.:—

	Grains.
Large stones	3,318
Smaller stones left on a ½-inch sieve	1,438
Small stones and indurated clay left on a ¼-inch sieve	10,691
Soil left on a ⅛-inch sieve	9,135
" 1/16-inch "	9,954
" 1/32-inch "	1,820
Very fine soil, which passed through a 1/32-inch sieve	849
	37,205

The five last portions were well mixed together, finely powdered, and the whole passed through the finest sieve; a portion of this was then employed for analysis.

The second soil, on analysis, gave the following results:—

Composition of Soil from the neighbourhood of Cirencester.
(Well adapted for burning.)

Moisture	·93
Organic matter	10·67
Oxides of iron and alumina	13·40
Carbonate of lime, with a little sulphate of lime ..	23·90
Carbonate of magnesia	1·10
Phosphoric acid	trace
Potash	·38
Soda	·13
Insoluble silicious matter (chiefly clay)	49·66
	100·17

This is a much deeper soil than the preceding one; it is tolerably free from stones, and extremely stiff and difficult to work. Like many other soils resting on forest marble clay, it is rather wet, though it had been drained. It affords an example of land called in the district heavy land.

Both the light and the heavy soil contain more than an average proportion of organic matters. Their destruction by fire does in nowise injure the land in either case, for both contain a large amount of clay, which, it is well known, possesses in a high degree the property of absorbing ammonia and moisture from the atmosphere; and as burning tends to accumulate in the surface-soil a large proportion of saline mineral matters, and otherwise improves the mechanical condition of the land, we need not lament the dissipation of organic matters by heat.

The first soil presents us with an instance, showing how desirable it is not to be content, in descriptions of agricultural operations, with general terms, such as light land; for such terms are apt to mislead others not acquainted with the true character of a soil on which a practice like that of paring and burning answers very well.

Were a farmer to burn light sandy soils, he would, as a rule, do decidedly wrong, for sandy soils are naturally open and porous; they readily admit atmospheric air, and consequently the decomposition of organic matters in the soil proceeds rapidly enough. It would thus be not only a needless expenditure to pay for the cost of paring and burning, but the destruction of vegetable remains in most sandy soils would also be followed with evil consequences; for it is evident that the destruction of constituents which possess the power of absorbing moisture and ammonia from the atmosphere must do harm in soils which do not contain, like clay soils, mineral matters which are capable of fulfilling this useful function.

ON RED OR (SO-CALLED) VEGETABLE ASHES.

(*Vegetable Ashes and Burnt Soil.*)

The favourable opportunity I had of collecting the red ashes produced on paring and burning both soils, the composition of which has just been stated, induced me to examine the ashes of each separately. In one instance, moreover, I ascertained the total amount of the red ashes per acre, and, having made a careful analysis of a well-prepared average sample, I am enabled to state in exact numbers how much phosphate of lime was contained in these ashes.

Composition of Red Ashes from a Field on the Farm attached to the Royal Agricultural College.

The physical characters of the soil of this field, as well as its chemical composition, have been described already; I need not, therefore, repeat the analysis expressing its chemical composition. The season, on the whole, was favourable for burning, and the soil, which, it will be remembered, contained, in an air-dry condition, about 13 per cent. of organic matter, was sufficiently dry to allow of its being burned in a fair average quantity. The probable produce in red ashes, as estimated by inspection of the number and size of heaps of ashes on the field, did not appear very great; this soil, it will be remembered, had no depth, and therefore could not give, on paring and burning, a very large quantity of ashes. In many instances I have seen, on the hill-lands in our neighbourhood, double the quantity of ashes per acre. The soil in the field was burned in small heaps, varying somewhat in size. Each little heap produced from 2½ to 4 bushels—or, on an average, about 3 bushels of red ashes. On an acre of land I counted 146 such heaps. Weighed in their natural condition, I found that 1 acre had furnished 14 tons 17 cwt. 2 qrs. 11 lb., or, in round numbers, 15 tons of red ashes.

A large sample, amounting to several pounds, taken at the same time when the ashes were weighed, was finely powdered, well mixed together, and in a portion of it the amount of water determined at once:—

	1st Exp.	2nd Exp.	Average.
Amount of water in red ashes when weighed ..	22·36	22·04	22·20

According to these determinations, the rough produce per acre, amounting to nearly 15 tons of ashes, will give 11 tons 11 cwt. 2 qrs. 4 lbs., or nearly 12 tons of perfectly dry ashes (dried at 212°).

As ashes are sometimes mixed with superphosphate and drilled in for turnips, and the ashes usually measured out, I may observe that I find the weight of a bushel of red ashes, on an average, to amount to 72½ lbs. This weight refers to ashes not sifted, but just as they are when taken from the heap. Finely sifted ashes of that kind, I imagine, would weigh rather more.

A well-prepared fair average sample was next used for analysis, and, in the state in which it was analysed, found to contain 1·18 per cent. of accidental moisture. This sample had a dull or dirty red colour, due to oxide of iron and some charcoal not completely burned off. Much, however, of what is mentioned in the following analysis under Organic Matter and Water of Combination, I am inclined to think is water of combination, and arises from the admixture of unburnt soil.

The following table exhibits the composition of these ashes:—

Composition of Red, so-called Vegetable, Ashes from a Field on College Farm, Cirencester.

Moisture	1·18
Organic matter and water of combination ..	3·32
Oxides of iron and alumina	18·42
Carbonate of lime	8·83
Sulphate of lime	1·15
Phosphoric acid	·71
(equal to bone-earth)	(1·56)
Potash	1·08
Chloride of sodium	1·03
Magnesia	1·76
Insoluble silicious matter	62·52
	100·00

These analytical results suggest one or two observations:—

1. It will be observed that the proportion of phosphoric acid in these ashes is considerable in comparison with the amount of this acid found in soils. Even in very fertile land it rarely amounts to two-tenths or three-tenths of one per cent.

2. The ashes contain, as will be seen, a large proportion of potash in a soluble condition, as well as of chloride of sodium; and as alkalies are very beneficial to green crops, the presence of alkalies, especially that of potash, no doubt accounts in part for the benefits resulting from the application of red vegetable ashes to root-crops.

2. The insoluble silicious matter consists chiefly of burnt clay, and contains a good deal of potash in a state in which it is not at once soluble in water. But as burnt clay is more readily penetrated by atmospheric air, there can be no doubt that the insoluble potash contained in it will be rendered soluble and made available for the use of plants much more readily than it is from unburnt clay.

I have just stated that the total amount of perfectly dry ashes per acre was ascertained to be 11 tons 11 cwt. 2 qrs. 11 lbs. 100 parts of these ashes contained ·71 of phosphoric acid.

This percentage, calculated for the total produce in ashes, gives 184 lbs. of phosphoric acid; 184 lbs. of phosphoric acid, united with lime, give 398 lbs. of tribasic phosphate of lime or bone-earth per acre.

Commercial bone-dust, I find, contains, on an average, 46 per cent. of bone-earth. 398 lbs. of bone-earth, accordingly, are equivalent to the phosphate of lime contained in 7 cwt. 2 qrs. 25 lbs. of commercial bone-dust.

The weight of a bushel of bone-dust varies from 40 to 44 lbs. Taking 43 lbs. as the average weight per bushel, 7 cwt. 2 qrs. 26 lbs. of bone-dust will give almost exactly 20 bushels.

Thus the ashes from this field contained a quantity of phosphoric acid which is equal to that contained in 20 bushels of bone-dust.

This is an important fact, and affords the explanation why vegetable ashes are so beneficial to turnips, and why better crops of roots are obtained on the thin brashy soils of the Cotswold hills, by paring and burning, than with the use of any amount of farmyard manure or any description and quantity of artificial manure. Many Cotswold hill farmers are not a little proud of growing good roots on poor thin soils without manure. I once heard a farmer in our neighbourhood quite exult in the idea that he never used a single bushel of bone-dust for his turnips, and had not the least confidence in phosphates, or would ever think of using superphosphate, or any other new-fangled manure, for his roots. But are red ashes no manure? In point of fact, the land, in the case before us, received a heavier dressing of essentially valuable fertilizing constituents in these ashes than it would be likely to receive in any other description of manure, for I take it for granted that no farmer would think of laying out on such poor thin soils as the one from which the ashes were obtained something like 2*l.* 10*s.* per acre for bone-dust alone.

My agricultural friend, no doubt, was perfectly right in his practice, but not quite in his theoretical speculations respecting the utility of phosphates for root-crops. Perhaps he would have had a more favourable opinion of phosphates, if he had been told that the red vegetable ashes which he was in the habit of using in all probability contained more phosphates than a very heavy dressing of the best superphosphate, or perhaps 20 tons of good farmyard manure.

Moreover, there are good reasons for the fact that, on land which is well adapted to be regularly pared and burned, farmyard manure, guano, superphosphates, or other artificial manures, often do no good to turnips, or, at any rate, do not improve root-crops in the same degree as vegetable ashes. I shall revert to this subject again, after having given an account of the ashes from the second and stiffer field in our neighbourhood.

Composition of Red, or so-called Vegetable, Ashes from a Soil in the neighbourhood of Cirencester.

The red ashes from the College farm may serve to give a fair idea of the composition of the ashes which will be obtained on paring and burning, when the season is dry, and there is sufficient vegetable matter in the soil to keep the fire alive for six or eight days in small but well-covered heaps. Such ashes, of course, contain a large proportion of burnt clay. On the other hand, the subjoined analysis may serve to represent the composition of the vegetable ashes which will be produced in a wet or showery season on stiff soils of a wet description. There is a good deal of land of that character in the neighbourhood of Cirencester. Except in a very dry season it is impossible to get the clay sufficiently dry for burning. It often happens, therefore, that such land cannot be properly burned, that is to say, little of the soil itself can be burned. The ashes produced under these circumstances are, of course, much less in quantity, but at the same time a great deal more valuable, than the preceding ones.

This will appear clearly from the following table, in which is stated the composition of the ashes obtained on burning (principally) the vegetable matter of a soil from a field in the neighbourhood of Cirencester.

The composition of the soil before burning has been given above.

Composition of Vegetable Ashes from a Field in the neighbourhood of Cirencester.

Moisture and organic matter	9·12
Oxides of iron and alumina	14·56
Carbonate of lime	17·17
Sulphate of lime	1·73
Magnesia	·40
Chloride of sodium	·08
Chloride of potassium	·32
Potash	1·44
Phosphoric acid	1·84
equal to bone-earth	(3·98)
Soluble silica (soluble in potash)	8·70
Insoluble silicious matter	44·64
	100·00

A comparison of these analytical results with the analysis of the preceding ashes shows, amongst other things:—

1. That the former ashes contain much less phosphoric acid and less potash. And as the value of ashes as manure depends principally on these two constituents, a bushel of the last-mentioned ashes may be worth 2 or 2½ bushels of the first.

2. There is much less burnt clay in the second ashes, which accounts for the very much larger proportion of phosphoric acid and potash.

3. Both kinds contain a good deal of gypsum, and (especially the latter) much carbonate of lime. The large proportion of lime in these ashes is, no doubt, in great measure due to the calcareous character of the soils in our neighbourhood.

As just mentioned, in the latter ashes there was not so much burnt soil as in the former.

They may indeed be called, with propriety, vegetable ashes with some burnt soil, and the former, with equal reason, burnt clay with some vegetable ashes.

ON THE RELATIVE ADVANTAGE OF FARMYARD-MANURE, ARTIFICIALS, AND VEGETABLE ASHES PRODUCED BY PARING AND BURNING.

It remains for me now to offer some remarks on the economy of paring and burning in comparison with the direct supply of farmyard-manure or artificial fertilizers, and also to state the reasons why I believe that on certain soils paring and burning is almost the only means of getting a good crop of turnips; and lastly, to show how it is that on such soils the best manures often do no good whatever, or even do harm.

In the first place I would observe that an average quantity of red vegetable ashes produced from one acre of ground contains a larger amount of those fertilising constituents, which are especially useful to root-crops, than a heavy dressing of farmyard-manure, guano, superphosphate, or other artificial manures; and as the expense of procuring the ashes is certainly much less than that of even a moderate manuring, paring and burning must be considered decidedly an economical agricultural operation. Thus it has been shown that the bone materials contained in the ashes of an acre of land are equivalent to about 20 bushels of bone-dust, worth at the present time about 2*l.* 10*s.* Assuming the rest of the fertilising matters in the ashes to be worth only 10*s.*, which is a very low estimate, their total value in fertilising matters will be at least 3*l.* per acre. In this estimate no account is taken of the mechanical improvement of the land, of the uniform distribution of the manuring agents, and the advantages of paring and burning as a most efficient cleaning operation.

In the next place, I would remind the reader that most of the soils upon which paring and burning is practised with marked benefit are so impervious that, for want of necessary atmospheric air, the organic remains of former crops largely accumulate in the soil. This inert vegetable matter appears to be injurious to vegetation, or implies, at any rate, an unfavourable condition of the land, which has first to be amended before anything else can be done with it with effect. In our present state of knowledge no available means afford so efficient and cheap a remedy against this evil. There are no doubt soils which can be brought round by other means, but I question whether these means would be available on the thin, poor, brashy soils on the Cotswold Hills.

Lastly, it may be stated that artificial manures, such as guano and superphosphate, and even farmyard-manure, produce hardly any effect upon turnips when applied to land which is in a raw unprepared state. In proof of this assertion I may mention that two years ago I tried small and large doses of good superphosphate upon land which evidently was not properly pulverized, and did not get a single cwt. the acre more turnips from the manured plots than from those which were left unmanured. A more efficient operation can hardly be conceived than paring and burning for increasing the porosity of a soil and thoroughly pulverizing a large proportion of it. As a mechanical improvement it is therefore invaluable.

Soils well adapted for burning, we here see, contain invariably a large proportion of clay, from which, on burning, potash is liberated. And as the effect of potash appears to be similar to that of ammonia, viz. to favour the development of leaves, it is not necessary to apply ammoniacal manuring constituents to soils that have been pared and burned. Indeed, I am inclined to think that under these circumstances ammoniacal manures do more harm than good. At any rate, direct experiments, repeated during three seasons, have shown me that on our farm ammoniacal salts either produce no effect upon the produce of roots or (if anything) diminish it. Many of the soils in this neighbourhood are extremely thin; and when it is considered that the ashes produced from them contain a large supply of readily available food, it will be easily conceived that the further application of much farmyard-manure is likely to induce an over-luxuriance in the turnips, which manifests itself in the development of large tops to the injury of the bulbs. Having observed this injurious effect of rich ammoniacal manures, I would suggest not to use any farmyard-manure, or guano, or, indeed, any other manure, in all cases in which a good quantity of ashes has been produced upon a naturally poor and thin soil.

The foregoing account of an inquiry undertaken with a special reference to the cultivation of turnips on certain thin soils, I trust embraces sufficient scientific and practical evidence to warrant the following conclusions:—

CONCLUSIONS.

1. The destruction of organic matter in soils adapted for paring and burning is not attended with evil consequences, because such soils contain a large proportion of clay, which, like organic matter, possesses the power of absorbing moisture and fertilizing gases from the atmosphere.

2. Inert vegetable matter is changed by paring and burning into highly effective mineral food for turnips.

3. The operation of paring and burning improves materially the mechanical condition of naturally impervious soils by rendering them more porous and pulverulent.

4. Not only does it improve the mechanical condition of the soil, but it likewise contributes to highly important changes in the chemical constitution of the soil constituents.

5. It brings within reach of the young turnip crop a large quantity of readily available mineral food from the soil.

6. The ashes produced by paring and burning are especially useful to turnips, and also to other green crops, because they contain a large proportion of phosphates and potash, constituents which, it is well known, favour in a high degree the luxuriant growth of root-crops.

7. The operation of paring and burning is applicable only on soils containing clay; in sandy soils it is undesirable, and likely to do mischief.

8. The beneficial effects of a fair quantity of vegetable ashes

upon root-crops in certain soils are more striking than the effects produced by guano, superphosphate, and other artificial manures.

9. Thin land, from which a good quantity of ashes has been obtained, should not be dressed with rotten dung, guano, or, indeed, any kind of manure. Ammoniacal manures especially should be avoided.

10. The operation of paring and burning is the most economical means for raising on certain poor soils a good crop of turnips.

11. It is therefore not likely soon to give way to other plans of cultivation on such soils.

12. Lastly, instead of being an antiquated operation, it is a practice the advantages of which are fully confirmed and explained by modern chemical science.

Royal Agricultural College, Cirencester, Dec. 1857.

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EXPERIMENTS UPON SWEDES,

WITH

REMARKS ON THE MANURES EMPLOYED.

By AUGUSTUS VOELCKER.

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EXPERIMENTS UPON SWEDES,

In 1855 I published in this Journal some experiments upon Swedish turnips, grown on a calcareous soil with guano, superphosphate, bone-dust, night-soil manure, dissolved coprolites, nut-refuse-cake, and several other fertilizers. The object I had then in view was to ascertain practically the comparative economic merits of some artificial manures, which at that time were much recommended as turnip manures. The result of these trials proved that whilst one of the fertilizers, namely, the British economical manure, which I regret to say is still sold in many parts of England, turned out to be a complete failure, and others produced no remunerative crops, superphosphate of lime greatly excelled all other manures employed in the experiments, not even Peruvian guano excepted. The superphosphate used in these experiments was made on our farm by dissolving bone-dust in one-third of oil of vitriol, and consequently contained a considerable quantity of animal nitrogenized matter, which, on decomposition, readily yielded ammonia. On land yielding, when unmanured, 5 tons 4 cwt. of roots, topped and tailed, 2*l.*-worth of home-made superphosphate gave an increase of 8 tons 8 cwt. 16 lbs., whilst the same amount of money expended in bone-dust yielded only an increase of 3 tons 12 cwt.

Guano produced 2 tons less of swedes per acre than home-made superphosphate—a difference, considering the small crop furnished by the unmanured land, which is considerable. On the other hand, dissolved coprolites gave an increase of 6 tons 8 cwt., or very nearly the same increase as guano alone; and a mixture of guano and dissolved coprolites an increase of 7 tons 12 cwt. 16 lbs. The purely mineral superphosphate, made by dissolving coprolites in acid, thus produced a less favourable effect than the bone-superphosphate, but, when added to guano, dissolved coprolites increased the efficacy of the latter as a turnip manure. The produce obtained with other manures poor in phosphate fell short of the crops raised with phosphatic manures.

The legitimate conclusions which may be drawn from these field experiments are—

1. That on the particular soil, in the season in which the experiments were made, and the quantities of manures employed, guano was a less economical manure for swedes than bone-superphosphate.

2. That phosphatic manures greatly increased the yield of the root-crop, and much more so than other kinds of artificials.

3. That the form in which the phosphates were employed very much indeed affected the result, since superphosphate gave more than 2½ times as much increase per acre as an equal money value of bone-dust.

4. That a purely mineral phosphate, when dissolved in acid and perfectly free from ammonia, under favourable circumstances may produce as large a return as guano, a manure rich in ammonia.

It does not appear, however, from these experiments whether ammonia had any share in the final result or not. The fact that bone-superphosphate, containing from 2 to 2½ per cent. of ammonia, gave a much larger return than the mineral superphosphate, and also the equally important fact that the addition of a small quantity of guano to dissolved coprolites had a very beneficial effect, would seem to indicate that ammonia, in moderate proportion, is a desirable fertilizing ingredient of a turnip manure. A critical examination of these facts, however, I think neither proves nor discountenances the conclusion that ammonia has had a beneficial effect in the recorded experiments; for when comparing the effects of bone-superphosphate with dissolved coprolites, no account was taken of the proportion of soluble phosphate contained in each. I have since ascertained that the dissolved coprolites contained most of the phosphate in an insoluble state, not near enough acid having been employed for dissolving the coprolite powder. Indeed the coprolite manure contained but little soluble phosphate; and as insoluble phosphate, in the shape of coprolite powder, has as little effect upon vegetation as sand, whilst the insoluble phosphates in bones, partially decomposed by acid, unquestionably are sufficiently available to produce an immediate effect on the turnip crop,—the difference in the result obtained by dissolved bones and dissolved coprolites, therefore, may have been due to the larger amount of available phosphates, and not to the ammonia contained in the former. On the other hand, the addition of some guano to dissolved coprolites having produced a beneficial effect, it may be inferred that the ammonia in the guano produced this effect; but since Peruvian guano contains both soluble phosphates and bone-earth, in a highly finely-divided state, it may be maintained with equal force that the additional produce resulted from the additional quantity of available phosphates in guano. In short, my former experiments, of which a detailed account will be found in vol. xvi., of this Journal, are not calculated to decide the question whether or not ammonia can be dispensed with as a manuring constituent in a turnip manure, nor do they show that superphosphate is a more economical manure for roots than guano; for it is quite possible that an excess of ammonia will do harm to turnips, whilst a small quantity is likely to benefit the same crop, provided available phosphates are present at the same time. It also occurs to me that the assimilation of phosphates may be much facilitated by the presence of a quantity of ammonia not large enough to injure the roots. In other words, it is possible that whilst 2*l.*-worth of guano per acre produces a less favourable result than 2*l.*-worth of dissolved bones, 1*l.*-worth of guano per acre may be found a more economical dressing, and 10*s.*-worth of guano and 10*s.*-worth of superphosphate may give a more favourable result than either guano or superphosphate separately.

It may appear a simple matter to ascertain the comparative value of ammonia as a fertilizing agent for root-crops, but this is not the case. Notwithstanding all the experiments that have been made with various ammoniacal and phosphatic manures, our knowledge on this subject is so imperfect, that those who are best acquainted with the experience of good farmers in different parts of England will hesitate to give a definite answer when the question is asked, Is ammonia a useful or necessary fertilizing constituent in a turnip manure? I do not think we are at present in a position to give a satisfactory answer to this question, for the simple reason that, important as it is, it has not yet been sufficiently investigated in all its bearings. The contradictory testimony of equally good and intelligent agriculturists—some maintaining that ammonia has a decidedly beneficial effect upon turnips, others that it is of no use whatever for that crop—shows plainly enough that we have still a good deal to learn before it can be decided on what soils and under what system of cultivation ammonia can be dispensed with in a turnip manure, and what the conditions are that render the direct supply of ammoniacal matters to roots necessary or desirable.

We hear constant discussions as to whether guano is better than superphosphate, or whether a mixture of guano and superphosphate should be used; and these discussions are never brought to a successful issue, simply, I believe, because we are unacquainted with the precise circumstances under which ammonia exerts a beneficial or contrary action upon root-crops. The question of the superiority of guano or superphosphate mainly hinges upon this: Can I dispense with the expensive ammonia, and yet get a good crop of roots? I have no hesitation in saying that there are many soils upon which excellent root-crops may be grown without the direct application of ammoniacal manures, and that at the present time a great deal of ammonia, the most expensive constituent of guano, is, comparatively speaking, lost, and therefore guano itself to a great extent wasted, in the cultivation of turnips.

In support of these assertions, I may mention the fact that phosphatic guanos that are comparatively poor in ammonia, such as Saldanha-bay or Ichaboe, have been found to yield much larger crops of turnips than Peruvian guano, which contains a great deal more ammonia; likewise the fact that a mixture of superphosphate and guano generally answers better than guano alone. Again, I may mention that excellent crops of turnips are now grown every year, which are manured with nothing else but superphosphate, made exclusively from bone-ash or mineral phosphates.

It is, indeed, worthy of notice, that at least 90 per cent. of all the artificial manures that are now offered for sale, whatever their name may be, are in reality superphosphates, and that most of these manures contain either no appreciable amount of nitrogenized matters, or, at any rate, are very poor in nitrogen or ammonia. It is not likely that an intelligent class of men like the manufacturers of artificial manures, would shorten the supply of nitrogenized or ammoniacal matters in turnip manures, if they had not found out by experience that they can give more satisfaction to the farmer by supplying him for his turnips with a manure rich in available phosphates and poor or destitute of nitrogen, than by sending manure poor in phosphates and containing much ammonia.

It is certainly remarkable that, in nine cases out of ten, even those artificials, which, like nitro-phosphate, ammonia-phosphate, blood-manure, &c., convey the idea of manures rich in nitrogen or ammonia, when prepared for turnips, hardly contain any nitrogen. Still I am informed, on good authority, that there are many soils on which the very cheapest manure that can possibly be used for turnips is guano.

How can these contradictory facts be reconciled? I believe only when the subject is thoroughly investigated, without direct reference to the immediate advantages that will result from the investigations to the farmer. It is by laborious, long-continued, and expensive field experiments, and purely theoretical investigations, like those referring to the assimilation of nitrogen by plants, and carried out at present in a masterly manner in Mr. Lawes's laboratory at Rothamsted, that, after all, most practical questions have to be answered. The establishment of a single truth in science, especially if it refers to living organisms, is often the work of the lifetime of a man. Many excellent experiments, whether made in the field or in the laboratory—experiments conceived in a philosophical spirit, and carried out by men accustomed to perform accurate researches with the most praiseworthy industry, perseverance, and personal expense, too—have had the fate of being denounced as unpractical. Such experiments necessarily must appear quite mysterious to the uninitiated; but, after all, they are much more likely definitely to settle important practical questions than many so-called practical trials, made for the special information of the farmer.

With a view of throwing some light on the action of ammonia on root-crops, more especially on swedes, I made some experiments in 1856 and 1857, and have now the pleasure of laying the results of those experiments before the Royal Agricultural Society. I would notice particularly that my object was not to ascertain how large a crop of turnips I could obtain by the application of certain mixed manures, but to determine, if possible, whether on our farm and the soils in our neighbourhood we can dispense with the use of ammonia or not, and what manuring constituents are likely to be of the greatest benefit to this root-crop.

EXPERIMENTS UPON SWEDES IN 1856.

Skirving's Liverpool Swede.

The field on which the following experiments were made was sown with rye in the autumn of 1855, to afford an early bite for our sheep; but the green rye having partially failed, the field was ploughed up early in spring and repeatedly worked with the cultivator and harrows before the seed was sown.

The surface soil is brashy, thin and poor; when separated from the limestones which render it apparently lighter, it constitutes a stiffish clay-marl, which in wet weather is very tenacious and heavy, and in warm weather dries into hard masses which do not readily fall into powder. The subsoil is a stiff tenacious clay; the field has been well drained.

Like most soils in the neighbourhood of Cirencester, it contains a considerable quantity of lime. It was also richer in organic matter than most arable soils on our farm. It will be seen likewise, by inspecting the following analysis of this soil, that it contained a good deal of soluble silica and much clay, since the insoluble silicious matters consist almost entirely of clay.

Composition of Soil of Experimental Field, No. 22, on the Royal Agricultural College Farm, Cirencester.

Moisture, when analysed	4·72
Organic matter and water of combination	11·03
Oxides of iron	9·98
Alumina	6·06
Carbonate of lime	12·10
Sulphate of lime	·75
Alkalies and magnesia (determined by loss) ..	1·43
Soluble silica (soluble in dilute caustic potash) ..	17·93
Insoluble siliceous matters (chiefly clay)	36·00
	100·00

The experimental field was carefully measured out, and after rejecting the headlands, divided into 12 parts of $\frac{1}{20}$th of an acre each. These plots were arranged side by side in continuous rows of 4 rows each. The different manuring matters were sown by hand, and the seed drilled in on the 21st of June. Two of the experimental plots were left unmanured for the purpose of ascertaining the natural produce of the land, and also whether it was uniform or not. The produce of both unmanured plots sufficiently proved the equal agricultural capability of the experimental field. Although it was my principal object to ascertain whether or not ammonia could be dispensed with for turnips on this field, and which other manuring constituents produced the most marked effect on this crop, I was anxious to ascertain how far the natural produce could be raised by a good dressing of well-rotten farmyard manure, and therefore applied to one plot farmyard manure at the rate of 15 tons per acre.

In all field experiments, at least one, or better two plots, should be left unmanured; if possible one plot also should receive a good dressing of farmyard manure. By doing this an insight into the natural condition and agricultural capabilities of the soil may be obtained; and the results of trials with special manures will be interpreted in a more satisfactory manner than is the case when such experimental plots are omitted in a series of field experiments.

My twelve experimental plots were treated in regard to manure as follows:—

				At the rate of per Acre.
To Plot I.	was applied	well *rotten farmyard manure*		15 tons.
„ II.	„ „	*gypsum*		6 cwt.
„ III.	„ „	bone-ash dissolved in sulphuric acid		6 cwt.
„ IV.	„ „	sulphate of ammonia		6 cwt.
„ V.	„ „	bone-ash dissolved in sulphuric acid,	6 cwt.	
		sulphate of ammonia	6 cwt.	
		together		12 cwt.
„ VI.	„ „	bone-ash, dissolved in sulphuric acid		12 cwt.
„ VII.	„ „	sulphate of potash		6 cwt.
„ VIII.	„ „	Nothing.		
„ IX.	„ „	crystallised sulphate of soda		12 cwt.
„ X.	„ „	bone-ash, dissolved in acid	6 cwt.	
		sulphate of potash	6 cwt.	
		sulphate of ammonia	6 cwt.	
		together		18 cwt.
„ XI.	„ „	bone-ash dissolved in sulphuric acid		3 cwt.
„ XII.	„ „	Nothing.		

These manuring matters were all finely powdered and thoroughly mixed with ashes, in order to secure their more uniform distribution over the land.

When bone-ash is dissolved in sulphuric acid, soluble phosphate and gypsum are produced. Soluble phosphate alone cannot readily be used in field trials. The influence of the gypsum in the dissolved bone-ash upon the produce in these experiments, however, is determined by the dressing of gypsum applied to Plot No. II. At the same time we have here sulphuric acid in combination with ammonia, as well as with soda and with potash, and thus the means of comparing the manurial efficacy of sulphuric acid with that of phosphoric acid. To apply sulphuric acid diluted with water would have been to no purpose; for since the soil contained rather more than 12 per cent. of carbonate of lime, gypsum would have been formed immediately on putting free sulphuric acid on the land. Since turnips contain a good deal of sulphur, it is not unlikely that sulphates will be beneficial to that crop, at least on soils naturally deficient in sulphate of lime, the usual state in which sulphuric acid occurs in soils. In these experiments we have sulphuric acid in combination with lime as a difficult soluble salt with an earthy base, and sulphuric acid in combination with the three alkalies—potash, soda, and ammonia. With the three last-mentioned substances sulphuric acid forms salts more or less readily soluble in water. It might therefore have been expected that sulphuric acid, if at all capable of showing any specific effect on turnips, would have produced a marked effect in one or other of these combinations.

I have carefully analysed the bone-ash dissolved in sulphuric acid, and obtained the following analytical results:—

Water	32·80
Organic matter	·13
Biphosphate of lime	18·49
Equal to bone-earth, rendered soluble by acid ..	(28·80)
Insoluble phosphates	6·43
Hydrated sulphate of lime	38·39
Alkaline salts	1·94
Sand	1·82
	100·00

The swedes were taken up in the last week of November, topped and tailed, and the whole produce of each plot weighed.

Table, showing the Produce of trimmed Swedes of Experimental Plots, calculated per Acre, as well as the Increase over the unmanured part of Field.

		Produce per Acre.			Increase per Acre.			
Plot		tons.	cwts.	lbs.	tons.	cwts.	lbs.	
I.	15 tons of farmyard manure yielded	7	16	38	5	0	75	
II.	6 cwts. of gypsum yielded	2	1	45	0	14	30	decrease.
III.	6 cwts. of boneash, dissolved in sulphuric acid, yielded	8	3	38	5	7	40	
IV.	6 cwts. of sulphate of ammonia yielded	2	12	51	0	3	24	decrease.
V.	6 cwts. of sulphate of ammonia, and 6 cwts. of boneash, dissolved in acid, yielded	8	6	41	5	10	78	
VI.	12 cwts. of bone-ash, dissolved in acid, yielded	8	12	90	5	17	15	
VII.	6 cwts. of sulphate of potash yielded	2	10	0	0	5	75	decrease.
VIII.	Nothing yielded	3	0	19	.. ..			
IX.	12 cwts. of crystallised sulphate of soda yielded	3	6	9	0	10	46	
X.	6 cwts. of dissolved bone-ash, and 6 cwts. of sulphate of ammonia, and 6 cwts. of sulphate of potash yielded	6	17	6	4	2	43	
XI.	3 cwts. of dissolved bone-ash yielded	7	19	51	5	4	88	
XII.	Nothing yielded	2	11	19	.. ..			

In constructing this Table, the natural produce of the experimental field was taken at 2 tons 15 cwt. 75 lbs., being the average of the two unmanured plots Nos. VIII. and XII.

In explanation of the results of these field trials, I beg to offer the following observations:—

1. It will be seen that only those plots yielded an increase which contained phosphates; the other manuring constituents either had no effect upon the turnip crop, or slightly diminished it.

2. On comparing the produce of No. I. with that of No. XI., it will be seen that 3 cwt. of superphosphate, made from bone-ash and sulphuric acid, and containing no appreciable quantity of nitrogen, produced as good a result as 15 tons of well-rotten farmyard manure. This is an important fact, well worth the serious consideration of the farmer; and though I would not be understood as saying in general terms that I consider 3 cwt. of good superphosphate to be worth, for the turnip crop, as much as 15 tons of well-rotten dung, I believe there are many soils in England which require nothing else but 2 or 3 cwt. of good superphosphate drilled in at the time of sowing, with liquid manure drill, in order to yield an abundant crop of turnips.

3. It is worthy of notice that 6 cwt. of bone-ash superphosphate hardly produced a heavier crop than 3 cwt.; and also that 12 cwt. of the same superphosphate yielded only 17 cwt. and 76 lbs. more than a dressing with 3 cwt. There are soils on which experience has shown that a large dressing of superphosphate produces a more favourable result than a more scanty supply of this fertilizer. I believe this to be the case with most light and sandy soils. But in the majority of instances, I have no hesitation in saying that much more superphosphate is applied to the land than is really required to produce the maximum effect which this fertilizer is capable of producing. This remark, however, applies only to superior superphosphates, rich in soluble phosphate of lime, and not to the majority of superphosphates which find their way into the hands of the farmer; for I regret to say there have been sold this season many samples so poor in soluble phosphate, that 2 cwt. per acre can produce but little effect; 10 or 12 cwt. of such superphosphates certainly will prove superior in efficacy to 6 or 8 cwt. of the same.

4. Gypsum had no effect whatever on the turnip crop, a result which was to be expected upon a soil naturally containing nearly ¾ per cent. of sulphate of lime. Indeed, gypsum yielded 14 cwt. less turnips per acre than the average produce of the unmanured plots, but I do not think it had an injurious effect, and ascribe the slightly-diminished produce of plot No. II. to purely accidental causes.

5. It will also be seen that neither sulphate of ammonia nor sulphate of potash had any effect, and that sulphate of soda produced but a small increase. The inefficacy of these sulphates

appears to prove satisfactorily that sulphuric acid was not wanted in the experimental field.

6. As sulphate of ammonia proved inefficacious when used by itself, or in conjunction with soluble phosphates, either the ammonia had no effect upon the swedes and might have been dispensed with, or the quantity of sulphate of ammonia was too large, and had injured the young plant, and to some extent had retarded its progress. I believe both to have been the case. Further experiments will show whether or not nitrogen, applied in other forms than that of ammonia, has a better effect upon roots, and also whether or not the result would have been different, if sulphate of ammonia had been more sparingly used. One series of experiments is totally unfit to dispose of so important a question as that of the utility of nitrogen for turnips. Without entering therefore further into the theoretical aspect of this question, I would observe, that sulphate of ammonia greatly retarded the germination of the turnip seed, and, instead of rapidly pushing on the young plant, it kept the plant back, and throughout the experimental period the turnips on plot No. IV. were far behind all the others. When devising the experiment with sulphate of ammonia, I expected to see a luxuriant development of the leaves at the expense of the bulbs, but, to my great astonishment, the leaves of the turnips on No. IV. were much smaller than those of the adjoining plots Nos. III. and V., and certainly not larger than the leaves of the unmanured turnips. In No. V., on the other hand, I observed, to some extent, the effects which are generally ascribed to ammoniacal manures. The leaves in No. V. had a much darker appearance than in other plots, not dressed with sulphate of ammonia, and the plants on this plot looked on the whole the most luxuriant. It is thus plain that ammoniacal salts like sulphate of ammonia are only leaf-producing manures, if they find in the soil or manure the proper mineral constituents which are essential to the formation of the leaves. My experience on this subject is not mature enough to speak with confidence on the relative value of ammonia for root-crops generally, and its functions in relation to other cultivated crops; but I can well conceive that on well-cultivated soils, rich in those mineral matters required by root-crops, ammoniacal manures may be used with advantage even for root-crops; whilst on poor thin soils, deficient in available phosphates, ammonia will do more harm than good. In the experiments here recorded, sulphate of ammonia used by itself had no effect whatever on the development of turnip-tops; used in conjunction with soluble phosphate it appeared to favour the growth of leaves. I regret not having weighed the tops, to verify this observation in the field.

7. On comparing the produce of plot X. with that of No. XI., it will be seen that 3 cwt. of bone-ash superphosphate produced nearly a ton more roots than a mixture of 6 cwt. of the same superphosphate with 6 cwt. of sulphate of ammonia and 6 cwt. of sulphate of potash. The smaller produce of No. X. either arises from the presence of too large a quantity of soluble saline constituents in this mixture of fertilizing substances, or from an unfavourable action of sulphate of potash. The crop on this plot looked far less healthy than on No. XI. or on No. V.

In concluding this report of my experiments made in 1856, I may mention that I have watched the appearance of the crop on the experimental field succeeding the swedes. This field was sown with barley in 1857. The barley came up well and grew much more luxuriantly on the plots manured the year before with phosphate. Indeed, the difference in the appearance of the plots manured with phosphates and those plots unmanured or dressed with sulphate of ammonia and other salts, was so marked in spring, that the most inexperienced observer could single out with the greatest facility the spots upon which superphosphate was applied the year before. I stated my conviction that superphosphate is often used in much larger quantities than requisite for turnips, but it is consoling to know that a superphosphate, which, like the one employed in my experiments upon turnips, contained nearly the whole of the phosphates in a soluble form, when once incorporated with the soil, remains there ready to benefit not only the crop for the immediate use of which it is used, but also the succeeding crop, especially if that crop is barley. My own observations on the effect upon the succeeding barley of an excess of superphosphate applied to swedes, fully confirm the elaborate and highly important experiments of Messrs. Lawes and Gilbert on the growth of barley.

EXPERIMENTS ON TURNIPS, MADE IN 1857.

1. *Germination Experiments.*

Having observed in 1856 that the turnips manured with sulphate of ammonia came up much later than those dressed with superphosphate, and even than the unmanured plots, I was anxious to verify this result by some additional experiments with sulphate of ammonia. It is generally believed that superphosphate pushes on rapidly the young turnip plant, and as phosphates form a large proportion of the ash of all seeds, it was not unlikely that the effect of a dressing of superphosphate would hasten the germination of the turnip-seed. At the same time, I thought it desirable to submit to experimental proof some other fertilizing matters, with respect to their power of either hastening or retarding the germination of turnip-seed; for it is self-evident that it would be extremely useful if by some means or other the germination of the seed could be hastened, and the rapid growth of the young turnip plant promoted. The idea of dressing seed with various fertilizing matters is not a new one. Several attempts of applying manure to the seed instead of to the land have been made, and the most preposterous advantages resulting from seed-manuring held out by certain men, whose interest it was to sell comparatively cheap fertilizing matters at an enormous profit. These attempts, as might have been expected, have proved complete failures. I allude to these attempts of manuring and steeping the seed, because I do not wish to be suspected of entertaining for a moment the idea, that the system of seed-manuring is based on rational principles. My sole object in engaging in the subjoined experiments, was to ascertain if, by any chemical means the germination of the turnip-seed could be promoted, and to collect additional evidence respecting the effect of ammoniacal manures on the germination of seeds.

With this object in view, I made the following experiments with new Norfolk-bell turnip-seed.

No.
1. 100 seeds were soaked for 20 hours in distilled water, containing 2 per cent. of sulphuric acid (SO_3, HO).
2. 100 seeds were soaked for 20 hours in distilled water, containing 1 per cent. of sulphuric acid (SO_3, HO).
3. 100 seeds were soaked for 20 hours in distilled water, containing 5 per cent. of sulphuric acid.
4. 100 seeds were soaked for 20 hours in distilled water, containing 2 per cent. of sulphate of ammonia.
5. 100 seeds were soaked for 20 hours in distilled water, containing 5 per cent. of sulphate of ammonia.
6. 100 seeds were soaked for 20 hours in 3 oz. of distilled water and ½ oz. bone-ash dissolved in sulphuric acid (the same of which an analysis is given above).
7. 100 seeds were soaked for 20 hours in 3 oz. of distilled water and 1 oz. of bone-ash, dissolved in sulphuric acid.
8. 100 seeds were soaked for 20 hours in 3 oz. of distilled water and ½ oz. of Peruvian guano.

The seed prepared in this way was sown on the 15th of May, 1857, in garden-mould in flowerpots. On the same day were sown also in flowerpots—

9. 100 seeds with ½ oz. of superphosphate, made by dissolving fine bone-dust in 50 per cent. of brown acid.
10. 100 seeds with ½ oz. of bone-ash, dissolved in acid (the same sample used in the other experiment).
11. 100 seeds with 1 oz. of bone-ash, dissolved in sulphuric acid.
12. 100 seeds with ½ oz. of Peruvian guano.
13. 100 seeds with ½ oz. of Peruvian guano, mixed with 1 oz. of soluble silica rock, finely powdered.
14. 100 seeds with ½ oz. of sulphate of ammonia, mixed with ½ oz. of powdered soluble silica rock.

15. 100 seeds, sown with 120 grs. of sulphate of ammonia and ½ oz. of powdered soluble silica rock.
16. 100 seeds with ½ oz. of Peruvian guano.
17. 100 seeds without anything.
18. 100 seeds without anything.

The flowerpots containing these 18 experiments were regularly watered every day. The soil was constantly kept in a moderately moist condition, and the result observed from time to time.

On reference to my notes, taken at the time, I find the entries embodied in the following Tabular Statement. (See page 166.)

An inspection of these Tables will show amongst other particulars :—

1. That the seed employed in the experiments was of good quality, 94 in one trial and 90 in a second, out of 100, having germinated.

2. That turnip-seed unprepared and merely moistened occasionally, germinated more rapidly than the seed in all the other experiments.

3. That very dilute sulphuric acid killed the seed.

4. That a dilute solution of sulphate of ammonia killed many seeds, and retarded greatly the germination of those that survived. Thus two-thirds of the number of turnip-seeds were killed, and only one-third germinated. It will also be seen that sulphate of ammonia sown in considerable quantity with the seed also killed it, whilst in more moderate doses it greatly retarded the germination of the surviving seeds.

5. That Peruvian guano, even in small quantities, had the same effect as sulphate of ammonia : hence the danger of drilling in turnip-seed or carrots with guano, even when previously mixed with ashes.

6. That superphosphate of lime, instead of hastening, rather retarded the germination of turnip-seed.

7. That superphosphate made from bones and containing ammonia is more liable to injure the seed, than superphosphate made from bone-ash or mineral phosphates. Thus it will be seen, that only 60 plants came up in No. 9, in which bone superphosphate was used, and 80 plants in No. 10, in which experiment the same quantity of bone-ash superphosphate was employed.

It follows from these experiments—

1st. That it is advisable to mix artificial manures, such as guano and superphosphate, with as large a quantity of ashes as is practicable, if the manure is sown dry, and to mix the artificial manure with much water if the liquid manure drill is used. 2ndly. That superphosphate of lime, especially when made from

TABLE, *showing the Number of Plants come up from* 100 *Turnip Seeds at different Periods.*
The Seed was sown on the 15*th of May*, 1857.

		May 19.	May 21.	May 22.	May 23.	May 24.	May 26.	May 29.	June 1.	June 10
No. 1	100 seeds, soaked in water containing 2 per cent. of sulphuric acid	none	none	none	none	none	none	none	none	none
„ 2	100 seeds, soaked in water containing 1 per cent. of sulphuric acid	,,	,,	,,	,,	,,	,,	,,	,,	,,
„ 3	100 seeds, soaked in water containing 5 per cent. of sulphuric acid	,,	,,	,,	,,	,,	,,	,,	,,	,,
„ 4	100 seeds, soaked in water containing 2 per cent. of sulphate of ammonia	,,	4	10	11	19	24	30	33	33
„ 5	100 seeds, soaked in water containing 5 per cent. of sulphate of ammonia	,,	14	24	24	29	33	33	33	33
„ 6	100 seeds, soaked in 3 oz. of distilled water and ½ oz. of bone-ash superphosphate	,,	1	1	2	3	3	3	4	4
„ 7	100 seeds, soaked in 3 oz. of distilled water and 1 oz. of bone-ash superphosphate	,,	none	1	1	1	1	1	1	1
„ 8	100 seeds, soaked in 3 oz. of distilled water and ½ oz. Peruvian guano	,,	,,	1	4	15	17	19	19	19
„ 9	100 seeds, sown with ½ oz. of bone-superphosphate ..	,,	2	15	26	35	a great many not counted	as be-fore	as be-fore	60
„ 10	100 seeds, sown with ½ oz. of bone-ash superphosphate	,,	10	29	37	58				80
„ 11	100 seeds, sown with 1 oz. of bone-ash superphosphate	,,	none	none	1	4	10	14	18	19
„ 12	100 seeds, sown with ½ oz. of Peruvian guano	,,	,,	,,	none	none	none	none	none	none
„ 13	100 seeds, sown with ½ oz. of Peruvian guano, mixed with 1 oz. of soluble silica rock	,,	,,	,,	,,	,,	,,	,,	,,	,,
„ 14	100 seeds, sown with ¼ oz. of sulphate of ammonia, mixed with ½ oz. soluble silica rock	,,	,,	,,	,,	,,	,,	,,	,,	,,
„ 15	100 seeds, sown with 120 grs. of sulphate of ammonia, mixed with ½ oz. of powdered soluble silica rock.	,,	,,	,,	,,	,,	,,	,,	4	16
„ 16	100 seeds, sown with ¼ oz. of Peruvian guano	,,	,,	,,	,,	,,	,,	,,	none	20
„ 17	100 seeds, sown without anything	a good many seeds had germinated	seed well up	as be-fore	as be-fore	as be-fore	as be-fore	as be-fore	as be-fore	94
„ 18	100 seeds, sown without anything									90

from bones, does not hasten the germination of turnip-seed, but rather the contrary.

I would observe, however, that when fairly up the plants manured with superphosphate grew much more vigorously than the others, and soon were twice as big as the rest. Although superphosphate does not promote a more rapid germination of the seed, it is yet extremely useful in favouring a vigorous growth of the plant, thereby bringing the crop out of reach of the turnip fly.

2. *Field Experiments made in* 1857.

The negative results obtained in 1856 with sulphate of ammonia induced me to try this salt again, as well as gypsum and phosphates, and phosphates in conjunction with sulphate of ammonia, in another part of our farm. It occurred to me, that probably the unfavourable results with sulphate of ammonia might have been due to an excess of this powerful manuring substance having been employed in my experiments in 1856. It will be remembered that I applied sulphate of ammonia at the rate of 6 cwt. per acre, a quantity which, considering the inconsiderable depth of the experimental field, may be called excessive.

It is remarkable, however, that in conjunction with soluble phosphate, sulphate of ammonia proved equally inefficient, showing neither a beneficial nor the contrary effect. In order to study the effects of small quantities of ammoniacal salts on the turnip crop, I used only 1½ cwt. per acre in my experiments made in 1857. In conjunction with these more theoretical experiments, I instituted several others with fertilizers much recommended as turnip-manures. The field selected for the experimental trials with these manures was somewhat deeper, more level, and altogether rather better than the experimental field in 1856. A portion of the soil taken from a large sample, from different parts of the field, was submitted to analysis, and the following results obtained:—

Composition of Soil from Experimental Field, No. 19, *of the Royal Agricultural College Farm, Cirencester.*

Moisture (when analysed)	1·51
Organic matter and water of combination	11·08
Oxides of iron and alumina	14·25
Carbonate of lime	10·82
Sulphate of lime	·71
Magnesia	·51
Potash (soluble in acid solution)	·32
Soda ditto ditto	·05
Phosphoric acid	·10
Insoluble silicious matter (chiefly clay)	61·78
	101·13

A comparison of the composition of this soil with that of the experimental field in 1856, shows, that the chemical characters of both soils are very much alike. It will be seen that both contained sulphate of lime as gypsum in appreciable quantities, and I may mention, in passing, that this is the case with most soils in our neighbourhood. The presence of gypsum in these soils, no doubt, accounts for the fact, that gypsum is of no use whatever in our neighbourhood, and I believe, generally, on the calcareous soils resting on the oolite. In other districts, gypsum is said to be a very useful fertilizer, especially for leguminous crops, such as beans or peas, but though I have repeatedly tried its effects on these crops as well as upon roots, clover, and grass, I have never seen the slightest effect produced by it.

The proportion of phosphoric acid in this soil is appreciable; the figures stated in the above analysis express the average of two separate determinations which yielded respectively :—

1st determination of phosphoric acid	..	·106 per cent.
2nd ,, ,, ,,	..	·094 ,,
Mean	..	·100 per cent.

These determinations were made with great care by a comparatively speaking new process, known to professional analysts as the molybdate of ammonia process. It would be out of place to describe in this Journal the precautions that have to be observed in employing this process, but I may be allowed to observe, that I find no accurate results can be obtained, unless the yellow precipitate obtained by adding molybdate of ammonia to the acid solution of the soil, and consisting of molybdic and phosphoric acid, is redissolved in dilute ammonia, and the phosphoric acid determined as phosphate of magnesia. If properly executed, this process yields wonderfully accurate results, and certainly is one of the most beautiful analytical processes for determining, quantitatively, small proportions of phosphoric acid in soils, marls, and other minerals.

An acre of this land was measured out and divided into twenty parts. The land was ridged up; the different manures sown by hand, after having been carefully mixed with three times their weight of fine red ashes or burnt soil; and the seed drilled on the ridge on the 10th of June. The turnip-seed sown was that of white swedes. Each experimental plot occupied four rows of equal length. All the plots were sown on the same day, and treated afterwards in precisely the same manner.

The following list exhibits the arrangement of the experimental field, the kinds of manures employed, and their quantities, calculated per acre :—

Experiments upon White Swedes, in Field No. 19, *Royal Agricultural College Farm, Cirencester.*

PER ACRE.

To Plot I. .. 3 cwt. of phospho-Peruvian Guano, No. 1.
„ II. .. 3 „ „ „ „ „ No. 2.
„ III. .. 1½ „ „ „ „ „ No. 1.
„ IV. .. 3 „ „ „ „ „ No. 3.
„ V. .. 3 „ „ „ „ „ No. 4.
„ VI. .. 4 cwt. of Binn's patent manure.
„ VII. .. 3 „ of superphosphate.
„ VIII. .. 3 „ of fine bone-dust.
„ IX. .. 3 cwt. of superphosphate, made by dissolving the same fine bone-dust used in No. VIII., in 50 per cent. of sulphuric acid.
„ X. .. 3 cwts. of bone-superphosphate (purchased).
„ XI. .. Nothing.
„ XII. .. 3 cwt. of home-made superphosphate, made from coprolites and fine bone-dust.
„ XIII. .. 1½ cwt. of sulphate of ammonia.
„ XIV. .. 1½ cwt. of sulphate of ammonia, and 1½ cwt. of bone-ash, dissolved in sulphuric acid.
„ XV. .. 1½ cwt. of bone-ash, dissolved in sulphuric acid, without ammonia.
„ XVI. .. 4 cwt. of gypsum.
„ XVII. .. 4 cwt. of wool-manure for turnips.
„ XVIII. .. 9 cwt. of red ashes alone (the same quantity of ashes was used with the manures in the other experiments).
„ XIX. .. 4 cwt. of poudrette de Bondy (Paris nightsoil manure).
„ XX. .. 3 cwt. of Peruvian guano.

On each plot a good plant was obtained, and the crop singled on the 16th of July, with the exception of the plots upon which sulphate of ammonia and Peruvian guano were employed. The plants here were not far enough advanced to be singled. We have here presented to us another instance, which shows that ammoniacal manures, even when used in moderate quantities, retard the growth of turnips in their first period of existence. Special care, I may mention, was taken in these experiments thoroughly to mix the ammoniacal and other manures with ashes, and to prevent the seed from coming into direct contact with the artificial manures.

The appearance of the crop was observed from time to time, and the turnips of each plot taken up on the 19th of November: after trimming and cleaning, the whole produce of each plot was carefully weighed.

The result of these weighings is embodied in the following Table, which also contains the increase of each plot over the unmanured portions.

TABLE, *showing Produce in Swedes, topped and tailed, and cleaned, per Acre, and Increase per Acre, on Field No.* 19, *College Farm.*

		Produce per Acre.				Increase per Acre.			
Plot		tons.	cwt.	qrs.	lbs.	tons.	cwt.	qrs.	lbs.
I.	3 cwt. phospho-Peruvian guano, No. 1.	9	6	2	18	2	14	3	22
II.	3 cwt. „ „ „ No. 2.	8	9	2	2	1	17	3	6
III.	1½ cwt. „ „ „ No. 1.	8	19	0	5	2	7	1	9
IV.	3 cwt. „ „ „ No. 3.	10	3	0	5	3	11	1	9
V.	3 cwt. „ „ „ No. 4.	10	5	2	24	3	14	0	0
VI.	4 cwt. Binn's patent manure	8	14	2	18	2	2	3	22
VII.	3 cwt. of superphosphate of lime	10	17	0	16	4	5	1	20
VIII.	3 cwt. of fine bone-dust	8	11	0	26	1	19	2	2
IX.	3 cwt. of fine bone-dust, dissolved in acid	9	14	3	1	3	3	0	5
X.	3 cwt. of bone superphosphate, purchased	9	17	2	2	3	5	3	6
XI.	Nothing	6	11	2	24		..	..	
XII.	3 cwt. of home-made superphosphate ..	10	12	0	21	4	0	1	25
							Decrease.		
XIII.	1½ cwt. of sulphate of ammonia	5	6	0	21	1	5	2	3
							Increase.		
XIV.	1½ cwt. of sulphate of ammonia, and 1½ cwt. of dissolved bone-ash	9	3	0	26	2	11	2	2
XV.	1½ cwt. dissolved bone-ash	8	18	3	22	2	7	0	26
XVI.	4 cwt. of gypsum	6	13	3	17	0	2	0	21
XVII.	4 cwt. of wool-manure	8	16	3	22	2	5	0	26
XVIII.	9 cwt. of red ashes alone	6	16	3	1	0	5	0	5
XIX.	4 cwt. of Poudrette de Bondy	8	14	1	25	2	2	3	1
XX.	3 cwt. of Peruvian guano	8	18	1	25	2	6	3	1

All the manures employed in the experiments were carefully analysed. In commenting upon the results obtained in the field, I shall give the analysis of the artificial manures, and accompany them with some general remarks, which I trust will be found useful to those readers who are in the habit of buying artificials for their root crops. I would also make the remark that in all accounts of manuring experiments it is absolutely necessary to convey to the reader some idea of the character of the manures employed in the experiments; and this can only be done by giving an analysis of the different fertilizers. I have no hesitation in saying that accounts of experiments, in which analyses of the manures experimented with are omitted, are much better suppressed than published, for such experiments are more calculated to do harm than good. This remark of course does not apply to fertilizers of a definite chemical composition, or to fertilizers like Peruvian guano, the average composition of which is well known. What is the use, I would ask, of recording experiments with superphosphate, when it is well understood that superphosphate can be prepared in twenty different ways and of a strength which may make it worth 2*l.* or 10*l.* a ton? Again, I would ask, what is the use of comparing the effects of superphosphate with nitro-phosphate without stating the composition of both, since nitro-phosphate is only a commercial name occasionally given to manures, which are essentially superphosphates? I have seen published accounts of experiments with superphosphate, blood-manure, nitro-phosphate, and ammonia-phosphate, and with mixtures of these manures; but had the author of those experiments known that blood-manure is but a name that applies to artificial manures which in nine cases out of ten are in reality superphosphates, and that nitro-phosphate and ammonia-phosphate often hardly contain any nitrogen or ammonia, but are nothing more or less than superphosphate, he would have modified his experiments, or at any rate given the reader some clue as to the character of the manures with which he experimented.

Plot I.—Manured with phospho-Peruvian guano, No. 1, at the rate of 3 cwt. per acre.

Produce	9 tons 6 cwt. 2 qrs. 18 lbs.
Increase per acre	2 tons 14 cwt. 3 qrs. 22 lbs.

The swedes looked remarkably healthy until the beginning of September, when they were attacked by mildew and made but slow progress.

Composition of Phospho-Peruvian Guano, No. 1.

Moisture		11·84
* Organic matter and ammoniacal salts		10·35
Bi-phosphate of lime		11·88
Equal to bone-earth, rendered soluble by acid		(18·54)
Insoluble phosphates		29·32
containing: Phosphoric acid	13·51	
containing: Lime	15·81	
Hydrated sulphate of lime		25·47
Alkaline salts, containing ·21 phosphoric acid		4·77
Magnesia		·86
Insoluble silicious matter (sand)		5·51
		100·00

* Containing nitrogen	2·09
Equal to ammonia	2·34
Percentage of phosphates, rendered soluble by acid	18·54
,, of insoluble phosphates, calculated as bone-earth	34·25
Total phosphates, calculated as bone-earth	52·79

It will be seen that this and the other samples of phospho-Peruvian guano are very valuable manures that are distinguished from other fertilizers by a high percentage of phosphates, a large proportion of which is rendered soluble by treatment with sulphuric acid.

The insoluble phosphates in this guano are composed for the greater part of two equivalents of lime and one equivalent of phosphoric, instead of three equivalents of lime and one equivalent of phosphoric acid as in the ordinary bone-phosphate. Originally this guano does not contain any appreciable amount of soluble phosphate, but chiefly consists of bi-basic phosphate of lime, and as this phosphate requires only one equivalent of sulphuric acid to be rendered soluble or converted into bi-phosphate of lime, whereas the ordinary bone-phosphate requires two equivalents of sulphuric acid for this purpose, a valuable and highly concentrated manure can be prepared from it with less expenditure of sulphuric acid than is requisite in changing other phosphatic materials, such as bone-ash, coprolites, &c., into soluble phosphates. This circumstance fully accounts for the comparatively small quantity of sulphate of lime which this fertilizer contains.

Plot II.—Manured with phospho-Peruvian guano, No. 2, at the rate of 3 cwt. per acre.

Produce	8 tons	9 cwt.	2 qrs.	2 lbs.
Increase per acre ..	1 ton	17 cwt.	3 qrs.	6 lbs.

The tops of this plot were not quite so large as those in No. I. The plants grew very vigorously at first, but like all the other plots received a sudden check by the extremely warm and dry weather in August.

An analysis of the guano used in this experiment gave the following results:—

Composition of Phospho-Peruvian Guano, No. 2.

Moisture			15·42
* Organic matter and ammoniacal salts			3·85
Bi-phosphate of lime			15·22
Equal to bone-earth, rendered soluble by acid			(23·74)
Insoluble phosphates, consisting of: ..	Phosphoric acid ..	13·73	24·41
	Lime	10·68	
Hydrated sulphate of lime			32·13
Alkaline salts			1·87
Insoluble silicious matter			7·10
			100·00

* Containing nitrogen	·40
Equal to ammonia	·49
Percentage of phosphates, rendered soluble by acid	23·74
,, of insoluble phosphates, calculated as bone-earth (tribasic phosphates, $3\,CaO, + PO_5$)	29·74
Total percentage of phosphates calculated as tribasic phosphates	53·48

In this sample of phospho-Peruvian guano the proportion of soluble phosphate is larger than in the preceding, and the total amount of phosphates in both is about the same. There is a great difference in the amount of ammonia in this and the preceding guano.

Notwithstanding the larger percentage of soluble phosphate, the guano No. 2 has not given quite so good a result as No. 1, and it appears to me that this may have been due to the sudden check which the crop sustained, and which will be felt all the more, the more rapid the progress has been at first.

Plot III.—Manured with 1½ cwt. of phospho-Peruvian guano per acre.

Produce	8 tons 19 cwt. 5 lbs.
Increase per acre ..	2 tons 7 cwt. 1 qr. 9 lbs.

Half the quantity of the same guano used in Plot No. 1, it will be perceived, gave very nearly the same increase as the larger quantity, which is a convincing proof of the fact that the larger amount of phosphates in these manures has not had a fair chance of producing the effect which in more favourable seasons they would no doubt have produced.

Plot IV.—Manured with phospho-Peruvian guano, No. 3, at the rate of 3 cwt. per acre.

Produce ..	10 tons 3 cwt. 5 lbs.
Increase ..	3 tons 11 cwt. 1 qr. 9 lbs.

No difference in the appearance of this and the preceding plots.

The composition of this guano was found as follows:—

Moisture			10·07
Organic matter and ammoniacal salts			16·97
Bi-phosphate of lime			9·89
Equal to bone-earth, rendered soluble by acid			(15·42
Insoluble phosphates, consisting of: ..	Phosphoric acid ..	18·79	37·61
	Lime	18·82	
Hydrated sulphate of lime			16·98
Alkaline salts			3·13
Insoluble silicious matter			5·35
			100·00

Containing nitrogen	2·12
Equal to ammonia	2·57
Percentage of phosphates rendered soluble	15·42
„ of insoluble phosphates, calculated as tribasic phosphates of lime	40·71
Total phosphates	56·13

This guano resembles in composition the one used in Plot I., but contains less soluble and more insoluble phosphate.

Plot V.—Manured with phospho-Peruvian guano, No. 4, at the rate of 3 cwt. per acre.

Produce ..	10 tons 5 cwt. 2 qrs. 24 lbs.
Increase ..	3 tons 14 cwt.

Composition:

Moisture		13·06
* Organic matter and ammoniacal salts		3·65
Bi-phosphate of lime		11·75
Equal to bone-earth, rendered soluble by acid		(18·33)
Insoluble phosphates consisting of: Phosphoric acid	21·61	39·33
Lime	17·72	
Hydrated sulphate of lime		23·17
Alkaline salts		1·76
Insoluble silicious matter		7·28
		100·00

* Containing nitrogen	·32
Equal to ammonia	·38
Percentage of phosphates, rendered soluble	18·33
„ of insoluble phosphates, calculated as tribasic phosphate of lime	46·82
Total percentage of phosphates	65·15

The total percentage of phosphates in this guano is very large indeed; the amount of ammonia, on the other hand, is inconsiderable. Notwithstanding the small amount of ammonia, the sample marked No. 4 has given the best result of the four manures that bear the name of phospho-Peruvian guano.

All four are very concentrated manures, which, as mentioned already, in more favourable seasons would have given, I do not doubt, a much larger increase.

From the following experiments it will appear distinctly that the produce on the experimental field could not be raised by any description of manure much above ten tons per acre, nor can there be any doubt that a large proportion of the phosphates in these guanos, on account of the long-continued dry weather, remained in the soil inactive.

Plot VI.—Manured with Binn's patent manure at the rate of 4 cwt. per acre.

Produce	8 tons 14 cwt. 2 qrs. 18 lbs.
Increase	2 tons 2 cwt. 3 qrs. 22 lbs.

The turnips on this plot did not look quite so well as the five preceding lots, especially in the leaf and during the first three months.

On analysis Binn's patent manure gave the following results:—

Moisture	25·61
* Organic matter	20·15
Phosphates and oxides of iron and alumina	3·74
Sulphate of lime	1·67
Carbonate of lime	15·47
Chloride of sodium (common salt)	9·35
Insoluble silicious matter	23·61
Magnesia and loss	·40
	100·00

* Containing nitrogen	·845
Equal to ammonia	1·029

A comparison of the analysis of this patent article with that of genuine Peruvian guano will show at once the inferiority of Binn's manure, for it is poor in all the essential and expensive fertilizing matters. It contains no soluble phosphate whatever, and very little insoluble phosphate, nor is it rich in ammonia. On the other hand it abounds in sand and carbonate of lime—constituents which on a calcareous clay soil, like the one on which the experiments were tried, cannot possibly do any good.

It will be observed that Binn's manure contains likewise a considerable quantity of common salt, and I cannot help thinking that the salt in this otherwise all but valueless artificial manure has had a beneficial effect upon the crop. It is possible that salt added to superphosphate will prove as valuable to swedes as to mangolds, particularly in dry seasons like the last. I hope to be able at a future period to report the results of field experiments with salt as a manure for swedes. In the mean time I would recommend to the notice of agriculturists the following experiments, as likely to throw light on the use of salt as a manure for turnips :—

1. 3 cwt. of superphosphate per acre.
2. 3 „ of same superphosphate and ½ cwt. of salt per acre.
3. 3 „ of „ „ 1 „ of „
4. 3 „ of „ „ 1½ „ of „
5. 1½ „ of salt alone per acre.
6. 2 „ of „ „

Salt, perhaps, may be found useful in preventing mildew in turnips.

Whether or not it was the salt in Binn's patent manure that produced almost as good a crop as 3 cwt. of Peruvian guano, we have here presented to us a striking example of an inferior manure giving as good a result as the best artificials. This shows plainly how little dependence can be placed upon a single field experiment, and how fallacious it is as a test, so called practical, for arriving at anything like a fair conclusion as to the value of artificial manures.

In dry and unfavourable seasons, the very best manures are much more likely to do harm than poor or indifferent fertilizers. The reason of this is obvious. A manure, such as a concentrated superphosphate, rapidly pushes on the plant, and when there is abundance of moisture the process of assimilation goes on without interruption; but when dry weather sets in and continues for a long time, the vigorously growing plant receives a sudden check, from which it has difficulty in recovering, whilst plants scantily supplied with the more energetic fertilizing substances are far less liable to suffer under these circumstances.

Plot VII.—Manured with superphosphate at the rate of 3 cwt. per acre.

Produce ..	10 tons 17 cwt. 16 lbs.
Increase ..	4 tons 5 cwt. 1 qr. 20 lbs.

From first to last this experimental plot had the lead as to appearance, and the result of the weighings showed that it yielded in reality the best crop.

The superphosphate used in this experiment had the following composition:—

Moisture	10·80
* Organic matter	4·21
Biphosphate of lime	20·28
Equal to bone-earth, rendered soluble by acid ..	(31·63)
Insoluble phosphates	4·11
Hydrated sulphate of lime (gypsum)	46·63
Alkaline salts (common salt)	10·78
Insoluble silicious matter (sand)	3·19
	100·00

* Containing nitrogen	·34
Equal to ammonia	·41

I need hardly say that this is an excellent superphosphate, which, at 7*l.* 10*s.*, the price at which it was sold, is an exceedingly cheap manure. The price of all raw materials employed in the manufacture of artificial manures having gone up very much since the beginning of this season, I hardly think it possible that the maker of this superphosphate can supply his customers this season with an article quite so rich in soluble phosphate at 7*l.* 10*s.* per cwt. But should the proportion of bone-earth rendered soluble by acid be only 22 or 23 per cent., and the manure be prepared equally dry and fine as hitherto, I have no hesitation in saying, that such a superphosphate at 7*l.* 10*s.* will be 2*l.* or 3*l.* cheaper than most samples which I analysed during this season.

It is worthy of notice, that this superphosphate contained very little ammonia, but an appreciable quantity of salt, which I have no doubt added to its efficacy; for I find that other superphosphates, rich in soluble phosphates, and containing a considerable proportion of ammonia, but no salt, had not near so good an effect upon the turnip-crop in 1857.

Plot VIII.—Manured with 3 cwts. of fine bone-dust per acre:—

Produce ..	8 tons 11 cwt. 26 lbs.
Increase ..	1 ton 19 cwt. 2 qrs. 2 lbs.

This bone-dust was extremely well pounded, being as fine as the finest sawdust.

On analysis it yielded in 100 parts :

Moisture	6·86
* Organic matter	13·14
Phosphates of lime and magnesia (bone-earth)	68·17
Carbonate of lime	6.79
Alkaline salts	1·90
Insoluble silicious matter (sand)	3·42
	100·00

* Containing nitrogen	1·83
Equal to ammonia	2·22

Although sold as the finest bone-dust, this article was, in reality, a mixture of about equal parts of fine bone-dust and commercial powdered bone-ash. The proof of this is furnished in the above analysis; and as bone-ash can be bought at a cheaper rate than fine bone-dust, it is not fair to offer for sale a mixture of 50 per cent. of fine bone-dust and 50 per cent. of bone-ash under the name of genuine bone-dust.

I may mention, in passing, that I analysed another sample of fine bone-dust, bought from the same maker, but earlier in the season, probably at a time when there was less demand for fine dust than later, when the deficiency in the supply evidently was made up by a larger proportion of bone-ash.

This sample consisted of about two-thirds of fine bone-dust and one-third of bone-ash, as will be seen by inspecting the following results, which it yielded on analysis:—

Water	9·11
* Organic matter	21·25
Phosphates of lime and magnesia (bone-earth)	61·94
Carbonate of lime	5·89
Alkaline salts	1·70
Insoluble silicious matter (sand)	1·32
	100·00

* Containing nitrogen	2·84
Equal to ammonia	3·45

Plot IX.—Manured with 3 cwt. of superphosphate, made by dissolving fine bone-dust used in previous experiments in 50 per cent. of oil of vitriol:—

Produce	9 tons 14 cwt. 3 qrs. 10 lbs.
Increase	3 tons 19 cwt. 2 qrs. 2 lbs.

On comparing the produce of Plot IX. with Plot VIII., the advantage of dissolving bone-dust in acid will appear at once.

When analysed this superphosphate gave the following results :—

Water	24·33
* Organic matter and ammoniacal salts	5·04
Bi-phosphate of lime	17·00
Equal to bone-earth, rendered soluble by acid	(26·52)
Insoluble phosphates	9·89
Hydrated sulphate of lime	39·25
Alkaline salts and magnesia	2·81
Insoluble silicious matter (sand)	1·68
	100·00

* Containing nitrogen	1·28
Equal to ammonia	1·55

Plot X.—Manured with 3 cwt. of bone-superphosphate:—

Produce	9 tons 17 cwt. 2 qrs. 2 lbs.
Increase	3 tons 5 cwt. 3 qrs. 6 lbs.

The superphosphate used in this experiment was bought, and had been prepared from coarse bone-dust, and differed materially in composition from the preceding superphosphate, which I specially prepared for experimental purposes.

It will be seen by the subjoined analytical results, that the superphosphate used upon Plot X. contained very little soluble phosphate, but a large proportion of insoluble phosphate and much ammonia.

Notwithstanding the deficiency of soluble phosphate, it gave quite as good a produce as the preceding superphosphate, which was much richer in soluble phosphate.

The following are the results obtained on analysing this superphosphate:—

Water	13·79
* Organic matter and ammoniacal salts	15·00
Bi-phosphate of lime	2·84
Equal to bone-earth, rendered soluble	(4·43)
Insoluble phosphates	25·54
Hydrated sulphate of lime	21·75
Anhydrous sulphate of lime	4·58
Alkaline salts and magnesia	4·36
Insoluble silicious matter (sand)	12·14
	100·00

* Containing nitrogen	2·45
Equal to ammonia	2·91

Plot XI.	Nothing	Produce,	6 tons	11 cwt.	2 qrs.	24 lbs.
,, XVI.	4 cwt. of gypsum	,,	6 ,,	13 ,,	3 ,,	22 ,,
,, XVIII.	(9 cwt. of red ashes)	,,	6 ,,	16 ,,	3 ,,	1 ,,

The produce of these three plots is so much alike, that the small differences may be safely ascribed to natural variations of the soil; at the same time, the produce of Plots XI., XVI., and XVIII., shows that the field on which the experiments were tried was uniform in its character, and also that gypsum had no effect whatever on the turnip-crop.

Plot XII.—Manured with 3 cwt. of home-made superphosphate:—

Produce	..	10 tons 12 cwt. 21 lbs.
Increase	..	4 tons 1 cwt. 25 lbs.

The superphosphate used in this experiment was made on our farm from coprolites, fine bone-dust, sulphuric acid, and salt. It yielded on analysis—

Water	22·83
* Organic matter	4·88
Bi-phosphate of lime	8·28
Equal to bone-earth, rendered soluble by acid ..	(12·91)
Insoluble phosphates	16·21
Hydrated sulphate of lime	37·42
Alkaline salts (common salt)	5·53
Insoluble silicious matter (sand)	4·85
	100·00

* Containing nitrogen	·55
Equal to ammonia	·66

It will be observed, that this superphosphate contains little ammonia, and about 5½ per cent. of salt besides soluble and insoluble phosphate. In its effect upon the crop it was nearly equal to the superphosphate used in Plot VII., which is a far superior and more expensive fertilizer.

Again, it will be observed, that it produced a better result than the superphosphate made by dissolving fine dust in sulphuric acid, and costing at least 30*s*. more per ton.

Plot XIII.—Manured with 1½ cwt. of sulphate of ammonia:—

Produce	..	5 tons 6 cwt. 21 lbs.
Decrease	..	1 ton 5 cwt. 2 qrs. 3 lbs.

The sulphate of ammonia used in this experiment was found to consist in 100 parts of:—

Pure sulphate of ammonia ..	98·28
Fixed salts	·78
Moisture	·94
	100·00

The roots on this plot came up much later, and throughout the whole experimental period were in a backward condition, when compared with the rest of the field.

The plants looked decidedly worse than those on the unmanured portion. I mention, especially, that the swedes, contrary to what I expected, had a less luxuriant foliage than even on the unmanured plot.

Under the circumstances in which the sulphate of ammonia was tried in 1857, it had a decidedly injurious effect upon the yield of the turnip crop, although only 1½ cwt. of sulphate of ammonia had been employed per acre.

Plot XIV.—Manured with 1½ cwt. of sulphate of ammonia, and 1½ cwt. of dissolved bone-ash:—

Produce ..	9 tons 3 cwt. 26 lbs.
Increase ..	2 tons 11 cwt. 2 qrs. 2 lbs.

Plot XV.—Manured with 1½ cwt. of dissolved bone-ash:—

Produce ..	8 tons 18 cwt. 3 qrs. 22 lbs.
Increase ..	2 tons 7 cwt. 26 lbs.

The dissolved bone-ash used in these experiments was found to contain in 100 parts:—

Water	32·80
Organic matter	·13
Bi-phosphate of lime	18·49
Equal to bone-earth, rendered soluble by acid ..	(28·80)
Insoluble phosphates	6·43
Hydrated sulphate of lime	38·39
Alkaline salts	1·94
Sand	1·82
	100·00

The produce of these two plots may be considered as identical, and, as the superphosphate made from bone-ash contained no nitrogen or ammonia at all, we have here a positive proof of the inefficacy of ammonia on the soil of the experimental field in 1857.

Plot XVII. — Manured with 4 cwt. of wool manure for turnips:—

Produce ..	8 tons 16 cwt. 3 qrs. 22 lbs.
Increase ..	2 tons 5 cwt. 26 lbs.

The composition of this manure was found to be as follows:—

Moisture	21·26
* { Ammoniacal salts and soluble organic matter ..	10·52
Insoluble organic matter	5·28
Bi-phosphate of lime	1·41
Equal to bone-earth, rendered soluble by acid ..	(2·21)
Insoluble phosphates	12·63
Hydrated sulphate of lime	23·41
Alkaline salts (chiefly common salt	15·26
Insoluble silicious matter (sand)	10·23
	100·00

---

* **Containing nitrogen**	**2·96**
Equal to ammonia	**3·63**

Plot XIX.—Manured with 4 cwt. of Poudrette de Bondy, or dried night-soil from Paris:—

Produce	..	8 tons 14 cwt. 1 qr. 25 lbs.
Increase	..	2 tons 2 cwt. 3 qrs. 1 lb.

A sample of this manure, on analysis, yielded the following results:—

Water	25·20
* Organic matter	26·14
Phosphates	17·17
Sulphate of lime	4·21
Carbonate of lime	3·09
Alkaline salts	3·22
Magnesia	1·78
Insoluble silicious matter (sand)	18·61
	99·42

* Containing nitrogen	3·35
Equal to ammonia	4·07

It will be seen, that the Paris night-soil manure contains a good deal of phosphates, as well as nitrogenized matters. It is far superior to any description of night-soil manufactured in this country.

In its practical effects upon the turnip-crop in these experiments, it proved equal to wool-manure and Peruvian guano, but it does not follow from this, that its commercial value is equal to that of Peruvian guano.

Plot XX.—Manured with 3 cwt. of Peruvian guano:—

Produce	..	8 tons 18 cwt. 1 qr. 25 lbs.
Increase	..	2 tons 6 cwt. 3 qrs. 1 lb.

Composition:

Moisture	18·50
† Organic matter and ammoniacal salts	52·33
Phosphate of lime and magnesia	21·66
* Alkaline salts	6·41
Insoluble silicious matter	1·10
	100·00

* Containing phosphoric acid	1·46
† Containing nitrogen	14·16
Equal to ammonia	17·19

The analysis shows that the guano used in the experiment was genuine Peruvian guano of superior quality.

The turnips on this plot were for a long time decidedly inferior to the superphosphate turnips. But towards the middle of September the plants took a start, and the crop in Plot XX. then appeared the best in the field, so far as the tops were considered. Shortly before the time when the turnips were taken up, the guano turnips were at least 3 inches higher in tops, and promised, so far as appearance went, the heaviest crop; but the weighing showed that the yield in bulbs was smaller than that of the plots manured with superphosphate free from nitrogen.

It appears in these experiments :—

1. That ammoniacal salts like sulphate of ammonia, used alone, had a decidedly injurious effect upon the turnip-crops, even when used in small quantities.

2. That ammoniacal manures applied to the turnips in the experimental field, kept back at first the turnip-crop, and had no beneficial effect either alone or in conjunction with phosphates.

3. That guano proved a less economical manure than superphosphate.

4. That the addition of salt to superphosphate is likely to be attended with beneficial results when used for turnips.

5. That, in dry seasons, the best artificial manures often produce hardly any greater effect upon roots, and may produce even less, than inferior and all but worthless manure.

6. That the value of an artificial manure, and its special effect upon different crops, cannot be determined by a single field-experiment.

In conclusion, I would observe that I intend continuing similar experiments on swedes for a number of years, and hope, on a future occasion, to present to the Society another Report on this subject.

AUGUSTUS VOELCKER.

Royal Agricultural College, Cirencester,
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ON

LIQUID MANURE.

By AUGUSTUS VOELCKER.

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ON

LIQUID MANURE.

THERE is scarcely any agricultural improvement so excellent that it could be carried out with advantage in every locality, nor any agricultural practice so intrinsically bad that it could justly be condemned unconditionally. If it were not so, we should find it difficult to explain reasonably how it is that certain modes of culture which by most men are considered antiquated or irrational should yet have a powerful hold on the minds of some skilled and experienced farmers.

It is true that agricultural improvements make their way but slowly into ordinary farm-routine, but, on the other hand, it must be confessed that any scheme, however visionary, meets in this country with eager advocates, whose extravagant ideas induce some people to introduce into practice suggestions which in other countries are only known in theory.

Experiments on a variety of agricultural subjects are nowhere so extensively tried as in England. Many of these experiments, though on the whole unsuccessful, are nevertheless of great advantage to the farming community, for they often bring to light matters of real practical importance, or at any rate act as beacons to warn others not to engage in unprofitable speculations.

The great success which has attended the application of liquid manure in Flanders is proverbial, where it produces most astonishing effects upon soils that are almost completely barren. Any one who has passed through Belgium, and examined the nature of the soil, must have been struck with the wonderful change which liquid manure has produced; and perhaps he may ask why such a profitable system of applying manure to the land is not adopted more extensively in other countries. Men zealous in devoting their best energies to the good of their countrymen have never been wanting in England, and it is but natural that at various times admirers of the Flemish system of agriculture should have raised their voice in favour of liquid manure. Indeed, expensive experiments have been set on foot in this country with most praiseworthy zeal in order to convince the British agriculturist of the benefit which, in the opinion of some, liquid manure is capable of securing to the farmer.

I am sure the agricultural community is much indebted to men like Mr. Mechi, Mr. Kennedy, Mr. Telfer, and others, for their exertions to adapt the Flemish system of liquid manuring to the peculiarities and advanced condition of English agriculture. And though many may differ as to the extent to which irrigation with liquid manure may be carried out, no one can deny that on some farms in this country it has produced surprising crops.

In other places, however, liquid manure has not been so successfully employed, and in some cases its application has proved a complete failure.

Some instances have come under my personal observation in which considerable expense was incurred for the erection of tanks that now are deserted, experience having shown that no good whatever was produced by the application of liquid manure to the land. There can be no reasonable doubt that this conclusion is well founded on fact, and that there are soils which are not benefited in the least by its use.

It must be borne in mind that the system of liquid manuring can no longer be regarded as an agricultural novelty, but that it has been tested on a large scale under the most varied circumstances. At the best its success has been but partial; and as the necessary arrangements involve a great outlay of money, it becomes a question of importance to decide whether on a particular farm it is likely or not to be more remunerative than the ordinary methods of applying manure to the land. The solution of this important question is difficult, since it is complicated by considerations of a purely practical kind. Means of procuring the necessary amount of water for the proper dilution of liquid manure do not exist everywhere, or can only be devised at a ruinous expense; it is, moreover, still a question with our best agriculturists whether the expenses which have to be incurred for erecting steam-engines, constructing liquid-manure tanks, and laying down a network of distributing pipes, are commensurate with the result. It is not my province to touch the question in this aspect; practical considerations of this kind are much better left in the hands of those who have a more immediate interest in the cultivation of the soil, and who are in a much better position than myself to form a reliable opinion on questions that involve considerations of pounds, shillings, and pence.

But apart from the purely practical difficulties that stand in the way of properly estimating the merits of liquid manuring, there are several points which justly belong to the province of the agricultural chemist. It devolves upon him to ascertain on what principle or principles are based the astonishing effects which liquid manure produces in some instances, and to endeavour to explain the reasons why in others it does no good, or is attended with but partial success. The question of profitable return for the expense of proper arrangements for the distribution of liquid manure is one for after consideration; it may overrule or not the theory which informs us that in the liquid form manuring constituents are most conducive to the rapid development of certain kinds of agricultural produce. But in the first place we have to examine carefully whether this doctrine can be accepted unconditionally, or whether this very generally received opinion has not to be modified in a considerable degree. A principle like that which informs us that fertilising matters produce their maximum effect in a liquid form may be true in the abstract, or with reference to particular kinds of plants, or in certain climates, or with reference to soils of a particular character; but in other climates or other soils there may be operating causes which render it by no means advisable to administer manuring matters in a state of solution.

Having given of late much attention to this subject, it is my purpose to give in the following pages my views on the utility of introducing the system of liquid manuring into ordinary farm-practice. I would premise, however, that I wish the present article to be considered in the light of an attempt to explain the somewhat conflicting experience with respect to the application of liquid manure.

It will, I think, be admitted by every one that, under the name of liquid manure, fertilisers of widely different characters are applied to the land, and that probably the differences in the observed effects of liquid manure may be due, at least to some extent, to its variable composition. It will therefore devolve upon me, in the first place, to point out the composition and fertilising value of several descriptions of liquid manure which I have selected for examination, and to show how far differences in composition influence the effects which it is capable of producing in the field.

In the next place I propose to examine the circumstances in which liquid manure is employed with decided advantage, and to attempt giving an explanation of the causes of success.

In the third place I shall discuss the characters of soils upon which liquid manure produces no beneficial effect, and state the reasons of failure; and

Lastly, I propose to offer some remarks on the means of disposing of liquid manure.

I. ON THE COMPOSITION AND FERTILISING VALUE OF LIQUID MANURE.

Liquid manure, it need hardly be observed, may be produced in a variety of ways. It may consist chiefly of the fermented urine of horses, or cows, or pigs, or a mixture of them all; or it may be produced by converting the *solid and liquid* excrementitious matters of our domestic animals into a muddy liquid; and in this process of liquefying the solid excrements and preparing them for distribution on the land, much or little water may be used. These and several other circumstances must, of course, affect the composition of liquid manure, and with it its fertilising value.

In order, therefore, to ascertain how far the observed dissimilarity in the practical effects of liquid manure depends on differences in composition, I procured six samples of liquid manure, namely:—

1. From Westonbirt, near Tetbury, Gloucestershire.
2. From Badminton.
3. From Royal Agricultural College farm; collected 1857.
4. From ditto, collected 1858.
5. From Tiptree Hall, Essex; clear liquid.
6. From ditto; muddy liquid.

A strong, disagreeable smell, and more or less dark colour, were common to all; but the differences in the concentration of the liquids were much greater than I expected.

No. 1.—*Liquid Manure from Westonbirt, near Tetbury.*

A large jar filled with liquid manure from Westonbirt farm, the property of Stainer S. Holford, Esq., was kindly furnished me by Mr. Rich, Mr. Holford's agent. The tank from which the liquid was taken had been recently erected, and no expense appears to have been spared in making it perfectly water-tight. A perfectly well-fitting cover sheltered the contents against rain, and against evaporation in hot and dry weather. The contents of the tank consisted chiefly of the drainings of the stables, and contained comparatively little cows' or pigs' urine. On setting the liquid-manure pump in motion hardly any liquid made its appearance, but in its stead a thick white froth continued to flow off for some minutes; after which a dark greenish-brown, very offensive and pungent-smelling liquid was pumped up. On agitating this liquid it became very frothy, and at the same time gave off a strong and pungent smell. The froth and pungent smell no doubt were due to the evolution of carbonate of ammonia.

At 62° Fahr. the liquid manure from Westonbirt had a specific gravity of 1·006.

Evaporated to dryness an imperial pint (7000 grs.) furnished 41·8025 grs. of solid residue (dried at 212°).

On burning in a platinum dish this amount of solid matter left 26·281 of ash. A separate portion of dry residue was used for the determination of the amount of nitrogen present in the shape of non-volatile ammoniacal salts and nitrogenized organic matters.

A fresh quantity of liquid manure (7000 grs.) was next neutralized with dilute hydrochloric acid, and thereby the volatile carbonate of ammonia was fixed, and obtained on evaporation to dryness on the water-bath as sal ammoniac. The addition of hydrochloric acid had also the effect of decomposing humate and ulmate of ammonia, both of which occur in liquid manure, and impart to it a more or less dark colour. The organic acids separate in the form of a brownish flaky substance, whilst the ammonia unites with the hydrochloric acid, forming with it sal ammoniac. Liquid manure, on boiling, yields ammonia, even if it contains no free nor volatile carbonate of ammonia. This evolution of ammonia arises from the decomposition of ulmate or humate of ammonia—two compounds which, on boiling with bicarbonate of potash, a constituent that is always present in liquid manure, yield free ammonia.

The dry residue obtained by evaporating 7000 grains of liquid manure, with the addition of hydrochloric acid, was employed for determining the whole amount of nitrogen present in the shape of nitrogenized matters, as well as non-volatile and volatile salts of ammonia. By deducting the amount of nitrogen found in the residue obtained on evaporation without acid from the residue obtained with acid, and calculating the remainder as ammonia, the proportion of ammonia existing as carbonate and as humate and ulmate of ammonia was ascertained.

The mineral portion left on burning the residue was carefully analysed according to the best and most recent methods, which need not be mentioned here in detail.

According to the several results obtained in the analysis, an imperial gallon of liquid manure from Westonbirt, Tetbury, Gloucestershire, contained :—

Ammonia driven out on boiling (chiefly in the shape of volatile carbonate and some as humate and ulmate of ammonia)		108·36
* Organic matters and non-volatile ammoniacal salts		155·44

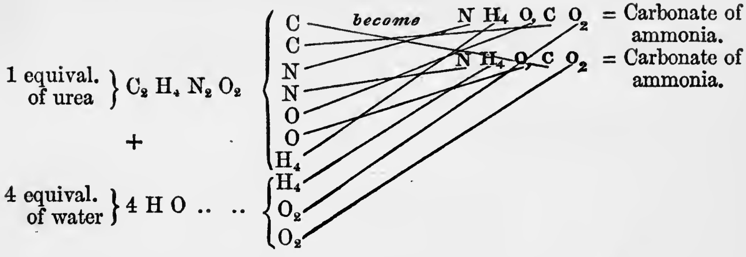
* Containing 4·78 grains of nitrogen.

Mineral matters (ash)	262·81	
Consisting of—		
Soluble silica		2·49
Oxide of iron		·70
Lime		5·34
Magnesia		2·96
Potash		103·23
Chloride of potassium		72·00
Chloride of sodium		17·18
Phosphoric acid		2·70
Sulphuric acid		22·31
Carbonic acid and loss		33·90
Total		526·61

An imperial gallon of this liquid thus contains:—

Total amount of mineral matters	262·81
" non-volatile combustible matters	155·44
" nitrogen	94·02
Which is equal to ammonia	114·16

It will be seen that the proportion of ammonia in this description of liquid manure is very considerable. It is indeed very much greater than in any other kind which I have examined. We may therefore expect that it will produce a powerful effect, more especially upon grass-land. But as carbonate of ammonia is a caustic agent, and acts too energetically when applied to a standing crop in a liquid so rich in ammonia as the tank liquid from Westonbirt, a considerable quantity of water—say three times the bulk of water—should be added before the liquid can be applied with safety. It will likewise be noticed that nearly the whole of the nitrogen which originally existed in the urine of horses in the state of urea had been changed into carbonate of ammonia. This change of urea in a liquid containing a variety of other organic matters proceeds with extreme rapidity. Urea, an organic compound consisting of two equivalents of carbon, two of oxygen, two of nitrogen, and four of hydrogen, has only to take up the elements of four equivalents of water in order to become converted into two equivalents of carbonate of ammonia. This change will at once become intelligible by glancing at the following diagrammatic representation:—



As carbonate of ammonia is volatile, and escapes gradually even from dilute liquids, it is desirable to fix it at once. This can be done most effectually and with little trouble by throwing into the tank from time to time a Winchester quart of brown sulphuric acid. This acid, uniting with the ammonia, drives out the carbonic acid of the carbonate, which causes a more or less extreme effervescence, and changes the volatile carbonate into non-volatile sulphate of ammonia—a salt which is far less caustic than carbonate of ammonia, and more valuable than the latter as a fertilising agent.

The inorganic portion of the liquid manure from Westonbirt consists principally of alkaline salts. The proportion of potash in these salts is very considerable. Most of the potash mentioned in the above analysis occurs in the state of bicarbonate of potash; there is also a good deal of chloride of potassium and some sulphate of potash. Phosphoric acid, on the other hand, exists only sparingly in this, and, I may add, in most other kinds of liquid manure; and as this acid is so essential for the healthy growth of all cultivated crops, we can readily understand that liquid manure, however valuable it may be in other respects, on account of the great deficiency of phosphoric acid and the preponderance of ammonia, when applied by itself to grass-land produces an over-luxuriant and rank herbage, and when applied to a white crop produces corn more remarkable for long, coarse, and abundant straw than for fine and plentiful grain.

Liquid manure, when produced exclusively from the liquid excrements of horses, cattle, or pigs, cannot, on account of this deficiency of phosphoric acid, be regarded as a perfect manure, and should not be used alone, but always in conjunction with manures rich in phosphoric acid, such as bone-dust or superphosphate.

In the following Table I have calculated the percentage composition of the solid matters that remain behind on evaporation, and also the percentage composition of the mineral portion or ash:—

	Per cent. Composition of Solid Substances in Liquid Manure.	Per cent. Composition of Ash of Liquid Manure.
* Organic matters	37·16	
† Inorganic matters (ash)	62·84	
	100·00	
* Containing nitrogen	1·14	
† Consisting of—		
Soluble silica	·59	·95
Oxide of iron	·16	·27
Lime	1·28	2·04
Magnesia	·70	1·13
Potash	24·82	39·51
Chloride of sodium	4·10	6·54
Chloride of potassium	17·21	27·40
Phosphoric acid	·64	1·03
Sulphuric acid	5·33	8·49
Carbonic acid	8·01	12·64
	62·84	100·00

2.—*Liquid Manure from Badminton.*

Mr. Thompson, agent to his Grace the Duke of Beaufort, kindly supplied me with a specimen of liquid manure, which had been kept for several years in the tank. It was much darker coloured than the liquid from Westonbirt, and contained a larger amount of organic matter in solution than any of the other varieties of liquid manure which I examined. It was nearly neutral to test-paper, but on boiling gave off a strong smell of ammonia. Its smell was not so offensive as the liquid from Westonbirt.

The Badminton liquid was composed chiefly of the drainings of cattle-sheds and yards. Its examination appeared to me desirable for the sake of comparison with the preceding sample, which was principally composed of horse-urine.

On evaporation to dryness on the waterbath, 7000 grains furnished 60·112 grains of solid residue dried at 212° Fahr. This quantity on burning gave 36·190 grains of mineral matter or ash.

On analysing the ash it was found to contain in 100 parts of—

Soluble silica	2·76
Oxide of iron	·19
Lime	6·96
Magnesia	4·24
Potash	31·02
Chloride of potassium	21·55
Chloride of sodium	12·72
Phosphoric acid	2·63
Sulphuric acid	10·39
Carbonic acid and loss	7·54
	100·00

The residue left on evaporation of 7000 grains of liquid manure, burnt with soda-lime, was found to contain ·898 grains of nitrogen.

Another 7000 grains of the same liquid, evaporated with hydrochloric acid, gave a residue which, burnt with soda-lime, yielded 1·838 of nitrogen.

The solid matter left on evaporation consequently contained :—

Organic matters		39·79
Containing 1·49 of nitrogen.		
Mineral matters	60·21	
Consisting of—		
Soluble silica		1·66
Oxide of iron		·11
Lime		4·19
Magnesia		2·55
Potash		18·67
Chloride of potassium		12·97
Chloride of sodium		7·65
Phosphoric acid		1·58
Sulphuric acid		6·20
Carbonic acid and loss		4·63
		100·00

The specific gravity of the liquid at 62° Fahr. was 1·007. According to these determinations a gallon of liquid manure from Badminton contained :—

Ammonia (chiefly as ulmate and humate of ammonia)		11·41
* Organic matters		239·22
* Containing 8·98 of nitrogen. Which is equal to 10·90 of ammonia.		
Inorganic matters (ash)	361·90	
Consisting of—		
Soluble silica		9·98
Oxide of iron		·68
Lime		25·18
Magnesia		15·33
Potash		112·26
Chloride of sodium		46·03
Chloride of potassium		77·38
Phosphoric acid		9·51
Sulphuric acid		37·60
Carbonic acid		27·95
		612·53

On comparing the composition of the two samples from Westonbirt and Badminton, it will be found that the latter contains both more organic and mineral matters in solution. Notwithstanding the larger amount of organic matter, it contains very much less ammonia. A somewhat smaller proportion of ammonia might have been expected, since cows' urine, which entered largely into its composition, is much poorer in nitrogen than horse-urine, which chiefly composed the liquid manure from Westonbirt. However, the quantity of ammonia (only 11·41 in a gallon) is so inconsiderable that the differences in the proportion of the original liquids which chiefly composed these two kinds of liquid manure are altogether insufficient to account for the small quantity of free ammonia in that from Badminton. This liquid, having been kept in an open tank for more than three years, has evidently lost by evaporation carbonate of ammonia, which we have seen is rapidly formed during the decomposition of urea. That this really was the case was proved by the small quantity of carbonate of ammonia which was left in it. During the long time it was kept in the tank the volatile carbonate of ammonia had every chance of escaping. We may thus learn that it is not advisable to preserve liquid manure for a long period, and that the safest plan is to fix the ammonia at once by the addition of some sulphuric acid.

The organic matters left on evaporation of both kinds of liquid manure presented the same characters, and both contained an identical percentage of nitrogen. Thus 155·44 grains of organic matters contained in that from Westonbirt yielded on analysis 4·78 grains of nitrogen, whilst 239·32 grains of organic matters found in the Badminton liquid furnished 8·98 grains. This gives for 100 parts 3·75 grains of nitrogen for each of the two samples. No appreciable difference is observable in the composition of the mineral portion. The ash of the Westonbirt manure, like that of the Badminton liquid, is rich in salts of potash and is greatly deficient in phosphoric acid.

3.—*Liquid Manure from the Royal Agricultural College Farm, Cirencester. Collected in* 1857.

The liquid-manure tank on the College Farm is placed close to the manure-pit, in which stable manure, cows' and pigs' dung are collected together. It is of a sufficient capacity to hold, in addition to the drainings from the manure-pit and stables, the sewerage from the College. Animal refuse matters, such as the blood of animals killed on the farm, the carcases of dead sheep, lambs, &c., are thrown into the liquid manure-tank; and by these additions no doubt the fertilising properties of this kind of liquid manure are greatly increased.

The smell of this liquid, especially in summer, is very bad; the decomposition of the animal matters proceeds more rapidly in hot weather, and in a dry season like the last the smell of sulphuretted hydrogen is so strong that, except on a rainy day, the liquid cannot be pumped over the manure-heap without creating a nuisance.

The soil on all the fields of the College farm contains a good deal of clay; and, though many fields are called light, the soil is only light in virtue of the limestone and gravel that abound in those places. Separated from the stones, the soil from these so-called light fields is quite stiff and heavy, since it contains hardly any sand, and is composed chiefly of clay and lime.

We have applied our tank-liquid by itself on various occasions, but have never seen much good produced by it. The soils on the College farm and neighbourhood derive, I believe, little or no benefit from liquid manure. In a subsequent page I shall state the reasons why land like this is not benefited by it. On account of the inefficacy of this liquid when applied by itself on our farm, and the expense of distributing it, the liquid manure is now rarely used by itself, but is pumped when required over the manure-heap.

Abundance of straw being produced on the farm, which in some way or other has to be converted into manure, the dung in the pit is generally drier than it is desirable it should be, and affords an excellent opportunity for the absorption of the tank-liquid.

Seven thousand grains of tank-liquid collected in 1857 gave on evaporation to dryness 12·110 grains of solid matter, which furnished on burning 7·394 grains of mineral matters.

The mineral matters were found to contain in 100 parts:—

Silica	1·56
Lime	17·59
Magnesia	2·24
Chloride of sodium	23·34
Chloride of potassium	10·43
Potash	18·14
Phosphoric acid	3·12
Sulphuric acid	4·62
Carbonic acid	18·96
	100·00

Seven thousand grains evaporated to dryness with the addition of hydrochloric acid gave a residue that produced on burning with soda-lime 2·296 grains of ammonia.

The residue from another 7000 grains evaporated without acid only yielded ·303 of nitrogen.

The following is the composition of the solid substances in this sample of liquid manure:—

Organic matters	38·94
Containing 2·504 of nitrogen. Which is equal to 3·040 of ammonia.	
* Inorganic matters (ash)	61·06
	100·00

* Consisting of—	
Silica	·95
Lime	10·75
Magnesia	1·37
Chloride of sodium	14·25
Chloride of potassium	6·36
Potash	11·08
Phosphoric acid	1·91
Sulphuric acid	2·81
Carbonic acid and loss	11·58

According to these analytical data the liquid manure drawn in 1857 from the tank on the College farm, Cirencester, had the following composition:—

An imperial gallon contained:—

Water and volatile ammoniacal compounds	69878·900
Solid residue (dried at 212°) matter	121·100
	70000·000

A gallon contained:—

Ammonia (volatilized on heating, and present chiefly as carbonate and humate of ammonia		22·964
Organic matters		47·157
Containing 3·033 of nitrogen. Equal to 3·683 of ammonia.		
Mineral matters (ash)	73·943	
Consisting of—		
Silica		1·154
Lime		13·011
Magnesia		1·660
Potash		13·411
Chloride of potassium		7·712
Chloride of sodium		17·258
Phoshoric acid		2·304
Sulphuric acid		3·408
Carbonic acid and loss		14·025
		144·064

There is a very marked difference in the composition of this liquid and that from Badminton or Westonbirt. In the first place, it will be noticed that the proportion of solid matter in the Cirencester liquid is very much smaller than in the other two.

In that from Badminton we have almost exactly 5 times as much solid matter as in that from Cirencester, and in that from Westonbirt about 3½ times as much.

In the next place, it will strike any one who carefully compares these analytical results that, notwithstanding the much larger proportion of water in the Cirencester liquid, it contained more than double the amount of ammonia which was found in the sample from Badminton.

Thus the proportion of ammonia which is driven out on boiling amounts in the Badminton liquid to only 11·41 grains per imperial gallon, whilst in that from Cirencester there are 22·964 grains of such ammonia per gallon.

I have observed already that the Badminton liquid has evidently lost ammonia by long keeping; while injurious evaporation of this kind does not appear to have deteriorated the contents of the Cirencester tank. Again, it will be seen that even the total amount of nitrogen is somewhat larger in the Cirencester than in the Badminton sample. In the former we have 18·911 grains of nitrogen, equal to 22·964 of ammonia, present in the state of volatile compounds of ammonia, and 3·033 of nitrogen, equal to 3·683 of ammonia, present in the state of nitrogenised organic matters and fixed salts of ammonia, or together 21·944 per cent. of nitrogen, corresponding to 26·647 of ammonia; whilst in the latter we have only 9·40 grains of nitrogen in the state of volatile compounds of ammonia, corresponding to 11·41 grains of ammonia, and 8·98 grains of nitrogen, in the shape of nitrogenised organic matters and fixed ammoniacal salts, or together 18·38 of nitrogen, which is equal to 22·31 grains of ammonia.

The composition of the ash of the Cirencester liquid manure also offers some points of interest, which, however, I shall consider after having given some particulars respecting the characters of the contents of our tank in 1858.

4.—*Liquid Manure from Royal Agricultural College Farm, Cirencester. Collected in* 1858.

I was anxious to ascertain whether or not the contents of our tank varied much at different periods, and for this purpose pumped up a quantity of liquid sufficient for examination in 1858.

The physical characters of the tank-liquid were the same as in 1857. It was allowed to subside for some days, and was perfectly clear when submitted to analysis.

Specific gravity of liquid manure at 62° Fahr. = 1·0014.

7000 grains evaporated to dryness gave 11·186 grains of dry residue, and this reduced to ashes in a platinum capsule gave 9·127 grains of ash.

We have thus in one imperial gallon:—

	Grains.
Water and volatile compounds	69,888·14
Organic matters	20·59
Mineral matters	91·27
	70,000·00

Evaporated to dryness with hydrochloric acid a residue was obtained which yielded on combustion with soda-lime 30·80 grains of nitrogen calculated per gallon. The residue obtained by evaporation without acid gave 1·49 grains of nitrogen per gallon.

The ash of this liquid manure contained in 100 parts:—

Soluble silica	2·57
Lime	12·58
Magnesia	3·15
Potash	18·54
Chloride of potassium	3·01
Chloride of sodium	44·21
Phosphoric acid	5·30
Sulphuric acid	4·32
Carbonic acid and loss	6·32
	100·00

An unexpectedly large amount of chloride of sodium having been found in this analysis, and rather less potash than I expected, I caused fresh determinations of chlorine and the alkalies to be made. In the first chlorine determination I obtained 28·27 per cent. of chlorine in the ash; in the second 27·90 per cent. The second determinations of potash and soda likewise yielded satisfactory results, for I obtained 18·63 of potash, 1·51 of chloride of potassium, and 44·81 of chloride of sodium; thus proving that the ash of this liquid manure really contained the amount of chloride of sodium and potash which is given in the above analysis.

The following numbers express the per cent. composition of the solid matters:—

* Organic matter	18·40
Inorganic matter	81·60
	100·00
* Containing nitrogen	1·33
Consisting of—	
Soluble silica	2·09
Lime	10·26

Magnesia	2·57
Potash	15·06
Chloride of sodium	36·07
Chloride of potassium	2·45
Phosphoric acid	4·32
Sulphuric acid	3·52
Carbonic acid	5·26

Calculating the preceding results per imperial gallon, we have in the tank-liquid from the College farm, Cirencester, collected in 1858, the following proportions of the various constituents :—

Ammonia (in the state of carbonate and humate)		35·58
Organic matters		20·59
Containing 1·49 of nitrogen.		
Equal to 1·81 of ammonia.		
Inorganic matters (ash)	91·27	
Consisting of—		
Soluble silica		2·34
Lime		11·48
Magnesia		2·87
Potash		16·92
Chloride of potassium		2·74
Chloride of sodium		40·35
Phosphoric acid		4·83
Sulphuric acid		3·94
Carbonic acid and loss		5·80
		147·44

A comparison of the liquid manure from Cirencester with the preceding kinds examined will show that there is a great deal more solid matter contained in solution in the samples from Westonbirt and Badminton; that there is more ammonia in that from Westonbirt than in that from Cirencester, but that the latter contains more ammonia than the Badminton manure.

It will also be observed that chloride of sodium enters more largely into the composition of the liquid from the College farm, and also that it contains more phosphoric acid and less potash than the preceding liquids.

Comparing the composition of the Cirencester sample collected in 1857 with that collected in 1858, it will be seen that in 1858 this tank-liquid contained less than half the quantity of organic matters that were found in it in 1857, but that in 1858 it was somewhat richer in ammonia.

On the other hand, the proportion of mineral matters in 1858 was larger than in 1857, and the percentage of phosphoric acid and chloride of sodium in the mineral portion of the liquid collected in 1858 was more considerable than in the ash of the liquid collected in 1857.

At different periods the liquid manure obtained on the same farm thus exhibited marked differences in composition, which differences cannot fail to influence the effects which it is capable of producing in the field.

The large proportion of salt in the liquid collected in 1858 I am inclined to think owes its origin to a heap of refuse salt which had been purchased at a very cheap rate. In all probability, some of this salt had, by some means or other, found its way into the tank.

5.—*Liquid Manure from Tiptree Hall, Essex.*

I am indebted to Mr. Mechi for kindly supplying me with the material of which the subjoined two analyses were made. Mr. Mechi keeps the greater part of his stock on boards, and collects the solid and liquid excrements together in a large tank. Before distributing the contents by means of steam-power and underground pipes it is much diluted with water.

The tank-liquid from Tiptree Hall possessed a strong smell and had a dark muddy appearance. A portion of the well-shaken liquid was allowed to subside, and the clear portion examined separately. This clear liquid had a light yellowish colour, and gave a very faint ammoniacal reaction with red litmus paper.

An imperial gallon gave on evaporation to dryness 29·19 grains of fixed residue dried at 212° Fahr.

On burning, this residue left 21·49 grains of ash.

A gallon thus contained:—

Water and volatile matters ..	69,970·81	
Organic matters	7·70	29·19 fixed residue.
Inorganic matters	21·49	
	70,000·00	

The inorganic portion, on analysis, was found to consist in 100 parts of—

Soluble silica	7·84
Insoluble silicious matter (fine clay)	3·54
Lime	20·62
Magnesia	8·31
Potash	6·11
Chloride of potassium	5·16
Chloride of sodium	25·45
Phosphoric acid	11·01
Sulphuric acid	10·02
Carbonic acid	1·94
	100·00

In the preparation of the ash the greater part of the lime, which exists in the original liquid as bi-carbonate, was burned caustic; hence the small proportion of carbonic acid which was found on analysis.

The mineral portion of this liquid resembles in its general characters that of the preceding ones. But the relative proportions of the several constituents differ considerably from those of the liquid manures from Badminton, Westonbirt, and Cirencester.

It is chiefly by a much larger percentage of lime and phosphoric acid that the Tiptree Hall sample is distinguished from the others. Being prepared from solid as well as liquid excrements, the larger amount of phosphoric acid finds a ready explanation, as it occurs abundantly in the solid excrements of animals, whilst it is absent in their urine.

During the fermentation of the solid excrementitious matters, insoluble combinations of phosphoric acid are rendered soluble and made available for the immediate use of plants.

On account of the more abundant occurrence of phosphoric acid in this species of liquid manure, it is a fertiliser which is better adapted for general manuring purposes than the liquids previously examined. The solid residue left, on evaporating to dryness an imperial gallon of liquid, gave on burning with soda-lime ·52 grains of nitrogen, equal to ·63 of ammonia.

Evaporated with the addition of hydrochloric acid, the same quantity of liquid yielded on combustion with soda-lime 3·29 grains of nitrogen, which is equal to 3·99 of ammonia.

The following analysis expresses the percentage composition of the solid matter contained in this liquid :—

* Organic matters	26·38
† Inorganic matters	73·62
	100·00

* Containing nitrogen	1·78
Equal to ammonia	2·16
† Consisting of—	
Soluble silica	5·77
Insoluble silicious matter (fine clay)	2·60
Lime	15·18
Magnesia	6·11
Potash	4·49
Chloride of potassium	3·79
Chloride of sodium	18·73
Phosphoric acid	8·10
Sulphuric acid	7·37
Carbonic acid	1·48

These analytical data lead to the following composition :—

Soluble silica (soluble in caustic potash)	6·75
Insoluble silicious matter (fine clay)	15·84
Oxides of iron and alumina	2·46
Lime	6·90
Magnesia	·81
Potash	·36
Chloride of potassium	2·03
Chloride of sodium	5·02
Phosphoric acid	3 88
Sulphuric acid	2·02
Carbonic acid and loss	·52

According to these analytical results, an imperial gallon of the muddy liquid manure from Tiptree Hall contained:—

* Water and ammonia driven out on boiling		69,904·24
† Organic matters		50·19
Mineral matters	45·57	
Consisting of—		
Soluble silica		6·47
Insoluble silicious matter (clay)		15·17
Oxides of iron and alumina		2·36
Lime		6·60
Magnesia		1·73
Potash		·35
Chloride of potassium		1·95
Chloride of sodium		4·81
Phosphoric acid		3·72
Sulphuric acid		1.94
Carbonic acid and loss		·47
		70,000·00
* Containing ammonia		2·846
† Containing nitrogen		2·17
Equal to ammonia		2.63
Total quantity of nitrogen per gallon		4·51
Equal to ammonia		5·476

It will be seen that the proportion of organic matter, as well as that of mineral matters, in the muddy liquid is much larger than in the clear liquid. But even this additional quantity of fertilising substances does not materially increase its value, for the additional amount of organic matters furnishes only 1·65 grains of nitrogen beyond the nitrogen contained in the organic substances of the clear liquid; and the additional mineral matters chiefly consist of fine clay, which of course adds nothing to the fertilising value of this manure.

Since the intrinsic value of all manuring substances is mainly dependent upon the amount of nitrogen, phosphoric acid, and potash which they contain, some idea of the relative merits of these six kinds of liquid manure may be formed by comparing the proportions of these constituents which each kind contains. I have, therefore, grouped together these determinations of nitrogen, potash, and phosphoric acid, as well as some other data which will facilitate comparison.

In the first place, I would observe that five of the liquid manures possessed the following specific gravities at 62° Fahr. :—

Liquid manure from	Westonbirt	1·006
,,	Badminton	1·007
,,	College Farm, 1858	1·0014
,,	Tiptree Hall, clear liquid ..	1·0006
,,	Tiptree Hall, with sediment	1·001

The specific gravity of these five liquids corresponds with the amount of solid matters which each kind contains in solution. To a certain extent the specific gravity of different kinds of liquid manure may serve as an indication of their relative fertilising value.

Proportion of dry Organic and Inorganic Matters in 1 *Gallon of*—

——		Organic Matters.	Mineral Matters.	Total.
Liquid manure from	Westonbirt	155·44	262·81	418·25
,,	Badminton	239·22	361·90	601·12
,,	College Farm, 1857 ..	47·157	73·943	121·10
,,	College Farm, 1858 ..	20·59	91·27	111·86
,,	Tiptree, clear liquid ..	7·70	21·49	29·19
,,	Tiptree, with sediment	50·19	45·57	95·76

The difference in the amount of solid matters contained in liquid manure are much greater than I expected to find them, and, curiously enough, the liquid manure from Tiptree Hall, which I anticipated would be very concentrated, was by far the weakest of all; the clear liquid contained in reality not more than one-twentieth part of the amount of solid fertilising substances which I found in the Badminton manure, and between one-fourth and one-fifth of the amount contained in the Cirencester tank-liquid, which I always considered very poor stuff, though it smelt extremely disagreeable.

In the next place I shall group together—

The Proportion of Nitrogen, ready-formed Ammonia, and total Nitrogen in 1 *Gallon of*—

——		Nitrogen in Organic Matters.	Nitrogen as Ammonia.	Total Nitrogen.	Equal to Ammonia.
Liquid manure from	Westonbirt	4·78	89·24	94·02	114·16
,,	Badminton	8·98	9·40	18·38	22·32
,,	Cirencester, 1857 ..	3·033	18·911	21·944	26·647
,,	Cirencester, 1858 ..	1·49	29·31	30·80	37·39
,,	Tiptree, clear liquid	·52	2·77	3·29	3·99
,,	Tiptree, muddy liquid	2·17	2·34	4·51	5·476

In the Government Report by Mr. Austin, C.E., on the Means of Deodorising and Utilising the Sewage of Towns, published in

1857, the author gives a short account of a visit to Mr. Mechi's farm, and, amongst other particulars referring to the working expenses for distributing liquid manure at Tiptree, states on page 57:—

> "The quantity delivered daily in ten working hours would be 130 tons of water; but Mr. Mechi estimates that the cost of delivery may be fairly placed at from 1½*d.* to 2*d.* per ton, the specific gravity of liquid manure being so much greater than water.
>
> "There will be distributed over the whole farm on the average from 45,000 to 50,000 gallons of liquid manure per acre per annum."

Assuming the composition of the liquid manure not to vary materially at different periods, 50,000 gallons of liquid manure, with the sediment, would yield 50,000 × 5·476 grains, or 273,800 grains of ammonia, or in round numbers 39 lbs. of ammonia.

Peruvian guano yields from 16 to 18 per cent. of ammonia. To produce the above-mentioned 39 lbs. of ammonia, we should require 2 cwt. of Peruvian guano of the best quality. At 13*l.* per ton, the 2 cwt. would cost 26*s.* For this outlay of money the same amount of ammonia would be obtained which is yielded by 50,000 gallons of Mr. Mechi's muddy tank-liquid.

Deducting the clay and earth which swell the amount of solid matter in the muddy tank-liquid, and taking no account of the suspended organic matter, which may be done with propriety, since account has been taken of the nitrogen, the only valuable portion in it, we have as nearly as possible the same weight of solid matter in 2 cwt. of Peruvian guano which is contained in 50,000 gallons of the Tiptree liquid manure. But the solid constituents of Peruvian guano being more valuable than those in the liquid, a balance would be left in favour of guano. Allowing 4*s.* for sowing 2 cwt. of guano, 30*s.* would cover the cost price and expense of applying the guano.

If 1 ton of liquid manure, according to Mr. Mechi's estimate, costs for delivery 2*d.*, 50,000 gallons, = 500,000 lbs., will cost 1*l.* 17*s.* 2*d.*

The fertilising matters in 50,000 gallons of liquid manure thus will cost for delivery 7*s.* 2*d.* more than the price of the materials and expenses of application would amount to were they put upon the land in the shape of Peruvian guano. Whether or not it is good economy to spend 1*l.* 17*s.* 2*d.* for the delivery of fertilising materials which are intrinsically worth about 26*s.*, or at the most 30*s.*, is a question which may be safely left in the hands of practical men. It is a question which, I think, cannot be answered in a general way. On some soils I believe even a larger expense for delivery may be incurred, whilst on others less than a quarter the expense may be ruinous.

Many persons, deceived by the bad smell and dark colour of liquid manure, entertain very extravagant notions respecting the amount and intrinsic value of the fertilising matters which it contains. Such notions are a great bar to the fair adjustment of the question so frequently asked—Will liquid manure pay or not? It is well, therefore, to remember that 50,000 gallons may not contain more fertilising matter than 2 cwt. of good Peruvian guano; and that this opinion is based on analytical facts which are quite independent of any theoretical reasonings.

In the following Table I have placed side by side the—

Amount of Phosphoric Acid, Potash, and Chloride of Potassium, expressed in Grains and Fractions of Grains, in 1 Imperial Gallon of—

——	Phosphoric Acid.	Potash and Chloride of Potassium together.
Liquid manure from Westonbirt	2·70	175·23
,, Badminton	9·51	189·64
,, Cirencester College, 1857 ..	2·304	21·123
,, Cirencester College, 1858 ..	4·83	19·66
,, Tiptree, clear liquid	2·36	2·41
,, Tiptree, with sediment	3·72	2·30

Even a superficial reader will be struck with the great variations which are exhibited in any of the Tables in which is contrasted for convenience of comparison the relative amount of the more important fertilising substances contained in a gallon of liquid manure. It is evident that the practical effects which it is capable of producing depend upon the nature and amount of fertilising matters which enter into its composition; and as the composition of the different kinds differs so very widely, we cannot feel surprised to hear that in one instance it has done marvels, and in others little or no good. However, there are other circumstances besides the difference in composition which must be taken into account if we wish to entertain correct ideas respecting the utility of liquid manure. I shall therefore consider in the next chapter the character of the soils upon which it is applied with decided advantage.

II. ON THE CHARACTER OF SOILS UPON WHICH LIQUID MANURE IS APPLIED WITH MANIFEST BENEFIT, AND ON THE REASONS OF SUCCESS.

Experience has shown that liquid manure produces the most beneficial and most striking effects when applied to light, deep, sandy soils, resting upon a porous subsoil. However poor originally such a soil may be, after repeated applications of liquid manure it is rendered capable of yielding remunerative

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Provided the subsoil be well drained or of a porous nature, it may be safely asserted that *any* sandy soil, however sterile in its natural state, may be made to yield heavy crops through the instrumentality of liquid manure. Indeed the poorer the soil the more striking would be the result.

For poor, sandy soils, the system of liquid manuring cannot be too highly recommended, for I believe that all other plans of applying fertilizing materials to them will be found far less efficacious in their results. If we examine into the chemical and physical characters of soils similar to those which abound in Flanders, we shall not be long in discovering the causes of the astonishing success which has crowned the system of liquid manuring in Belgium and other countries.

In order to render more intelligible the explanation of the causes of the highly beneficial effects which liquid manure produces under these circumstances, I may be allowed to introduce here the composition of two sandy soils which I have lately examined.

Composition of Two Sandy Soils from the neighbourhood of Cirencester.

	No. I.	**No. II.**
Organic matter and a little water of combination	5·36	4·82
Oxide of iron and alumina	5·78	12·16
Carbonate of lime	·25	·15
Potash, soda, and magnesia	·49	·46
Phosphoric acid	none.	faint trace.
Sulphuric acid	trace.	trace.
Chlorine	trace.	trace.
Insoluble silicious matter (chiefly fine quartz sand with but little clay)	88·12	82·41
	100·00	100·00

It will be observed that both soils abound in quartz-sand and are deficient in clay and lime. No. I. especially is very sandy, and even poorer than No. II., for I could not detect in it any phosphoric acid, and found in it less clay than in No. II.

On land of that description, corn, roots, or grass cannot possibly be grown with advantage without manure, for in these soils all the more important mineral constituents which are required for sustaining a healthy and luxuriant vegetation, are either altogether absent, or are greatly deficient. Thus No. I. contains no appreciable quantity of phosphoric acid, and No. II. mere traces. Again, it will be noticed that lime, which in smaller or larger quantities is contained in every kind of agricultural produce, occurs very sparingly in these soils, and that the percentage of potash and soda in both is far from what it ought to be in order to meet the wants of growing plants. Taking potash, soda, and magnesia together, there is not quite a half per cent. in these soils, and probably the major part of this fractional percentage consists of magnesia. Sulphuric acid likewise is wanting in both soils. In short, both are poor soils that require to be heavily manured before they can be made to yield a respectable crop, and that soon return to their natural sterile state when the usual dressings of manure are withheld.

Hungry soils of such and similar composition are grateful for almost any kind of manure, for, as they are greatly deficient in plant-food, manures that contain even small quantities of phosphoric acid or alkalies must produce a beneficial effect. The poorer the soil the more striking will be the effect which the manure produces, and the more diluted may the latter be before it ceases to produce any visible effect. A liquid which is very poor in these fertilizing constituents, when applied to land which contains already potash, lime, phosphoric acid, and other mineral substances required by plants, though possibly in deficient quantities, may not make any perceptible impression, simply because it does not materially increase the original store of the available fertilising substances in the soil; whilst the same liquid, when put upon land that contains no phosphoric acid whatever, and a much smaller proportion of lime, potash, &c., than is contained in the liquid manure, will produce a striking effect, inasmuch as the fertilizing constituents in the manure materially increase the store of plant-food in the soil.

Several of the liquid manures which I examined, compared with other fertilisers, are poor manures. For the reasons just mentioned liquid manure of this description cannot produce any marked effect upon naturally fertile land, but on poor sandy soils it unquestionably may be used with very great benefit.

Nay, I think it can be shown (and experience confirms me in this) that liquid manure in a concentrated state would act injuriously upon the vegetation on most soils which are benefited by liquid manure, and that the more sterile and sandy the soil naturally is, the greater the necessity for diluting the manure.

Under ordinary circumstances it is the soil that furnishes to plants a considerable proportion of the mineral matters which are left behind on reducing them to ashes. As a rule the manure, in addition to nitrogenised substances and other organic constituents, is required to supply in preference those mineral matters which, like phosphoric acid or potash, are generally sparingly distributed through the soil. The natural resources of mineral plant-food vary greatly in quantity and in quality in different soils. In most, the more common fertilizing materials, such as lime and magnesia, sulphuric acid, silica, and even potash, are found in such abundance, that we need not care to replace them in the measure in which they are carried off the land in the different crops of a rotation. There are *a few* soils upon which we can continue to grow paying crops of roots, clover, or corn, without restoring in the shape of manure the more valuable minerals, such as phosphoric acid; but where it is yet necessary to replace the nitrogenised food of plants, which, it appears, is diminished in a high degree by the growth of white crops. Upon land rich in available mineral matters, purely nitrogenised or ammoniacal manure may be used with far more safety (and in many instances with true and permanent economy) than upon soils deficient in available mineral food. The injurious effects of an excess of ready-formed ammonia and nitrogenised matters readily furnishing ammonia on decomposition, show themselves nowhere plainer than upon poor sandy soils. Daily experience tells us to use ammoniacal manures but sparingly in such cases. Now liquid manure, we have seen, always contains a considerable proportion of nitrogenised organic matters, as well as ready-formed ammonia, but it is deficient in phosphoric acid and other mineral matters which, under ordinary circumstances, are furnished to the plant by the soil. The liquid manure produced on a farm, when applied in a concentrated state, of course cannot penetrate the soil to any great depth, or, at any rate, cannot soak so deeply into the soil as it would had it been previously diluted with three or four times its bulk of water. There are many sandy soils in which lime, magnesia, phosphoric acid, and other minerals occur but in very small quantities. If such soils are manured with a too concentrated description of liquid manure, there will not be a sufficient quantity of mineral food in the soil and the manure to counterbalance the injurious effects which an overdose of purely nitrogenised food is well known to produce. Grass land under such circumstances will produce abundant, but rank, innutritious, bad-keeping hay; wheat will give abundance of straw, but little and inferior corn; swedes, turnips, and other root-crops will make rapid progress, and then become attacked by disease.

For these reasons it is necessary to dilute liquid manure largely if we wish to put it on poor sandy soils. Diluted with much water it penetrates a larger mass of soil, and, so to speak, becomes more saturated with the mineral fertilizing matters that are wanted by the plant, and are so sparingly distributed throughout the soil.

And this leads me to observe that liquid manure is particuarly well adapted for porous sandy soils, because it penetrates them when properly diluted deeply and uniformly, which is a great advantage, since the porous nature of sand allows the roots of plants to penetrate the soil to a great depth, and in every direction, in search of food. In other words, sandy soils are excellent vehicles for holding a diluted liquid manure, in which the different constituents occur in an immediately available, or, so to say, cooked condition.

The porous and often uniform physical character of such soils, moreover, causes great fluctuations in the amount of moisture, and in dry and warm weather they dry to a considerable depth, leaving a porous and friable surface exposed to the action of the atmosphere.

All these are peculiarities that strikingly characterise porous sandy soils, and render intelligible the improvement which liquid manure is well known to produce on them.

Let us contrast with these chemical and physical properties of sandy soils some peculiarities that are most distinctly observed in stiff clay land.

III. On the Characters of Soils not benefited by Liquid Manure, and on the Causes of Failure.

Soils containing a fair proportion of clay, especially stiff clay soils, are diametrically opposed in their chemical and physical characters to those which are porous and sandy. Generally the more retentive and stiff soils contain not only the more common mineral elements which we find in the ashes of plants, such as lime, magnesia, soluble silica, sulphuric acid, &c., in sufficient abundance, but also the more valuable mineral substances, such as phosphoric acid and potash. They moreover possess in a high degree the power of absorbing ammonia from the atmosphere, and retaining it; and in addition to this ammonia, under good cultivation, the vegetable remains left in such soils in the shape of roots and leaves from former crops, yield plenty of organic food for plants. It is true that stiff soils are not always very productive, but generally speaking they contain within themselves all the elements of fertility, and it is only for want of proper cultivation that their productive powers are not fully developed.

Whatever the agriculturist may think of the Lois Weedon system of culture, the Rev. Mr. Smith certainly has the great merit of having shown with indefatigable perseverance and zeal that certain clay soils only require constant working in order to yield remunerative crops of wheat in succession for a number of years. This would be an utter impossibility if they did not contain a practically inexhaustible store of mineral elements of nutrition, and if they did not under his system of cultivation also provide an ample supply of organic food.

In illustration of this part of my subject, I may mention the following analysis, which I recently made of a soil and its subsoil of moderately retentive and naturally very fertile properties.

This soil and subsoil contained in 100 parts :—

	Surface soil.	Subsoil.
* Organic matter and water of combination	4·38	2·59
Alumina	2·15	5·39
Oxides of iron	3·15	7·16
Lime	·77	·26
Magnesia	·13	1·22
Potash	·49	·88
Soda	·13	·28
Phosphoric acid	·12	·19
Chlorine	trace.	trace.
Carbonic acid	·31	1·79
Insoluble silicates and sand	88·31	80·24
Consisting of—		
Silicic acid	85·11	62·61
Alumina	2·36	14·55
Lime	.. ..	·85
Magnesia	·50	·23
Potash	·25	1·77
Soda	·09	·21
	100·00	100·00
* Containing nitrogen	·182	·09
Equal to ammonia	·220	·11

Submitted to a mechanical analysis these soils furnished :—

	Surface-soil.	Subsoil.
Sand	76·16	55·15
Clay	18·09	41·79
Lime, magnesia, &c.	1·37	·47
Organic matter	4·38	2·59
	100·00	100·00

The surface soil, it will be noticed, contains a considerable proportion of sand, whilst the subsoil contains less sand and more clay. We have here an example of a friable loamy soil resting on a stiffish clay subsoil.

It will be observed that the surface soil abounds in all the mineral matters which are required by cultivated plants, and also contains an appreciable quantity of nitrogenized organic matters. If we calculate the total amount of the available fertilising substances for a depth of soil of only 10 inches, we shall find a quantity of mineral and organic fertilising matters, in comparison with which the amount of manuring constituents supplied in 50,000 gallons of liquid manure (even more concentrated than Mr. Mechi's tank-liquid) appears altogether insignificant. I believe this to be the chief reason why little benefit results from the application of liquid manure to clay soils and fertile friable loams. It may be said, if these soils abound in available fertilising substances, how is it that upon them ordinary farmyard manure is employed with advantage? To this objection I would reply: Farmyard manure, in the first place, is a more perfect manure than liquid manure, inasmuch as it contains a considerable proportion of soluble and insoluble phosphates which are very deficient in liquid manure, and, being a bulky manure, performs important mechanical functions that cannot be realised by the use of a liquid. In the second place, I would observe that the retentive physical characters of clay soils preclude the young plant from availing itself of the total amount of fertilising matters dispersed through the whole mass of the soil. In fact, plants growing on stiffish soils feed only upon a very small proportion of the bulk of soil; whilst those grown on a porous sandy soil penetrate it to a greater depth and in every direction, and avail themselves of the manuring constituents uniformly distributed amongst a large bulk of soil by the agency of liquid manure. In short, a porous sandy soil is a more appropriate vehicle for holding liquid manure. I indeed believe that little benefit would arise from the application of solid manure to clay soils, if it were possible to incorporate it with the soil as uniformly as liquid manure, and to the same depth to which the latter penetrates them. But decided benefit results from a good dressing with ordinary yard-manure, because, in fact, only a small proportion of the soil is actually manured, and because by the very bulk of the manure the physical and chemical characters of a portion only of the soil are so altered that in reality the plant feeds upon a new and artificially-formed soil.

However, it is not every clay soil that encloses in its substance abundant stores of plant-food; there are poor clays as well as poor sandy soils, and it may be asked, Might not liquid manure produce a good effect upon sterile clay land? I do not think it would produce a very marked effect, for I conceive that the close texture, coldness, and want of porosity which characterize sterile clays, are opposed to the successful application of liquid manure. As just observed, only a small portion of such soils can be penetrated by the tender roots of plants, whilst by far the larger part of the soil enriched by the liquid manure is out of their reach. Consequently most of the liquid manure would be lost under these circumstances, and the small quantity left in the portion of soil penetrated by the roots cannot of course produce any very striking result.

Moreover, all clay-soils are generally more than sufficiently wet during the early part of the year; the additional quantity of water supplied in liquid manure renders them wetter still; and as much heat is absorbed during the evaporation of water, the injury done to the land by the resulting cold would not, I imagine, be counterbalanced by the small proportion of fertilising matters supplied.

Again, clay soils, whether fertile or barren, and all land that is moderately stiff, like the majority of soils in England, must by a heavy dose of liquid manure be rendered closer. Such soils certainly would not be improved in their physical character by an excess of water. The use of liquid manure at a time when such land is more than sufficiently wet is therefore objectionable. But it is equally objectionable when stiff soils get too dry. In summer soils of that description crack in all directions, and the liquid manure then runs through the cracks instead of passing through the soil, or it moistens the soil but very imperfectly. Much of the liquid manure is thus lost, and, moreover, injury is done by the insufficient proportion of manure that is absorbed by a thin layer of the surface soil, for it causes at first a more rapid development of the young plants, which receive a sudden check as soon as the small quantity of moisture is all evaporated.

We thus observe that, generally speaking, neither the chemical nor physical characters of clay soils, and others partaking more or less of the same nature, are favourable to the introduction of the system of liquid manuring. And since by far the greater part of the cultivated land in this country is more or less retentive, I feel assured that liquid manure will never be extensively employed by British agriculturists, but that its use will be confined to land of a light porous character.

The experience of those who profess to have used liquid manure with much benefit on clay land may be regarded as contradictory to my views on the subject. But I would observe that, as far as I could learn, the application of liquid manure on heavy land, where it is said to have produced astonishing results, was always preceded by thorough draining, subsoil ploughing, deep cultivation, clay-burning, and liming, each of which processes is well known to effect radical changes in the constitution of heavy land. Bearing in mind the experience of Mr. Smith of Lois-Weedon, and others who have practically tested the utility of deep cultivation; and on the other hand the failures of those who have applied liquid manure upon land not previously improved by any other process than thorough drainage, it appears to me, to say the least of it, doubtful, whether the improvements in such soils are due to the application of liquid manure, or to the processes of subsoiling, liming, and burning. Any one of these processes effects a radical improvement in heavy land, and much more conspicuous will the improvement be if all three are resorted to in succession, which was the case in one instance that has come under my notice.

In conclusion I offer some remarks—

IV.—On the Modes of Disposing of Liquid Manure.

With respect to the disposal of the liquid manure produced on a farm, I have come to the conclusion that on porous, sandy, naturally unproductive soils, the liquid excrements of animals are best disposed of, together with the solid excrements, by mixing both with much water and irrigating the land with such liquid manure. Where plenty of water can be obtained at a moderate expense, and where facilities exist for irrigation by gravitation, so that no expenses have to be incurred for the erection of steam-pumping engines and underground pipes, I believe that this will be found incomparably the most effective and economic mode of manuring the land.

But instances are comparatively rare in this country where the liquid and solid excrements can be disposed of together with advantage. The question therefore arises, how should liquid manure be disposed of on clay soils, and on land such as we frequently find it, that is neither so stiff as clay nor so loose in texture as sand.

This question involves the consideration of several purely practical matters. Thus, for instance, the quantity of liquid manure produced on a farm must necessarily influence a farmer in his proceedings; if there are only a few thousand gallons of liquid manure produced, it will of course not pay to construct an expensive tank and lay down pipes, whilst on another farm it may be good policy to collect the liquid in a water-tight tank. Again, a proper answer to this question cannot be given, unless it is stated whether fattening stock or young cattle are chiefly kept on a farm, or whether the farm consists chiefly of arable or pasture land, or whether most of the fields are light or heavy, whether much or little straw is produced, and in what way the straw is disposed of with most benefit. Such and similar considerations must necessarily influence the arrangements for collecting and disposing of the excrementitious matters produced on a farm. Nothing therefore can be more absurd than to lay down a fixed rule for the management of liquid manure. On one of my agricultural excursions I remember having visited a farm where I found the liquid-manure tank brim-full. On inquiry what was done with the tank liquid? I was told, "Nothing." This appeared to me a strange answer, and I was half inclined to consider my host behind the times. However, knowing him to be a remarkably intelligent and thoroughly practical man, I did not jump at once to such a hasty conclusion, but endeavoured to learn from him all the particulars which led him at first to erect a tank, and afterwards to allow the liquid manure to run over and find its way into the soil as best it could. The result of a morning's ramble over the whole of the farm, and an animated discussion afterwards between us, was, that I thought with my friend that the most practical mode of disposing of the liquid manure in this case, was to let it run away "as fast as it would." I trust I may not be understood as advocating this novel, and I believe by no means uncommon, method of dealing with the contents of liquid-manure tanks on heavy clay farms. We cannot avoid recognising in this practice a waste which, no doubt, may be avoided, but which, under peculiar circumstances, is an evil that is more economically endured than cured.

Disclaiming, therefore, the intention of laying down fixed rules for the management of liquid manure, and avoiding the consideration of many practical matters, I propose to point out, by way of example, one circumstance which I believe more than any other must affect the arrangements on a farm for disposing of the liquid excrements of animals.

There are three modes of disposing of the liquid excrements of animals on soils on which irrigation with liquid manure cannot be carried out with advantage :—

1. Where the urine of animals is completely absorbed by litter in feeding-boxes.

2. Where the urine and drainings of stables, cowhouses, and pigsties, are collected in a small tank in close proximity to a *covered* manure-pit.

3. Where the liquid excrements of domestic animals, the sewage of dwelling-houses, drainage-water, and every kind of animal refuse matter are collected together in a water-tight tank of larger capacity, situated, as in No. 2, close to the manure-pit.

I assume that the manure-tank in Nos. 2 and 3 is provided with a forcing-pump, by means of which the tank liquid can be spread over the solid manure, as occasion requires.

In no instance would I recommend that the liquid collected in the tank should be applied by itself. Manure I believe ought either all to be used in a liquid form or all in a solid state. I consider it decidedly a bad practice to employ separately the solid and the liquid excrements of animals.

The adoption of one or the other of these three modes of dealing with liquid manure must depend chiefly on the *supply of straw.*

On farms where no young stock is kept, and just enough straw is produced to provide fattening cattle and horses with the requisite quantity of chaff and a sufficient amount of bedding material, I believe the best mode of disposing the liquid and solid excrements is to make the manure in boxes.

In well-managed box-feeding there is no waste by drainage of the most valuable portion of manure, nor waste by evaporation of ammonia; the manure ferments regularly and slowly, and liquid and solid excrementitious matters, which are neither of them perfect manures when applied separately, are preserved together in the most admirable manner. But on many farms the whole of the manure cannot be made in boxes, for on some there is too *little* straw produced, and only some of the cattle can be kept in boxes. In other places the farmer has so *much* straw that he finds it difficult to dispose of; he can neither sell the excess to advantage nor make it all into manure in fattening-boxes.

In the former case, that is when straw is deficient, I would suggest that the urine of cattle should be conducted through iron pipes into a perfectly water-tight tank, placed in the midst of the dung-steading, or close to one side of it. Let the manure-pit be covered by a roof, supported by several upright poles. Such a roof perhaps might be cheaply made of asphalted felt—a material that is both waterproof and light. A roof made of this material would not I imagine take very stout posts for supports, and could be erected at quite a cheap rate. The four sides of this erection would be of course left open, so that the wind could sweep over the manure in the pit in every direction.

Care should be taken to prevent the water from the roofs of farm-buildings and cattle-sheds from finding its way into the liquid-manure tank. Unless the tank is perfectly water-tight, and the urine of the stables and cowhouses conducted through iron or stoneware pipes, it is hardly possible to exclude drainage-water. By adopting this course, only the urine of cattle, saturated more or less with solid excrements, will find its way into the tank, and a comparatively small quantity of liquid will collect in it. The liquid, being concentrated, will rapidly enter into fermentation, and will lose ammonia by evaporation. It is, therefore, desirable that some oil of vitriol be poured into the tank from time to time, or whenever a pungent smell is discernible. According to the size of the tank 5 to 10 lbs. of oil of vitriol may be poured into it perhaps every two or three months. By this inexpensive and most effectual mode of preventing loss in ammonia, the manure may be wonderfully improved.

The solid manure in the pit, being sheltered against rain, rapidly gets drier, for during the fermentation of dung heat is developed, which is spent in the conversion of a considerable portion of the water of the manure into vapour.

As it is of much consequence to ferment manure with regularity, and fermentation is almost altogether stopped when excrementitious matters and straw are completely immersed in water, it is advisable to give the dungpit a somewhat inclined position, and to lay down an iron pipe close to the bottom of the pit, and to carry by this means any excess of liquid back into the tank. If this arrangement be adopted, the liquid in the tank may frequently be pumped over the manure in the pit without doing any harm, which it would be sure to do if no provision were made for the excess of liquid to drain back into the tank. This is of particular importance on farms where cattle, for want of straw, are insufficiently littered, and the manure consequently is very wet. The bulk of the solid manure, as well as the quantity of absorbing materials, might be considerably increased if coal-ashes, dry sawdust, and dry refuse matters of every description, and even dry earth, were thrown upon the manure-heap; and I feel convinced that, with a little care and management, the whole of the liquid excrements might gradually be absorbed and incorporated with the solid manure and litter.

The third plan of disposing of liquid manure is most beneficially adopted on farms upon which much more straw is produced than can be sold or consumed in feeding-boxes. On many farms in the neighbourhood of Cirencester it is impossible to convert in boxes the excess of straw into manure. There is not sufficient moisture to rot the straw.

On our own farm we have so much straw in the manure that it would not ferment properly if it were not exposed in the manure-pit to the rain that falls, and if it were not besides moistened with the sewage that flows from the College into the liquid-manure tank. Where there is an excess of straw, no difficulty exists of disposing of liquid manure, since the straw is capable of taking up more liquid than is supplied in the urine of animals. For this reason it is of no use to erect a roof over the manure-pit on farms where a large excess of straw is employed in the making of manure. On such farms I think no sensible man would contemplate for a moment the introduction of the system of liquid manuring.

Royal Agricultural College, Cirencester,
December, 1858.

ON THE

CHANGES WHICH LIQUID MANURE UNDERGOES

IN CONTACT WITH

DIFFERENT SOILS OF KNOWN COMPOSITION.

By Dr. AUGUSTUS VOELCKER.

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LIQUID MANURE.

In a paper 'On Farmyard Manure and the Drainings of Dung-heaps,' published in vol. xviii., of the R. A. Society's Journal, I communicated the results of two experiments, which showed that drainings from dung-heaps, in passing through soils of known composition, undergo a series of remarkable and important changes. Since the publication of this paper I have been actively engaged in following up this interesting inquiry; and, at the request of the Council of the Royal Agricultural Society, have now the pleasure of laying before the readers of the Journal the results of my recent researches on the subject.

The liquid manure employed in the following four experiments contained in an imperial gallon:—

		Grains.
Ammonia (in the state of carbonate and humate of ammonia)		35·58
Organic matters		20·59
Containing 1·49 of nitrogen. Equal to 1·81 of ammonia.		
Inorganic matters (ash)	91·27	
Consisting of :—		
Soluble silica		2·34
Lime		11·48
Magnesia		2·87
Potash		16·92
Chloride of potassium		2·74
Chloride of sodium		40·35
Phosphoric acid		4·83
Sulphuric acid		3·94
Carbonic acid and loss		5·80
		147·44

In the fifth experiment it was thought desirable to use a very dilute fertilizing mixture; and, consequently, liquid manure, kindly supplied to me by Mr. Mechi, of Tiptree-hall, was selected. The composition of this liquid manure will be stated in a subsequent page.

The first filtration experiment was made with a soil from field No. 19 of the Royal Agricultural College Farm, Cirencester.

Submitted to a mechanical analysis, this soil was found to contain, in 100 parts,—

Moisture	1·51
Organic matter	11·08
Carbonate of lime	10·82
Clay	52·06
Sand	24·53
	100·00

It appears from this that the soil in question is a calcareous clay. In wet weather it is very sticky and stiff; worked in dry weather it breaks up in hard unmanageable lumps. By autumn cultivation its physical properties have been considerably improved. A portion of the soil, taken from a large well-prepared sample, yielded, on being submitted to chemical analysis, the following results:—

Moisture	1·51
Organic matter and water of combination	11·08
Oxides of iron and alumina	14·25
Carbonate of lime	10·82
Sulphate of lime	·71
Magnesia	·51
Potash (in acid solution)	·32
Soda (in acid solution)	·05
Phosphoric acid	·10
Insoluble silicates and sand (chiefly clay)	61·78
	101·13

This soil was mixed with liquid manure in the proportion of 2000 grains of soil to 7000 grains of perfectly clear liquid manure, the composition of which has just been stated. After shaking the soil and liquid together, and repeating this at intervals several times, the whole was allowed to settle; after a lapse of 24 hours the tolerably clear liquid was syphoned off. Notwithstanding that the filtration through fine filtering-paper was repeated many times, the liquid remained somewhat turbid. It was found, however, that a perfectly clear liquid could be obtained by allowing the filtered liquid to subside for eight days, and then carefully pouring off the clear liquid from the small deposit. This course has been followed in all subsequent experiments, and yielded tolerably satisfactory results.

The liquid manure originally had a brown colour; after filtration through the soil the colour of the liquid was scarcely less deep.

A portion of the clear liquid was evaporated to dryness, and in the residue the amount of fixed ammonia and nitrogen determined by combustion with soda-lime.

Another portion of the filtered liquid was supersaturated with hydrochloric acid, and thereby the volatile carbonate of ammonia and the humates and ulmates of ammonia, which lose ammonia on heating, were converted into chloride of ammonia. Evaporated to dryness on the water-bath, the acid liquid left a residue which, on burning with soda-lime, gave the total amount of nitrogen in the liquid. By deducting the amount of nitrogen found in the residue left on evaporation without acid from the total quantity of nitrogen, and calculating the remainder as ammonia, the proportion of ammonia existing as carbonate and as humate or ulmate of ammonia was determined.

A third portion of the filtered liquid was evaporated to dryness, the residue weighed, and afterwards burned in a platinum capsule at a moderate heat. The remaining ash was subsequently carefully analysed, according to well-known processes that need not be described here in detail.

This ash was found to consist, in 100 parts, of—

Soluble silica	·90
Oxide of iron	3·24
Lime	28·52
Magnesia	1·49
Potash	4·33
Chloride of sodium	42·36
Phosphoric acid	·77
Sulphuric acid	3·67
Carbonic acid and loss	14·72
	100·00

The solid matter in the liquid manure, left in contact with soil for 24 hours, had the following composition:—

Organic matter		30·66
Containing 1·62 of nitrogen.		
Inorganic matter	69·34	
Consisting of:—		
Soluble silica		·62
Oxide of iron		2·24
Lime		19·77
Magnesia		1·03
Potash		3·00
Chloride of Sodium		29·37
Phosphoric acid		·53
Sulphuric acid		2·54
Carbonic acid and loss		10·24
		100·00

According to these data, an imperial gallon of liquid manure, mixed in the proportion of seven parts (by weight) to two parts (by weight) of soil, and filtered off after 24 hours, had the following composition:—

		Grains.
*Water and volatile compounds of ammonia		69,886·60
†Organic matters		34·77
Inorganic matters	78·63	
Consisting of :—		
Soluble silica		·70
Oxide of iron		2·55
Lime		22·42
Magnesia		1·17
Potash		3·40
Chloride of sodium		33·31
Phosphoric acid		·60
Sulphuric acid		2·88
Carbonic acid and loss		11·60
		70,000·00

* Containing ammonia (as carbonate and humate and ulmate of ammonia)	20·81
† Containing nitrogen	1·84
Equal to ammonia	2·23

The remarkable changes which took place in the composition of the original liquid when left in contact with the Cirencester soil will appear by a study of the subjoined tabular statement, in which the composition of the liquid manure before and after contact with the soil is given, and which also states the gain or loss in the several constituents found in the filtered liquid.

Composition of Liquid Manure before and after Filtration through soil from field No. 19, Royal Agricultural College Farm, Cirencester.

An imperial gallon contains :—	Before contact with Soil.	After contact with Soil.	Gain or Loss.
Water and volatile ammonia compounds	69,888·14	69,886·60	−1·54
Containing :—			
Ammonia, as carbonate and humate of ammonia	(35·58)	(20·81)	−14·77
Organic matters	20·59	34·77	+14·18
Containing nitrogen	(1·49)	(1·84)	+·35
Equal to ammonia	(1·81)	(2·23)	+·42
Inorganic matters	(91·27)	(78·63)	−12·64
Consisting of :—			
Soluble silica	2·34	·70	−1·64
Oxide of iron	none	2·55	+2·55
Lime	11·48	22·42	+10·94
Magnesia	2·87	1·17	−1·70
Potash	16·92	3·40	−13·52
Chloride of potassium	2·74	none	−2·74
Chloride of sodium	40·35	33·31	−7·04
Phosphoric acid	4·83	·60	−4·23
Sulphuric acid	3·94	2·88	−1·06
Carbonic acid and loss	5·80	11·60	+5·80
	70,000·00	70,000·00	

In the above table the gain is expressed by the sign + ; the loss by −.

The preceding analytical results suggest the following remarks:—

1. It will be noticed that liquid manure in contact with soil parts with a considerable quantity of ammonia, which, in some form or the other, is taken up by the soil. In this experiment soil and liquid manure were employed in the proportion of 2 of soil to 7 of liquid. A gallon of liquid manure in this experiment yielded to 20,000 grains of soil 14·77 grains of ammonia; accordingly, 1000 grains of soil absorbed ·738 grains of ammonia. Whether this is the maximum proportion of ammonia which this soil is capable of absorbing, or whether it would have taken up more or less ammonia when mixed with liquid manure in a different proportion than in the experiment, I am unable to tell for the present. It appears to me, however, probable that the concentration of the liquid in some measure determines the amount of ammonia which is retained by the soil.

Referring to a previous experiment with drainings of dungheaps, I find that 11,000 grains of a similar soil to the one from field No. 19 absorbed only ·365 grains of ammonia, or about half the quantity. These drainings of a dungheap originally contained 19·68 grains of ammonia to the gallon, and after filtration through soil 6·91 grains.

Further experiments with different descriptions of ammoniacal manuring matters and the same kind of soil are necessary before it can be decided whether the quantity of ammonia absorbed by a particular soil is constant, or whether it is influenced by the concentration or chemical composition of the manuring liquids with which the soil is brought into contact.

2. The amount of organic matter in the liquid manure employed in the experiment was less before than after filtration through the soil. Pure distilled water left in contact with arable land, I have shown before, extracts a considerable proportion of organic matter from the latter; and as the liquid manure originally contained but little, it need not cause surprise that it dissolved more when brought into contact with a soil containing a fair proportion of decomposed vegetable remains. The increase in organic matter accounts for the somewhat larger proportion of nitrogen in the organic portion of the filtered liquid.

3. On the other hand, the total quantity of mineral matter in the liquid manure after digestion with the soil has diminished in about the same proportion in which that of organic matter has increased.

4. It is worthy of notice that the liquid manure originally contained no oxide of iron. Left in contact with soil it dissolved 2·55 grains per gallon. The liquid analysed was *perfectly* clear, and the oxide of iron found cannot, therefore, arise from any suspended particles of soil. I have, moreover, repeated the

experiment with the same results, and find in all instances in which I operated with liquid manure upon soils rich in oxide of iron and organic matters, that oxide of iron is dissolved. In other cases no oxide of iron passed into the liquid manure. May not the oxide of iron, dissolved in considerable quantities from some soils through the agency of liquid manure, be injurious to vegetation, and partly account for the failure that is experienced with liquid manure on some soils?

5. Lime, it will be noticed, was rendered soluble by the liquid manure left in contact with soil. An imperial gallon contained nearly 11 grains more after than before filtration. Most of the lime occurred originally in the manure as bi-carbonate, and some only as sulphate. In the same states of combination, no doubt, the greater part of the lime occurs also in the filtered liquid.

Combining the sulphuric acid with lime, and the rest of the lime with carbonic acid, we have in this liquid manure, before and after filtration through soil:—

	Before Filtration.	After Filtration.
Sulphate of lime	6·69	4·89
Bi-carbonate of lime	22·45	50·24

Whilst thus the proportion of sulphate of lime in the filtered liquid is but little diminished, that of bi-carbonate of lime is very much greater than in the original liquid manure.

6. The small proportion of potash left in the manure after contact with soil is particularly interesting, inasmuch as it shows that the soil not only possessed the power of absorbing ammonia, but also potash—a constituent which in an agricultural point of view is of the greatest importance. It appears that potash is retained by the soil even with greater avidity than ammonia.

Besides the potash, which for the greater part exists in the liquid before and after filtration as carbonate of potash, the soil absorbed the whole of the chloride of potassium. 2·74 of chloride of potassium correspond to 1·73 of potash, which quantity added to the 16·92 grains of potash, present chiefly as carbonate of potash, gives 18·65 grains of potash in the gallon, or, expressed as carbonate of potash, 27·25 grains. After contact with soil, the gallon contained 3·40 grains of potash, or 4·99 of carbonate of potash.

15·25 grains of potash, or 22·76 of carbonate of potash, were thus absorbed by 20,000 grains of soil.

1000 grains absorbed ·763 of potash, or 1·138 of carbonate of potash.

7. In a much minor degree than potash the soil absorbed chloride of sodium. By far the larger proportion of common salt remained in the liquid. This result agrees perfectly with previous observations, and with all the experiments noticed in this paper.

The power of soils to absorb potash presents us with a striking contrast to the apparent indifference of soils to absorb soda from its soluble combinations.

8. It is likewise satisfactory to have in this experiment a direct proof of the power of the soil to take up phosphoric acid from soluble combinations with which it is brought in contact. Nearly the whole of the phosphoric acid originally contained in the manure was taken up by the soil. A much larger quantity of phosphoric acid would have been taken up by this soil, if a liquid richer in phosphoric acid had been passed through it. Experiments with soluble phosphates have shown that this is the case. My reason for alluding to this matter here is to guard the reader against the supposition that the quantity of phosphoric acid absorbed by the soil expresses its maximum absorptive power for phosphoric acid. The fact that some phosphoric acid was left in the liquid after 24 hours' contact with soil might readily give rise to such an opinion.

Direct experiments have shown to me that the power of this soil to absorb phosphoric acid is very much greater than appears in this experiment.

Although it is quite true that nearly the whole of the phosphoric acid contained in a liquid is retained by a moderate quantity of soil, it cannot be inferred from this that plants take up phosphoric acid in the shape of an insoluble compound; for a soil which is capable of absorbing a large quantity of phosphoric acid, when brought in contact with a liquid containing but a small proportion of the amount of phosphoric acid which the soil is capable of retaining, never completely removes the phosphoric acid. A certain quantity remains in solution—a quantity which I believe is sufficient to account for all the phosphoric acid which is found in the ashes of plants.

In all probability it is the function of the soil to transform readily soluble compounds of phosphoric acid into combinations which are so little soluble in water that in common life they pass for insoluble, but which are still sufficiently soluble to supply the growing plant with the necessary amount of this kind of mineral food. This beautiful power of soils effectually prevents the waste which heavy rains infallibly would occasion, and compounds more conducive to the health of plants are formed; for I believe we have sufficient evidence to show that all very soluble saline matters, however useful or necessary they may be for every kind of agricultural produce, impede the rapid growth of plants when they are presented too abundantly to the roots of plants.

The next experiment was made with a soil from a permanent pasture.

The mechanical analysis of this soil yielded the following results:—

Moisture	2·42
Organic matter	11·70
Lime	1·54
Clay	48·39
Sand	35·95
	100·00

On being submitted to chemical analysis, the following results were obtained:—

Moisture	2·420
Organic matter	11·700
Oxides of iron and alumina	11·860
Carbonate of lime	1·240
Sulphate of lime	·306
Containing sulphuric acid	(·180)
Phosphoric acid	·080
Chloride of sodium	·112
Potash (soluble in acid)	·910
Soluble silica	4·090
Insoluble siliceous matter	67·530
	100·248

The composition of this soil differs materially from that used in the preceding experiment. It is a soil which contains much less lime and a good deal more sand than the soil from the College farm. It belongs to the class of vegetable moulds, is moderately stiff, and bears a good and tolerably abundant herbage.

Soil and liquid manure were mixed as before in the proportion of 2 of soil to 7 of liquid; after 24 hours the clear liquid was poured from the soil; the liquid was then allowed to settle for 6 or 8 days and then filtered. Notwithstanding every care to obtain a perfectly clear liquid, a little finely suspended clay passed through the filter. This clay is mentioned in the subjoined analysis as *insoluble siliceous matter*, and of course does not belong properly to the liquid.

The analysis of the liquid left in contact with the soil was executed exactly in the same manner as that of the liquid in the preceding experiment, and the following results were obtained:—

Composition of the inorganic matter (*ash*).

Soluble silica	2·73
Insoluble siliceous matter	2·66
Lime	22·51
Magnesia	2·57
Potash	4·64
Chloride of potassium	4·36
Chloride of sodium	35·03
Phosphoric acid	1·56
Sulphuric acid	2·44
Carbonic acid and loss	21·50
	100·00

The fixed residue left on evaporation of the liquid had the following percentage composition:—

Organic matter		21·60
Containing nitrogen		(1·52)
Inorganic matters	78·40	
Consisting of:—		
Soluble silica		2·14
Insoluble siliceous matter		2·08
Lime		17·64
Magnesia		2·01
Potash		3·63
Chloride of potassium		3·41
Chloride of sodium		27·46
Phosphoric acid		1·22
Sulphuric acid		1·91
Carbonic acid and loss		16·90
		100·00

According to these data, the composition of the liquid manure per gallon is as stated in the following table:—

Composition of Liquid Manure, before and after Filtration through Soil from a permanent Pasture.

An imperial gallon contains:—	Before Filtration.	After Filtration.	Gain or loss.
Water and volatile ammonia compounds	69,888·14	69,856·85	−31·29
Containing:—			
Ammonia, as carbonate and humate of ammonia	(35·58)	(20·83)	−14·75
Organic matters	20·59	31·14	+10·55
Containing nitrogen	(1·49)	(2·20)	+·71
Equal to ammonia	(1·81)	(2·67)	+·86
Inorganic matters	(91·27)	(112·01)	+20·74
Consisting of:—			
Soluble silica	2·34	3·06	+·72
Insoluble siliceous matter	..	2·97	+2·97
Lime	11·48	25·21	+13·73
Magnesia	2·87	2·87	..
Potash	16·92	5·19	−11·73
Chloride of potassium	2·74	4·88	+2·14
,, sodium	40·35	39·23	−1·12
Phosphoric acid	4·83	1·74	−3·09
Sulphuric acid	3·94	2·73	−1·21
Carbonic acid and loss	5·80	24·13	+18·33
	70,000·00	70,000·00	

We learn from these results:—

1. That this soil absorbed very nearly the same quantity of ammonia which was absorbed by the soil from the College farm; 20,000 grains in this experiment absorbed 14·75 grains of ammonia, or 1000 grains absorbed ·737 grains.

2. Like the preceding soil the pasture land yielded to liquid manure some additional organic matter. This organic matter likewise contained some nitrogen.

3. The filtered liquid contained nearly 21 grains more of mineral matter than the manure before coming in contact with soil.

4. This increase in mineral matter is chiefly due to carbonate of lime, which is much more abundant in the filtered liquid than in the original liquid manure.

It is chiefly in the state of bi-carbonate that lime occurs in the manure; only a small proportion occurs as sulphate of lime or gypsum.

If the sulphuric acid in these analyses is united with lime to form gypsum, and the rest of the lime calculated as bi-carbonate of lime, there will be in the liquid manure—

	Before Filtration.	After Filtration.
Sulphate of lime	6·69	4·64
Bi-carbonate of lime	22·45	59·91

It will be seen that the proportion of bi-carbonate of lime which passed into the liquid manure is greater than in the preceding experiment, notwithstanding the much larger quantity of carbonate of lime in the Cirencester soil. We have here an indication that the changes which take place when manuring matters are brought into contact with soil are not merely dependent on the percentage composition of the soil, but likewise on the state of combination in which the constituents occur in the soil. A soil containing much less lime may thus yield to a liquid containing a number of organic and inorganic compounds even more lime than another soil three or four times as rich in carbonate of lime.

5. The proportion of chloride of sodium (common salt) in the filtered liquid is nearly as large as in the original liquid.

6. On the other hand the absorption of potash is very marked. Originally the manure contained 16·92 of potash and 2·87 of chloride of potassium per gallon. After having been left in contact with soil it only contained 5·19 grains of potash and 4·88 grains of chloride of potassium. Calculating the potassium in chloride of potassium as potash, and adding it to the rest, we have—

	Grains of Potash.
In manure before filtration	18·65
,, after filtration	8·26
Difference	10·39

20,000 grains of soil in this experiment thus absorbed 10·39 grains of potash, or 1000 grains absorbed ·519 grains of potash.

7. No absorption of chlorine took place in this experiment.

On looking at the composition of the soil used in this experiment, it will be noticed that pure water extracts from it more chloride of sodium than is usual in the case of other soils.

This circumstance no doubt fully explains the fact that the liquid manure, after passing through the soil, contained even a little more chlorine than before.

The amount of chlorine in the chloride of potassium and chloride of sodium found in a gallon of liquid before filtration is 25·78 grains.

After filtration through soil we have 26·12 of chlorine in the liquid, thus showing that no chlorine whatever was abstracted from the liquid by the soil.

8. Most of the phosphoric acid was taken up by this soil, but not so completely as by the Cirencester soil. However, the quantity of phosphoric acid left in the liquid after having remained in contact with the soil from a permanent pasture, is very trifling. We have here a proof, that soluble phosphates in passing even through soils poor in lime are rendered comparatively speaking insoluble.

On the whole, then, we find that this pasture-land, like the soil used in the preceding experiment, possesses in a high degree the power of absorbing from liquid manure, ammonia, potash, and phosphoric acid, and yielding to the liquid, lime, organic matters, and small quantities of other less important constituents. In other words, all the more valuable fertilizing ingredients of liquid manure were absorbed by the soil, or at all events brought into states of combination in which they are little soluble in water.

Having ascertained in previous trials that the power of different soils to absorb manuring matters varies greatly, I was anxious to institute an experiment with the same description of liquid manure and a very poor soil. I therefore selected a soil from the neighbourhood of Cirencester, which soil, although it occurs in the midst of the oolite formation, is greatly deficient in lime, and contains sand in great excess. The mechanical analysis of this soil gave the following results:—

Organic matter	5·36
Clay	4·57
Lime	·25
Sand	89·82
	100·00

Thus 9-10ths of the soil consisted of sand, about 1-20th part only was clay, and 1-20th part organic matter.

On being submitted to a detailed chemical analysis, 100 parts were found to contain, when dried at 212° Fahr.,—

Organic matter and a little water of combination ..	5·36
Oxides of iron and alumina	5·70
Carbonate of lime	·25
Alkalies and magnesia	·49
Phosphoric acid	a mere trace.
Sulphuric acid	·08
Soluble silica	1·01
Insoluble siliceous matter (sand)	87·11
	100·00

We have here a soil which hardly contains any lime, and such minute traces of phosphoric acid, that this constituent could not be determined quantitatively.

The sand obtained by washing had a deep red colour, and contained a good deal of oxide of iron.

The composition of this soil fully explains the extremely infertile character of the land, and its avidity to swallow up manure without exhibiting any corresponding effect on the produce.

A portion of the soil, sufficient for the purpose of ascertaining the changes which liquid manure undergoes in contact with the soil, was mixed with this liquid, and the experiment carried out in all particulars precisely in the same manner as in the two preceding cases.

The following results were obtained:—

General composition of Liquid Manure left in contact for 24 hours with Sandy Soil.

1 imperial gallon contained:—

		Grains.
*Water and volatile ammonia compounds		69,892·41
†Organic matters	25·06	107·59
Inorganic matters (ash)	82·53	
		70,000·00

* Containing ammonia	33 15
† Containing nitrogen	1·40
Equal to ammonia	1·70

The mineral portion, or the ash of filtered liquid manure contained in 100 parts—

Soluble silica	6·19
Insoluble siliceous matter	1·69
Oxide of iron	2·52
Lime	9·73
Magnesia	·90
Potash	14·55
Soda	·55
Chloride of sodium	47·56
Phosphoric acid	2·33
Sulphuric acid	4·45
Carbonic acid and loss	9·53
	100·00

The total dry residue left on evaporation of the filtered liquid, amounting to 107·59 grains per gallon, had the following percentage composition:—

Organic matter		23·28
Containing nitrogen		(1·30)
Mineral matter	76·72	
Consisting of:—		
Soluble silica		4·75
Insoluble siliceous matter (a little fine clay passed through filter)		1·29
Oxide of iron		1·93
Lime		7·56
Magnesia		·70
Potash		11·16
Soda		·42
Chloride of sodium		36·48
Phosphoric acid		1·78
Sulphuric acid		3·41
Carbonic acid and loss		7·24
		100·00

According to these and other details previously mentioned, the composition of liquid manure before and after contact with this soil, and the loss and gain, is given in the following table:—

Composition of Liquid Manure before and after contact with a Sandy, very infertile Soil, from the neighbourhood of Cirencester, and Loss or Gain in Constituents.

An imperial gallon contains:—	Before Filtration.	After Filtration.	Loss.	Gain.
Water and volatile ammonia compounds	69,888·14	69,892·41	..	+42·7
Containing:—				
Ammonia, as carbonate and humate of ammonia	(35·58)	(33·15)	−2·43	..
Organic matter	20·59	25·06	..	+4·47
Containing nitrogen	(1·49)	(1·40)	−·09	..
Equal to ammonia	(1·81)	(1·70)	−·11	..
Inorganic matters	(91·27)	(82·53)	−8·74	..
Consisting of:—				
Soluble silica	2·34	5·10	..	+2·76
Insoluble siliceous matter (fine clay)	..	1·39	..	+1·39
Oxide of iron	..	2·07	..	+2·07
Lime	11·48	8·03	−3·35	..
Magnesia	2·87	·74	−2·13	..
Potash	16·92	12·01	−4·91	..
Chloride of potassium	2·74	none	−2·74	..
Soda	..	·45	..	+·45
,, sodium	40·35	39·25	−1·10	..
Phosphoric acid	4·83	1·92	−2·91	..
Sulphuric acid	3·94	3·67	−·27	..
Carbonic acid and loss	5·80	7·90	..	+2·10
	70,000·00	70,000·00		

Noticing the chief points of interest that attach to these results, I would direct attention to the following particulars :—

1. It will be seen that this sandy soil possessed in a very weak degree the power of absorbing ammonia from liquids. Thus, 1 gallon of liquid, after having remained in contact with soil for 24 hours, only contained 2·43 grains less ; or, in round numbers $2\frac{1}{5}$ grains less of ammonia. This small quantity, it will be remembered, is removed by 20,000 grains of soil ; 1000 grains consequently absorbed only ·121 of a grain of ammonia. In this particular this soil offers a striking contrast to the soils used in the preceding experiments, which absorbed about 6 times as much ammonia.

2. The proportion of organic matter in the filtered liquid is a little larger than in the original liquid ; but no appreciable difference exists in the amount of nitrogen in the organic matter before and after filtration through the soil.

3. In passing through the red-coloured sandy soil, the liquid manure took up an appreciable quantity of oxide of iron. In all probability the oxide of iron was united with an organic acid, or with organic matters similar in character to the organic matters found in bog-iron ore.

4. The soil used in this experiment, it will be remembered, contains a good deal of soluble silica. Liquid manure in contact with it appears to dissolve an appreciable quantity of soluble silica.

5. In the two preceding experiments we have seen that liquid manure kept in contact with soil becomes much richer in lime. But in the case of the sandy soils, instead of lime being taken up by the liquid manure, a considerable quantity of the carbonate of lime contained in the liquid used in the experiment was actually removed by the soil. The amount of lime in this soil is evidently insufficient to supply the wants of the crops we cultivate on the farm ; it is therefore fortunate that a soil thus constituted possesses the power of depriving manuring mixtures of those constituents which are required in considerable quantities for sustaining a healthy growth of plants. This property of soils to store up food for plants is not confined to one particular kind of fertilizing matter, but it applies to them all, and manifests itself in different ways. In most cases special power exists in soils to remove ammonia, potash, and phosphoric acid from liquid fertilizers brought in contact with them ; and less important and more abundant materials pass into the liquid that drains from soils. But this order is reversed if liquid fertilizers act upon such soils as the one used in the experiment before us. Here lime, a cheap and usually abundant ingredient of soils, is actually

absorbed from liquid manure, and retained in a soil which is peculiarly deficient in lime. Experience has shown, moreover, that sandy soil is more benefited by lime and calcareous mixtures than by any other description of manure.

6. On comparing the amount of potash contained in the liquid after filtration through this sandy soil, with the quantity of potash found in the liquid manure after contact with the two preceding soils, a marked difference will be observed. Indeed, the proportion of potash taken up by the sandy soil is quite inconsiderable. We have in this result an indication that soils which do not manifest a high power of absorbing ammonia, likewise have not much effect upon soluble compounds of potash.

7. Still smaller is the power of this soil to absorb soda-salts and sulphuric acid. As regards the compounds of soda, more especially chloride of sodium, the results obtained here agree with the rest. In all the experiments which I have hitherto made, either with highly complex fertilizing mixtures, or with simple salts of soda, I find that soda generally passes through the soil unabsorbed.

8. Again, it may be noticed, that we have here an instance of phosphoric acid becoming absorbed from its soluble combinations by a purely sandy soil, in which lime is almost altogether absent. At the same time it will be seen that phosphoric acid is not so completely removed by such a soil, as by stiffer and more calcareous soils.

On the whole, these experiments afford a ready explanation of the fact that the effects of manure on proverbially hungry soils are very transient.

They suggest, likewise, that the observed failure of superphosphate as a turnip-manure on such land may be due in some measure to the facility with which soluble phosphates are washed out of the soil.

The fourth experiment with the same liquid manure was tried on a soil of moderately retentive and naturally very fertile properties.

The mechanical analysis of this soil and its subsoil gave :—

	Surface-soil.	Subsoil.
Sand	76·16	55·15
Clay	18·09	41·79
Lime, magnesia, &c.	1·37	·47
Organic matter	4·38	2·59
	100·00	100·00

Submitted to detailed chemical analysis, the soil and subsoil were found to contain in 100 parts :—

	Surface-soil.	Subsoil.
Organic matter and water of combination	4·38	2·59
Alumina	2·15	5·39
Oxide of iron	3·15	7·16
Lime	·77	·26
Magnesia	·13	1·22
Potash	·49	·88
Soda	·13	·28
Phosphoric acid	·12	·19
Chlorine	trace	trace
Sulphuric acid	·06	·02
Carbonic acid	·31	1·79
Insoluble silicates and sand	88·31	80·24
Consisting of :—		
Silicic acid	85·11	62·61
Alumina	2·36	14·55
Lime	..	·85
Magnesia	·50	·23
Potash	·25	1·77
Soda	·09	·21
	100·00	100·00
Containing nitrogen	**·182**	**·09**
Equal to ammonia	**·220**	**·11**

Both the subsoil and surface soil were of a red colour. The surface soil is a friable sandy loam; the subsoil is stiffer, contains less sand, and more clay.

Equal parts of soil and subsoil were employed in the experiment, and the liquid manure added to this mixed soil in the proportion of 7 of liquid to 2 of soil, as before. The liquid was left in contact with the soil for 3 days, and then filtered and treated in the same manner as the rest of the experiments.

General Composition of Liquid Manure left in contact with a fertile, friable, loamy Soil for three days.

An imperial gallon contains :—

*Water and volatile ammonia compounds		69,871·03
†Organic matter	35·52	128·97
Mineral matters	93·45	
		70,000·00
***Containing ammonia**		**25·84**
†Containing nitrogen		**·84**
Equal to ammonia		**1·02**

The analysis of the mineral matters gave the following results :—

Soluble silica	2·39
Insoluble siliceous matter (suspended clay)	4·69
Lime	17·66
Magnesia	2·54
Potash	11·73
Chloride of potassium	5·66
Chloride of sodium	41·85
Phosphoric acid	1·57
Sulphuric acid	5·51
Carbonic acid and loss	6·40
	100·00

The solid matter, amounting to 128·97 grains to the gallon, had the following percentage composition :—

Organic matters		27·54
Containing nitrogen		(·65)
Mineral matters	72·46	
Consisting of :—		
Soluble silica		1·73
Insoluble siliceous matter (suspended clay)		3·40
Lime		12·79
Magnesia		1·84
Potash		8·50
Chloride of potassium		4·10
Chloride of sodium		30·32
Phosphoric acid		1·14
Sulphuric acid		3·99
Carbonic acid and loss		4·65
		100·00

According to these and previous results obtained in the analysis of the original liquid manure, we find in an imperial gallon of liquid manure before and after having remained in contact with soil for 3 days, the constituents mentioned in the subjoined Table :—

Composition of Liquid Manure before and after contact with a red-coloured, friable, loamy, fertile Soil and Clay Subsoil, and Loss or Gain in Constituents.

An imperial gallon contains :—	Before Filtration. grains.	After Filtration. grains.	Loss.	Gain.
Water and volatile ammonia compounds	69,888·14	69,871·03	−17·11	..
Containing :—				
Ammonia, as carbonate and humate of ammonia	(35·58)	(25·84)	−9·74	..
Organic matter	20·59	35·52	..	+14·93
Containing nitrogen	(1·49)	(·84)	−·65	..
Equal to ammonia	(1·81)	(1·02)	−·79	..
Inorganic matters	(91·27)	(93·45)	...	+2·18
Consisting of :—				
Soluble silica	2·34	2·23	−·11	..
Insoluble siliceous matter (suspended clay)	..	4·38	..	+4·38
Lime	11.48	16·50	..	+5·02
Magnesia	2·87	2·37	−·50	..
Potash	16·92	10·96	−5·96	..
Chloride of potassium	2·74	5·29	..	+2·55
„ sodium	40·35	39·11	−1·24	..
Phosphoric acid	4·83	1·45	−3·38	..
Sulphuric acid	3·94	5·18	..	+1·24
Carbonic acid and loss	5·80	5·98	..	+·18
	70,000·00	70,000·00		

The changes which took place in the chemical constitution of the liquid manure in contact with this soil are similar to those noticed in the first and second experiment. It will be seen, however, that the power of this loamy soil to absorb ammonia and potash is not equal to that exhibited by the pasture land and by the calcareous clay from Cirencester. Thus, in the experiment before us, 20,000 grains of loamy fertile soil absorbed 9·74 grains of ammonia; or 1000 grains absorbed ·487; whilst 1000 grains of Cirencester soil absorbed ·738 of ammonia, and 1000 grains of pasture land, ·737.

We also find a smaller proportion of potash retained by the loamy soil than by the Cirencester soil and by the pasture land. It thus seems probable that soils which absorb much ammonia also absorb much potash.

Again, we find that some lime, though sparingly present in the soil, is taken up by the liquid manure; and that nearly the total amount of chloride of sodium of the original liquid passes unaltered into the liquid which was left in contact with this soil for three days. Other minor changes may be passed over unnoticed, as they agree with previous results on which some observations have been made already.

It will be noticed that none of the four soils used in these experiments had the power of absorbing completely the whole of the ammonia, potash, or phosphoric acid contained in the liquid manure. A certain amount of these constituents always remained in the liquid which was left in contact with soil. As the liquid manure contained a good deal of ammonia and potash, it may be urged that the quantity of soil employed in the experiments in relation to that of the liquid was insufficient for the purpose of complete absorption. But this argument certainly does not hold good in the case of phosphoric acid, and probably not in the case of ammonia or potash. With respect to phosphoric acid, I can speak positively on the subject, for I have filtered through the same soils a very much larger proportion of phosphoric acid, and found that nearly the whole of it was retained by three of the soils. But whether a solution containing much or little phosphoric acid be filtered through a moderately stiff soil, invariably some phosphoric acid passes into the filtered liquid. Again, if a dilute solution of a soluble phosphate is passed through a soil, it may be ascertained readily that there is phosphoric acid in the filtered liquid. If now a fresh quantity of a solution containing phosphoric acid be shaken with the soil through which the first solution has passed, it will be found that the soil takes up a fresh quantity of phosphoric acid. This circumstance appears to me to prove decidedly that soils have not the power of rendering soluble phosphates so completely insoluble that these compounds cannot enter into the vegetable organism in a soluble state. I believe that the quantity of water which passes into the plant is amply sufficient to dissolve from the soil a sufficient quantity of the various mineral matters required to meet the wants of cultivated plants. In accounting, therefore, for the presence of potash, phosphoric acid, &c., in plants, it cannot be reasonably urged that soluble manuring matters, such as potash, phosphoric acid, &c., in contact with soil, are rendered insoluble, and that therefore plants must take up their food in a solid state. It is true, that the most soluble, and, I may add, the most valuable substances, contained in fertilizing liqnids are rendered *comparatively* insoluble in contact with most soils; but I feel assured that it is impossible to render them *perfectly* insoluble.

All good soils left in contact for a short time with pure rain-water yield a considerable quantity of potash, phosphoric acid, &c., to the water; and water charged with carbonic acid dissolves a still larger proportion of these and other soil-constituents. Purely sandy soils alter (comparatively) but little the composition of liquid fertilisers which are passed through them; clay soils, on the other hand, materially alter the chemical constitution of this liquid. If there is truth in the remarks I have made respecting the solubility of mineral food of plants, and the improbability of plants taking up food in a solid form, we may expect that no soil, however stiff it may be, will completely remove all the ammonia, potash, phosphoric acid, &c., contained in dilute fertilizing liquids. On the other hand, if plants can take up solid food in some mysterious unexplained manner, it would not be surprising that clay soils rendered insoluble the whole of the ammonia, potash, &c., contained in a fertilizing liquid: for, supposing this to be the case, the plant might still grow luxuriantly. The changes which manuring liquids undergo in contact with soil, it will be perceived, have a much wider application than may appear at first sight; they are, indeed, intimately connected with the theory of vegetable nutrition. I am happy, therefore, to be able to report a fifth experiment, which is of peculiar interest in this respect. The experiment was made with a soil from Tiptree Hall, kindly sent to me by Mr. Mechi. This soil, and the subsoil on which it rests, yielded, on mechanical analysis:—

	Subsoil.	Surface-soil.
Moisture	9·46	3·91
Organic matter and water of combination	4·87	4·80
Sand	9·26	10·97
Lime	1·12	2·19
Clay	75·29	78·13
	100·00	100·00

Both the soil and subsoil, it will be seen, contain a large preponderance of clay; they are both very stiff, but when improved, I am informed, are very productive. The chemical analyses of these soils furnished the following results:—

	Subsoil.	Surface-soil.
Moisture	9·46	3·91
Organic matter and water of combination	4·87	4·80
Oxides of iron and alumina	17·38	7·85
Phosphoric acid	·06	·04
Carbonate of lime	1·02	2·08
Sulphate of lime	·13	·15
Magnesia	·92	·32
Alkalies and loss	·45	
Insoluble siliceous matter (chiefly clay)	65·71	80·85
	100·00	100·00

The surface soil exhibited bits of chalk, flint, and burnt clay; it had evidently been dressed with burnt clay at some time or other. Equal parts of surface and subsoil were mixed with liquid manure from Tiptree Hall Farm; soil and liquid were repeatedly agitated and then left to settle for three days, after that period the clear liquid was drawn off and analyzed as before. The filtered liquid manure had the following general composition per gallon:—

*Water and volatile ammonia compounds		69,954·92
†Organic matters	5·46	45·08
Mineral matters	39·62	
		70,000·00

*Containing ammonia	1·55
†Containing nitrogen	2·02
Equal to ammonia	·24

The residue which was left on evaporation to dryness, on analysis was found to contain in 100 parts:—

Organic matter		12·11
Containing nitrogen		(·44)
Mineral matters	87·89	
Consisting of:—		
Soluble silica		3·57
Insoluble siliceous matter (suspended clay)		3·57
Oxide of iron		·71
Lime		17·30
Magnesia		6·27
Potash		8·65
Soda		1·16
Chloride of sodium		20·24
Phosphoric acid		4·99
Sulphuric acid		12·40
Carbonic acid and loss		9·03
		100·00

The mineral portion of the residue contained in 100 parts:—

Soluble silica	4·07
Insoluble siliceous matter (suspended clay)	4·06
Oxide of iron	·81
Lime	19·69
Magnesia	7·25
Potash	9·85
Soda	1·33
Chloride of sodium	23·04
Phosphoric acid	5·68
Sulphuric acid	14·11
Carbonic acid and loss	10·11
	100·00

The next table expresses the composition of the liquid manure from Tiptree Hall Farm, in its natural condition and after having remained in contact with soil and subsoil, from a field of the farm at Tiptree Hall.

Composition of Liquid Manure from Tiptree Hall, before and after contact with very stiff Clay Soil and Subsoil from Tiptree Hall Farm, and Loss or Gain in Constituents.

An imperial gallon contains:—	Before Filtration. Grains.	After Filtration. Grains.	Loss. Grains.	Gain. Grains.
*Water and volatile ammonia compounds	69,970·81	69,954·92	−15·89	
†Organic matters	7·70	5·46	−2·24	
Mineral matters	21·49	39·62	..	+18·13
Consisting of:—				
Soluble silica	1·68	1·61	−·07	
Insoluble siliceous matter (fine clay)	·76	1·92	..	+1·16
Lime	4·43	7·80	..	+3·37
Magnesia	1·78	2·87	..	+1·09
Potash	1·31	3·90	..	+2·59
Soda	..	·52	..	+·52
Chloride of potassium	1·10	none	−1·10	
,, sodium	5·46	9·12	..	+3·66
Phosphoric acid	2·36	2·23	−·13	
Sulphuric acid	2·15	5·59	..	+3·44
Carbonic acid and loss	·45	4·06	..	+3·61
	70,000·00	70,000·00		
*Containing ammonia	3·36	1·55	−1·81	
†Containing nitrogen	·52	·202	−·318	
Equal to ammonia	·63	·24	−·39	

In comparison with the liquid manure used in the four preceding experiments, the Tiptree Hall liquid is very weak. It contains scarcely 30 grains of solid matter in the imperial gallon, and only 3⅓ grains of ammonia. The soil, on the other hand, contains clay in large preponderance, an appreciable quantity of lime, and but little sand: it is, in fact, a very stiff soil. According to all previous experience, such a soil possesses in an eminent degree the power of absorbing manuring matters; it might be therefore expected that the *whole* of the ammonia contained in such a weak solution as the Tiptree liquid manure would be removed by such a soil when used in the proportion of 2 of soil to 7 of liquid. The same might be suspected with regard to potash and phosphoric acid. However, this experiment shows that a soil distinguished for its great power of absorbing soluble fertilizing matters does not entirely remove them even from a very dilute solution. As the subject is of considerable scientific interest, I may be allowed to examine the results obtained in this experiment a little more in detail, and therefore notice:—

1. Although only 7·7 grains of organic matter were present in the Tiptree liquid manure, Mr. Mechi's soil removed only 2¼ in round numbers, leaving 5½ dissolved in the liquid.

2. In the preceding experiments—

1000 grs. of soils from	College Farm absorbed ..	·738	of ammonia.
,,	pasture land	·737	,,
,,	sterile sandy land	·121	,,
,,	fertile loamy land ..	·487	,,

None of these soils contained so much clay as Mr. Mechi's soil, but, nevertheless, they all absorbed more ammonia than the stiff clay soil in the experiment with a very dilute liquid. There are only 3·36 grains of ammonia in a gallon of the Tiptree liquid manure, which certainly might be expected to be absorbed by 20,000 grains of soil; for, if so, 1000 grains would only have absorbed ·168 of a grain of ammonia. Nearly the same quantity of ammonia, we have seen, was absorbed by a soil consisting almost entirely of sand, which, we know, does not possess in a high degree the power of retaining ammonia. Notwithstanding the large proportion of clay and the small quantity of ammonia in the liquid manure from Tiptree Hall Farm, only 1·81 grains of ammonia were absorbed by 20,000 grains of soil, and 1·55 grains remained in the liquid after three days' contact with it. 1000 grains of this soil thus absorbed only ·0905 of a grain of ammonia.

There can be no doubt that a stronger solution of ammonia passed through Mr. Mechi's soil would have parted with a much larger proportion of ammonia than in the present experiment. A distinct proof, then, is here afforded that soluble manuring matters—like ammoniacal salts in contact with soil—are not rendered entirely insoluble. In this experiment we have the most favourable condition for the complete absorption of ammonia, yet nearly one-half of the ammonia is left in the liquid after contact with the soil: thus showing plainly that the compounds which we cannot doubt are formed in clay soils, when soluble compounds of ammonia are brought in contact with them, are still to some extent soluble in water. This fact explains likewise the different results which are obtained in ascertaining the absorptive properties of soils for ammonia when limited quantities of strong or very dilute solutions of ammonia are employed in such experiments. If, therefore, 1000 grains of soil absorb in one particular experiment say ·55 of a grain of ammonia, it does not follow that this quantity expresses the maximum proportion of ammonia which that soil is capable of taking up.

3. In conformity with other experiments, a larger proportion of lime was found in the filtered liquid manure than in the liquid before coming in contact with the soil.

4. The proportion of magnesia and sulphuric acid in the filtered liquid likewise is larger than in the original manure.

4. It will be noticed that the amount of potash and chloride of potassium in the Tiptree liquid manure is very small. Instead of diminishing, when brought into contact with soil, as in all the other experiments, the amount of potash in a gallon of the liquid manure left in contact with soil for three days was larger than in the liquid before coming in contact with the soil. It thus appears that the soil contained, like most clay soils, abundance of alkaline silicates, which yielded to liquid manure a certain small amount of potash and also of soda, in addition to the alkalies naturally contained in the manure.

5. In conclusion, I would notice that the proportion of phosphoric acid in the liquid manure, after contact with this soil, is very nearly the same as that contained in the original liquid. Scarcely any absorption of phosphoric acid thus took place, or, perhaps, more correctly speaking, the compounds of phosphoric acid which are formed in the soil are so inconsiderable in amount that there is sufficient water in a gallon of liquid to keep them nearly entirely in solution.

CONCLUSIONS.

With a view of saving trouble to readers who are not disposed to go through all the chemical evidence contained in the preceding pages, I briefly notice in conclusion the chief points of interest which may be gathered from this account of my experiments.

1. Liquid manure, in contact with soil, undergoes a number of chemical changes.

2. These changes are greater in the case of clay and calcareous soils than in the case of sandy soils.

3. Passed through clay, loamy, and calcareous soils, liquid manure leaves a considerable quantity of ammonia in the soil.

4. Under the same circumstances, liquid manure parts likewise with potash and phosphoric acid.

5. Sandy soils remove from liquid manure but little ammonia and likewise not much potash.

6. With the exception of purely sandy soils, liquid manure, as used in practice, leaves the greater portion of all the most valuable fertilizing matters in the generality of soils.

7. The comparative power of different soils to remove ammonia, potash, and phosphoric acid from liquid manure differs greatly.

8. Liquid manure passed through sandy soils rich in soluble silica takes up soluble silica.

9. Soils that absorbed much ammonia also absorbed much potash, and the soils which absorbed little ammonia also absorbed little potash.

10. Soda-salts (common salt) are either not at all removed from liquid manure or only to a small extent.

11. Chlorine, and generally sulphuric acid, remain unaltered in quantity in liquid manure passed through different soils.

12. In most cases, liquid manure left in contact with different soils becomes richer in lime.

13. The proportion of lime which liquid manure takes up from the soils with which it is brought in contact does not altogether correspond with the relative proportions of lime in the different soils.

14. Liquid manure, passed through a sandy soil greatly deficient in lime, became poorer in lime: thus showing that the property of soils of storing up food for plants is not confined to ammonia, potash, or phosphoric acid; but that it is a property which manifests itself in a variety of ways. Thus, soils rich in lime yield this substance to liquid manure; soils in which lime is deficient may abstract it from liquid manure. Again, potash usually is removed from liquid manure left in contact with soil; but, in particular cases, liquid manure may even become richer in potash after filtration through soil.

15. Very soluble saline fertilizing compounds are probably injurious to vegetation when supplied too abundantly to the land.

16. All moderately fertile soils have the power of rendering the more important soluble fertilizing matters much less soluble; but in none of the experiments were ammonia, potash, phosphoric acid, and other compounds that enter into the composition of the ashes of our cultivated crops, rendered perfectly insoluble.

17. It does not appear probable that plants take up mineral food from the soil in the shape of totally insoluble combinations.

Royal Agricultural College, Cirencester.

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ANBURY;

AND THE

ANALYSIS OF DISEASED TURNIPS.

By Dr. AUGUSTUS VOELCKER.

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ANBURY; AND THE ANALYSIS OF DISEASED TURNIPS.

It is well known that turnips grown upon light sandy soils are much more frequently affected by "Anbury," or "fingers and toes," than roots grown on stiffer land, containing a fair proportion of the four chief components of all soils—clay, lime, sand, and vegetable matter.

The cause of these disorders in the turnip-crop is justly referred in most instances to the absence or insufficiency of lime in light sandy soils; hence the manifest benefit with which lime, chalk, marl, shell-sand, and other calcareous manures are used as preventives of this and similar diseases in turnips on such soils.

But, at the same time, it must not be supposed that the absence or deficiency of lime in land is *always* the cause of fingers and toes in turnips, and that liming is a *universal* preventive of this disease. In proof of this, I may observe that not long ago I examined a soil which contained plenty of lime, and yet produced diseased turnips; and also that I have seen fingers and toes in roots grown on calcareous soils, probably containing from 30 to 40 per cent. of lime. If it be remembered that the ash of turnips contains some ten or twelve different kinds of inorganic matter, it will not appear strange that the absence of available potash, or the insufficiency of phosphoric acid, or the want of sulphuric acid in the soil, may produce diseased turnips as well as the deficiency of lime. There can be no doubt that we should know much more respecting the causes of the increasing failures in turnips than we do at present, if we were less apt to take things for granted, and were more inclined to examine a great number of cases, even at the risk of adding nothing more to our existing stock of information on the subject. Viewed in this light every well-authenticated case of disease in turnips must have some interest to the botanist and the agricultural chemist.

I therefore gladly availed myself of an opportunity of inspecting a crop of turnips affected by Anbury in the most extraordinary degree. A brief account of the case, and the subsequent examination of the soil and evils to which it led, may, I trust, not be altogether void of interest to the agricultural reader.

The instance just referred to occurred on a farm at Ashton-Keynes, a village about six miles from Cirencester. On visiting the farm, Mr. Plumbe, the occupier, directed my attention to a field of considerable extent on the slope of a hill. Surrounded by a tract of country visibly abounding in limestone-gravel, the field on the slope and top of the hill presented a striking contrast, even to a superficial observer, with the fields at the base of the hill. These were moderately stiff, full of limestone-gravel; and the root-crops on them looked healthy, promising a fair average yield. The elevated field in question, on the contrary, was sandy in the extreme; apparently contained but little clay, no limestone-gravel whatever, and the turnips on it were affected by Anbury to such an extent as I never witnessed before. There was hardly a sound turnip to be seen, except on two isolated spots, to which I shall refer presently. With this exception, the whole of the roots were so much injured by the disease that it was not considered worth while to send sheep over the field. The young plants came up well, I was informed, looked remarkably strong and healthy up to the time of singling—so much so, that a very fine crop was confidently expected. However, soon after, the crop made no progress, and the roots on inspection were found to be all more or less attacked. At the time of my visit they presented a most extraordinary appearance, being forked and twisted into the most fantastical forms, and covered with wart-like excrescences; exhibiting thus the characters of Anbury in its most malignant form.

Part of the field was covered with a brownish-coloured sandy soil, part with a red-coloured ferruginous soil. I examined both on the spot, and prepared a well-mixed sample of each, as well as of the subsoil on which the red-coloured soil rested.

The subsequent chemical analyses of these three soils, dried at 212° Fahrenheit, yielded the following general results:—

	No. 1.	**No. 2.**	**No. 3.**
Organic matter and water in combination	5·36	4·82	7·64
Oxides of iron and alumina	5·78	12·16	22·77
Carbonate of lime	·25	·15	·44
Alkaline salts and magnesia	·41	·46	·69
Phosphoric acid	traces.	traces.	traces.
Sulphuric acid	·08	not determined.	
Insoluble siliceous matter (chiefly sand)	88·12	82·41	68·46
	100·00	100·00	100·00

No. 1 was taken from the top of the hill, where the turnips were most affected by Anbury.

No. 2 was a red-coloured soil from the slope of the hill, where the turnips were likewise much diseased.

No. 3 is a deep red-coloured ferruginous subsoil on which No. 2 rests.

In this subsoil, it will be noticed, there is a great deal of oxide of iron, a constituent which is likewise more abundant in No. 2 than in No. 1.

The amount of lime in all three is very trifling: in the surface soils, especially, it is totally inadequate to meet the requirements of a crop of turnips. We cannot doubt, therefore, that the deficiency of lime in these soils has been the principal cause of the failure of the root-crop on this field.

That lime might have been applied to this field with great success will appear from the following interesting circumstance with which I became acquainted on my visit to this farm. When walking over the field, Mr. Plumbe directed my attention to an isolated spot, not many square yards in extent. On this spot the turnips, though by no means large, were nearly all sound. On stooping down and examining the soil, I picked up some bits of whitish-looking substance, which appeared to me like dried gas-lime, and I learned afterwards that on this very spot a cart of gas-lime had been unloaded the year before. Mr. Plumbe likewise pointed out to me a spot in the corner of the field: here, likewise, the roots looked quite healthy, scarcely one diseased turnip being seen.

I took samples from both spots with me, and submitted them to analysis.

Dried at 212° Fahrenheit, 100 parts of each yielded the following results:—

	No. 1.	**No. 2.**
Organic matter and water in combination	4·15	4·24
Oxides of iron and alumina	4·01	4·98
Carbonate of lime	1·77	·93
Alkaline salts and magnesia	1·12	·69
Insoluble siliceous matter (chiefly sand)	88·95	89·16
	100·00	100.00

No. 1 is the soil from the spot on the field where gas-lime was distinctly visible.

No. 2 is the soil from a corner of the field where the turnips were quite sound.

It will be seen that in No. 1 there was a good deal of lime in the shape of gas-lime, and that in No. 2 there was also much more lime than in the rest of the field where the root-crop failed entirely.

The larger amount of lime in the soil taken from the corner of the field is probably due to a dungheap, which in previous years had been set up on this spot. As all the other fields on this farm abound in lime, the manure produced on this farm naturally must contain more lime than is found in farmyard manure made in districts where lime is less abundant in the soil than in localities where oolitic rocks abound.

I may state, in conclusion, that I have analysed one of the most diseased roots, and also separated the body, or more uniform portions of another root, from the finger-and-toe like excrescences.

The whole root, affected very much by Anbury, yielded the following results:—

	In natural state.	Calculated dry, (dried at 212° F.)
Moisture	88·02	..
*Protein compounds (flesh-forming matters)	3·56	29·55
Cellular fibre	3·27	27·29
Sugar, gum, pectin, and indigestible fibre ..	3·67	30·79
Inorganic matters (ash)	1·48	12·37
	100·00	100·00
* Containing nitrogen ..	·57	4·76

The more uniform portion, or the body of the second root, gave:—

	In natural state.	Calculated dry, (dried at 212° F.)
Water	89·50	..
*Protein compounds (flesh-forming matters)	2·34	22·37
Non-nitrogenized substances (heat producing principles)	7·13	67·77
Mineral matters (ash)	1·03	9·86
	100·00	100·00
* Containing nitrogen ..	·37	3·58

The finger-and-toe like excrescences of the same root gave:—

	In natural state.	Calculated dry, (dried at 212° F.)
Water	86·70	..
*Protein compounds (flesh-forming matters)	3·96	29·81
Non-nitrogenized substances (heat-forming principles	8·06	60·56
Mineral matters (ash)	1·28	9·63
	100·00	100·00
* Containing nitrogen ..	·63	4·77

Compared with sound turnips, the diseased roots are much richer in nitrogen and in mineral matters. It will be noticed that the root which was most affected by Anbury contained nearly the same proportion of nitrogen which was found in the finger-and-toe like excrescences of the second root. This is more than double the quantity of nitrogen which is contained in sound roots. I may observe, in passing, that I have been occupied for some years past with the examination of roots, and invariably find that roots which practical men pronounce to be worthless, or very poor, contain much more nitrogen than roots which are highly esteemed for their nutritious and fattening properties. But I must not enlarge on this matter at present. As I shall probably be occupied for several years with researches into the composition of turnips, before they are in a sufficiently advanced state for publication, I thought it desirable to mention in the mean time that *no greater error can be made in practice than to estimate the feeding value of turnips by the amount of nitrogen which different sorts contain.*

Royal Agricultural College, Cirencester,
June, 1859.

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ON THE

COMPOSITION OF A MANGOLD-WURZEL KEPT FOR TWO YEARS.

By DR. AUGUSTUS VOELCKER.

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MANGOLD-WURZEL.

SOME time ago Mr. Farmer of Fazeley exhibited to the Council a mangold-wurzel, which was grown by him and stored in 1857, and again stored amongst other roots in 1858. When examined in May, 1859, it was found apparently quite sound. It thus kept apparently healthy for about two years.

It was conceived that the analysis of this root might be of some interest, and I therefore submitted it to a careful and detailed analysis. The following is the general analysis of this root:—

	In natural state.	Calculated dry. Dried at 212° Fah.
Water	92·25	—
Soluble organic matter	3·27	42·32
Soluble mineral matter	1·23	15·87
Insoluble organic matter	3·12	40·16
Insoluble mineral matter	·13	1·65
	100·00	100·00

The more minute examination of the same root yielded the subjoined analytical results:—

Detailed Composition.

	In natural state.	Calculated dry. Dried at 212° Fah.
Water	92·25	—
*Soluble protein compounds	·97	12·51
Sugar, gum, and pectin	4·08	52·67
Soluble inorganic salts	1·23	15·87
†Insoluble protein compounds	·16	2·06
Woody fibre (cellulose)	1·18	15·22
Insoluble mineral matter	·13	1·67
	100·00	100·00
*Containing nitrogen	·155	2·00
†Containing nitrogen	·025	·32
Total nitrogen	·18	2·32

The juice of this root had a specific gravity of 1·022. The preceding analytical results suggest the following remarks:—

1. It will be noticed that the proportion of water in this root is very much larger than in roots of fair average quality. Indeed there is fully as much water in this root as in common white

turnips. In good mangolds the proportion of water amounts to 88 or 89 per cent., and sometimes is even lower than 88 per cent

2. The proportion of mineral matter or ash in this root likewise is very large, it being much more considerable than in good mangolds.

3. It will be noticed that nearly the whole of the mineral matter consists of soluble salts. As the root tasted rather saltish, I thought it worth while to determine the amount of common salt in it, and was surprised to find no less than ·64 of a grain of common salt in the root in its natural state, or 8·25 grains in the dried root. More than half of the soluble mineral matter found in this root therefore consisted of salt. In the growth of the mangolds, of which the root examined by me was a specimen, much salt was evidently employed as a manure.

4. The proportion of nitrogen in the root is rather above the average.

The legitimate conclusion that can be deduced from these observations is that this root, although apparently sound, has undergone some changes, which have deteriorated its feeding qualities. It is, however, no doubt still sufficiently well preserved, and contains sufficient nutritive matter to be given to cattle with great advantage.

I may observe that I have examined roots late in the season, after having been stored for seven months, and that in these roots I have always found less water, sometimes considerably less than in the roots at the time when they were stored in autumn.

The large quantity of water (92 per cent.) in the root which has been kept for two years, is larger than in the worst grown mangolds taken fresh from the field. There cannot therefore remain much doubt that keeping for two years has had an unfavourable effect upon the constitution of this root.

Again, the large amount of mineral matter in this mangold appears to me to indicate that probably a considerable quantity of the dry organic matter has entered into fermentation and escaped in a gaseous state. We know that roots put in heaps ferment, and also that every kind of fermentation if prolonged for any considerable time is accompanied with loss of substance. The fact that this mangold wurzel contained a great deal of ash, seems to me to imply that the fermentation in this case has been attended with considerable loss in feeding substances. The mineral portion cannot escape by evaporation, nor is it affected by fermentation; in the measure therefore in which the organic portion of the root diminished, that of the mineral portion must have increased.

It is to be regretted that a number of mangolds of the growth of 1857 were not weighed and one or two examined at the time when the crop was stored away, and again weighed and analysed at the end of the first year's storage, and also at the end of the second year. We might then have traced more definitively the changes in the root, which I feel assured have taken place. This is a subject well worthy the notice of root-growers; for it must be a matter of considerable interest to practical men to know how long mangolds can be stored without suffering injury, and it is likewise of importance to determine by precise experiments by what time stored roots have acquired their maximum feeding properties.

Although I am of opinion that it is bad policy to keep mangold for two years, it is still an interesting fact that this mangold could be kept apparently sound for so long a time. The question arises:—Do all mangolds when properly stored keep equally well? I confess that I doubt this, and am inclined to think that the large quantity of salt in this mangold may have had some share in preserving the root. Should it be found that mangolds manured with salt keep much better than roots without salt, additional inducement is offered to the farmer not to stint his mangold in salt. This leads me in conclusion to express the opinion that the character of the manures which are used for mangolds has a material influence on their composition, which no doubt must affect likewise their keeping qualities.

In the absence of precise information and experiments, I abstain from further speculating on this subject, and allude to it here mainly for the purpose of showing how desirable it is that the whole question should be thoroughly investigated. This, I believe, can only be done properly by a systematic series of practical and analytical experiments.

Royal Agricultural College, Cirencester.

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ON THE

COMPOSITION AND NUTRITIVE VALUE

OF

COTTON-CAKE.

BY AUGUSTUS VOELCKER.

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REPORT

ON THE

COMPOSITION AND NUTRITIVE VALUE OF COTTON-CAKE.

AN important addition to our stock of feeding materials has recently been made in the shape of cotton-cake. This cake can now be bought according to its quality, at from 6*l.* to 8*l.* per ton, and appears to offer considerable economic advantages to the feeder of stock in comparison with other descriptions of cake. Several agriculturists, who have used it in limited quantity, speak favourably of its nutritive properties, but precise comparative feeding experiments are yet required before the practical value of cotton-cake, and its relative merits, in comparison with linseed and other descriptions of cake, can be determined with certainty. To my knowledge it is now being tried on a large scale in various parts of this country, and ere long we may hope to obtain the desired information. We shall then be able to ascertain how far the theoretical value of cotton-cake, as deduced from analysis, corresponds with its practical effects on the system.

This cake is obtained on submitting to strong pressure the oily seeds of the cotton plant (*Gossypium barbadense*), which, as is well known, is cultivated extensively in the southern part of the United States, in India, China, the interior of Africa, and other warm climates.

Cotton-seed yields a dark brown coloured, semi-liquid, and agreeably smelling oil, which, in a purified state, is now used to some extent for the usual purposes for which other kinds of oil and fats are employed. The removal of the dark colour which the oil possesses in a raw state appears to be attended with considerable difficulties, which as yet have only been partially overcome. This perhaps will account for the fact that even now large quantities of cotton-seed are annually thrown aside as useless, or are used to some extent as a manure. However the production of cotton-seed oil has been steadily increasing, and large importations into England of cake, chiefly from St. Louis and New Orleans, have been effected during the past season. It may be confidently expected that the practical difficulties that stand in the way of the purification of the oil will soon be removed, and there can be but little doubt that then a constant and large supply of cotton-cake will be furnished to the English feeder of stock.

The first cargoes of cotton-cake were imported into England some years ago, but the trials of it were not very successful. This need not surprise, for the introduction of every new article into the market is beset with difficulties. Perhaps the partial failures that attended the use of the early shipments of cotton-cake arose from the crude methods of preparing it, and the inferior, half-spoiled state in which it was given to animals. Probably the first cargoes that were brought to England found no immediate purchasers; the cake had to be warehoused for a considerable length of time, during which it got mouldy by damp air, sour, and unpalatable, before it found its way into the feeding stall. Even now some cotton-cake is so mouldy and sour that it is hardly fit to be given to animals. But there is another reason for the unfavourable opinion entertained by those who tried the practical feeding value of this cake when first imported into England. The albuminous soft kernel of cotton-seed is encased in a hard, dark-coloured shell, composed chiefly of woody fibre, and as the hard shell constitutes a large proportion of the whole seed, and woody fibre possesses little or no feeding value, all the cake that reached this country some years ago being made of the whole seed, was of inferior quality, in comparison with linseed or even rape-cake.

I remember having analysed a sample of cotton-cake of this description four years ago. It contained only 5½ per cent. of oil and more than 30 per cent. of woody fibre.

Such inferior cake is still prepared in the United States as well as in England. The cake, however, made in this country from the whole cotton-seed is, I find, superior to the similarly prepared cake of foreign make.

For the last year or two a very much better article has been sent over from the southern parts of the United States. It is prepared from the shelled or decorticated seed, and is sold at present as decorticated cotton-cake at 7*l.* to 8*l.* per ton, or at about 1*l.* to 30*s.* more than the ordinary cake made of the whole seed. It occurs in commerce in two forms, namely, as thin and as thick cake. The latter, on account of the inconvenience which it presents to the consumer (as it is not readily crushed by ordinary oil-cake crushers), is reduced to a coarse powder by an American firm, who are large importers of both thin and thick decorticated cake. The coarse powder is sent to England in original bags, which are marked "Patent Kiln-dried Oil-meal," and also bear the name and address of the exporter.

We have thus, as far as I know, the following four varieties of cotton-cake offered for sale in the English market:—

1. *Thin decorticated cotton-cake.*
2. *Thick decorticated cake.*
3. *Ordinary cake made of whole seed.*
4. *Oil-meal.*

Having analysed recently samples of each kind, I now beg to lay before the readers of the Journal the results of my examinations, and to accompany the analytical data by a few observations that may assist intending purchasers in selecting for themselves the best description of cotton-cake. No other description of cake is subject to so great variations in composition as cotton-cake. In practical feeding experiments it is therefore most desirable that the composition of the cake should be stated, or at any rate the kind of cake be accurately described.

The following results plainly show that cotton-cake has been sold this year in England which is more than twice as nutritious and fattening as other samples. Those who have been fortunate enough to secure the best decorticated cake I doubt not will be led by their experience to consider it a most valuable feeding substance, whilst the experience of buyers of inferior cake, made from the whole seed, must lead to a much less favourable practical opinion.

1. THIN DECORTICATED COTTON-CAKE.

This cake, as mentioned already, is made from the shelled seed. It has about the same thickness and shape as American linseed-cake, but differs from the latter in outward appearance and in composition. The best decorticated cotton-cake has a light yellow colour, and is free from any strong smell; neither has it any well-defined taste. It shows here and there a few threads of cotton fibre, and contains very little of the dark-brown coloured seed-shells. Mixed with water, in a roughly powdered state, it does not become gelatinous like linseed-cake, nor does it develop any pungent smell under this treatment like rape-cake.

Cotton-cake does not contain any large amount of mucilage, nor anything that produces on mixing with water a volatile, pungent, and injurious essential oil.

Cattle often take at once to it, and even when fed upon linseed-cake they soon get accustomed to the taste of cotton-cake, and apparently eat it as readily as linseed-cake.

In the following Table I have incorporated the results obtained in the analysis of seven samples of decorticated cotton-cake :—

COMPOSITION OF DECORTICATED COTTON-CAKE (THIN CAKE).

—	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Water	7·67	8·27	9·01	10·37	10·01	9·41	10·19
Oil	14·93	19·19	17·93	13·98	17·21	15·64	13·50
* Albuminous compounds (flesh-forming principles)	43·21	42·62	41·81	40·68	40·48	42·75	37·18
Gum, mucilage, sugar, and digestible fibre (heat-producing matters)	14·47	12·25	13·67	18·88	18·09	14·83	22·97
Cellulose (indigestible fibre) ..	11·45	10·12	8·80	9·01	6·67	7·71	8·71
† Mineral matters (ash)	8·27	7·45	8·78	†7·08	7·54	9·66	7·45
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	6·91	6·82	6·69	6·58	6·47	6·84	5·95
† Containing sand	Not determined.			·68	1·53	Not determined.	·46
,, earthy phosphates	..	..	..	..	..	..	4·27
,, alkaline salts, including phosphoric acid	..	..	..	..	..	..	2·77 ·82

These analytical results suggest the following observations :—

1. The proportion of oil in all the samples analysed is higher than in the best linseed-cake. In the best linseed-cake the percentage of oil rarely amounts to 12 per cent., and 10 per cent. may be taken as a fair average. As a direct supplier of fat, cotton-cake therefore is superior to linseed-cake.

2. The amount of oil in samples sold under the same name is subject to considerable variations. In the oiliest cake, No. 2, there is 19·19 per cent., and in No. 7 only 13·50 per cent. of oil. The greatest difference in these cakes in this respect thus amounts to about 5½ per cent.

3. Decorticated cotton-cake contains a very high and much larger percentage of flesh-forming matters than linseed-cake. This circumstance suggests that cotton-cake may probably be given with great advantage to young stock and to dairy cows. As by far the largest proportion of nitrogen of food is not assimilated in the system, but passes away with the excrements of animals, the dung produced by stock fed upon cotton-cake will be found particularly valuable.

4. In comparison with linseed-cake there is much less mucilage and other respiratory matter in cotton-cake. This deficiency,

however, is compensated to a certain degree by the larger amount of oil in cotton-cake.

5. The proportion of indigestible woody fibre in decorticated cotton-cake is small, and not larger than in the best linseed-cake.

6. Lastly, it may be observed that the ash of cotton-cake is rich in bone-materials, and amounts to about the same quantity as that contained in other oil-cakes.

On the whole I am inclined to think, as far as I am able to judge on the strength of the preceding analytical indications, that the best decorticated cotton-cake possesses theoretically about the same nutritive value as linseed-cake. Cotton-cake, of average quality, is probably somewhat inferior to linseed-cake of average composition.

The physical condition of all the cakes, with the exception of No. 4 and No. 7, was excellent. No. 7 was not quite so fresh as the majority of the cakes, whilst No. 4 was decidedly an old badly-kept cake. It was very mouldy, and tasted quite sour, and appeared hardly fit to be given to animals. Cows and sheep refused at first to eat it, but pigs eagerly devoured it. After some time, however, both sheep and fattening cows took to it, and notwithstanding its sour taste and bad condition, I am informed, did well upon it.

I refer here to the condition of cake, because an analysis does not generally indicate whether a cake is new or old, well or badly kept, or otherwise injured. It is important to bear this in mind, for there can be no doubt that animals will thrive better when fed upon fresh and sweet than upon old, mouldy, or sour cake.

The preceding seven analyses, on calculation, yield the following average numbers, expressive of the *average* composition of thin decorticated cotton-cake:—

Water	9.28
Oil	16·05
* Albuminous compounds (flesh-forming matters)	41·25
Gum, mucilage, sugar, and digestible fibre (heat-producing materials)	16·45
Cellulose (indigestible fibre)	8·92
Mineral matters (ash)	8·05
	100·00
* Containing nitrogen	6·58

2. Decorticated Cotton-cake (*Thick cake*).

This cake is from 2½ to 3 inches thick, but does not otherwise differ materially in its outward appearance from thin cake. It is very hard, and cannot be broken into small bits by ordinary cake-crushers, and for this reason does not command so ready a sale as the thin cake, although it is sold at 10*s.* to 15*s.* less money.

Two samples of thick cake, both imported into Liverpool, yielded on analysis the following results :—

Composition of Decorticated Thick Cotton-cake.

	No. 1.	No. 2.
Water	10·25	9·08
Oil	14·05	19·34
*Albuminous compounds (flesh-forming matters) ..	41·31	43·31
Gum, mucilage, and digestible fibre (heat-producing substances)	18·05	10·48
Indigestible fibre	8·40	10·41
Mineral matters (ash)	7·94	7·38
	100·00	100·00
* Containing nitrogen	6·61	6·93

It will be observed that there is no perceptible difference in the composition of thick and thin cake. In both the thick cakes, being very hard pressed, I expected to find a smaller percentage of oil than they actually contained. I was particularly surprised to find in the second cake quite as high a percentage of oil as that contained in the richest thin cake I have had an opportunity of examining. Fearing a mistake might have occurred in the oil-determination, I had a second determination made, which yielded nearly the same quantity, namely, 19·05 of oil. The oil, extracted by means of ether from thick cake, I observed, presented a darker colour than the oil from the majority of the thin cakes, which seems to indicate that more heat has been employed in pressing the thick cake.

3. ORDINARY COTTON-CAKE MADE FROM THE WHOLE SEED.

Cake made of the whole cotton-seed presents a much less inviting appearance than the thin cake; it has a dark-brown colour, is full of hard, dark-coloured seed-shells, is not liked so much by cattle as thin cake, and is altogether a cake of inferior quality.

Some of this cake is prepared in England from imported cotton-seed. The English pressed cake is better than foreign made cake of the same kind. Three samples of this cake furnished on analysis the following results :—

COMPOSITION OF ORDINARY COTTON-CAKE MADE OF WHOLE SEED.

—	No. 1.	No. 2.	No. 3.
Moisture	10·53	12·03	11·46
Oil	6·10	6·37	6·07
* Albuminous compounds (flesh-forming principles)	22·62	25·62	22·94
Gum, mucilage, sugar, and digestible fibre (heat-producing compounds)	26·48	29·90	36·52
Indigestible woody fibre	26·96	19·79	16·99
† Mineral matters (ash)	7·31	6·29	6·02
	100·00	100·00	100·00
* Containing nitrogen	3·62	4·10	3·67
† Containing sand	1·76	·91	..
,, earthy phosphates	3·83	..	..
,, alkaline salts	1·72	..	..

On comparing the composition of these cakes with the average composition of decorticated cake it will be seen :—

1. That the proportion of oil in the common cake is very much smaller than in the decorticated cake. The amount of oil is in reality inconsiderable, since most other oil-cakes, such as linseed, rape, poppy, and others, contain a good deal more fatty matter.

2. In decorticated cotton-cake there is a much higher percentage of albuminous compounds.

3. On the other hand, the proportion of indigestible fibre in ordinary cotton-cake is far more considerable than in decorticated cake.

Common cotton-cake is sold at a lower price than the decorticated cake, but, considering the inferior character of the former, its lower price offers little inducement to intending purchasers. A ton of the best decorticated cake, I am inclined to think, is worth quite as much as two tons of the inferior cake made of the whole seed. I consider the latter dear at the price at which it is sold.

The first sample of the three contained much more woody fibre than the two others. I may observe, however, that the proportion of woody fibre mentioned in the analyses of these cakes does not indicate the amount of seed-shells. What is here called indigestible woody fibre was obtained by treating the cake with cold and boiling water, and subsequently with dilute potash solution and dilute sulphuric acid. By these means the albuminous compounds, pectinous matters, and other constituents of the seed-shells are rendered soluble, and the insoluble residue is conceived to be indigestible cellular fibre.

I have endeavoured, approximately, to determine the proportion of shells in the first cake. As the shells are reduced to powder only with great difficulty, whereas the kernel powders readily enough, the proportion of the former may be ascertained with tolerable accuracy by carefully grinding the cake in a stone mortar, and sifting off the hard shells. Proceeding in this way, I found in No. 1, 58·42 per cent. of shells. This is a great deal more than the average amount of seed-shells in cotton-cake made of the whole seed. It appears to me, therefore, not unlikely that this cake contained an additional quantity of shells beyond that which cotton-seed in its raw state naturally furnishes. In the manufacture of decorticated cake large quantities of shells must be obtained, and it is not unlikely that these shells, with the addition of a little good cake, are pressed into an inferior cake. No. 2 and No. 3 were cakes made in England; they are better cakes than No. 1.

4. OIL-MEAL.

It has been already mentioned that, on account of the difficulty which the consumer experiences in crushing the thick cake, the manufacturers of this article break up the cake into a coarse powder. This is afterwards kiln-dried, and brought into commerce under the name of patent kiln-dried oil-meal. Two specimens of such oil-meal gave on analysis the following results:—

Composition of Patent Kiln-dried Oil-meal.

	No. 1.	No. 2.
Moisture	9·40	10·21
Oil	17·39	19·71
* Albuminous compounds (flesh-forming matters) ..	43·81	40·25
Gum, mucilage, sugar, and digestible fibre (heat-producing substances)	11·21	16·38
Indigestible woody fibre	10·44	5·84
Inorganic matters (ash)	7·75	7·61
	100·00	100·00
* Containing nitrogen	7·01	6·44

Oil-meal, if genuine, it thus appears, is identical in composition with the best decorticated cotton-cake.

No. 2, it will be seen, contained nearly 20 per cent. of oil, which is more than I ever found before in any kind of oil-cake.

The process of kiln-drying is resorted to for the purpose of preserving the meal in good condition. It imparts to the cake a peculiar and by no means unpleasant flavour, which is said to be much liked by cattle.

On the whole, oil-meal, when genuine, and of as good a quality as the two specimens analysed by me, presents a handy form of supplying cattle with decorticated cotton-cake; and as it is, moreover, cheaper than the thin cake, its use for feeding purposes is not only more convenient, but likewise more economic, than that of thin cotton-cake.

There is, however, a certain degree of danger in buying a powder, for rubbish of various sorts may be mixed with the meal by unprincipled dealers. But, on the other hand, the respectability of the dealer and chemical analysis afford the means of preventing this species of fraud.

As decorticated cotton-cake is likely to be extensively used for feeding purposes, I have thought it advisable to submit the mineral constituents which it furnishes on burning to a detailed examination.

The following results were obtained in my laboratory by my friend and pupil Mr. Gardner, of Shrewsbury, on analysing the ash prepared from several samples of decorticated cake:—

Average Composition of the Ash of Decorticated Cotton-cake.

Potash	39·045
Soda	none
Chloride of sodium	none
Lime	3·750
Magnesia	13·500
Oxide of iron	1·530
Phosphoric acid	39·649
Sulphuric acid	·930
Carbonic acid	·362
Soluble silica	3·252
Insoluble silicious matter (sand)	17·706
	99·724

Like other oily seeds, cotton-seed contains, it will be seen, a considerable quantity of phosphate of magnesia. In addition to these compounds it contains phosphate of lime and phosphate of potash, and other salts of potash.

The proportion of phosphoric acid in cotton-cake ash is very large, and that of potash likewise is considerable. Soda does not enter into the composition of the ash. For the purpose of supplying animals with bone-materials, it is a very valuable kind of food.

CONCLUSION.

The principal points of interest, in reference to cotton-cake, are collected together in the following short summary:—

1. The best cotton-cake is richer in oil and albuminous (flesh-forming) compounds than linseed-cake, but contains less mucilage and other respiratory constituents.

2. The mineral portion of cotton-cake resembles closely in composition that of linseed and other oil-cakes. Like the ash of all cakes, it is rich in earthy and alkaline phosphates, and well adapted to supply animals with bone-materials.

3. As far as the indications of chemical analysis can be depended on, the best decorticated cotton-cake possesses about the same nutritive value as linseed-cake.

4. At the present time four distinct kinds of cotton-cake are offered for sale in the market, namely:—

1. Thin decorticated cotton-cake.
2. Thick decorticated cake.
3. Common cake made of the whole seed.
4. Oil-meal (No. 2 reduced to coarse powder).

5. The thin decorticated cake is a far better and more economic food than the ordinary cake, which is often quite unfit for feeding purposes.

6. Thick cake scarcely differs in composition from thin cake, but being hard, and 2½ to 3 inches thick, it cannot be crushed by an ordinary oil-cake crusher, and therefore presents inconvenience to the consumer.

7. Genuine oil-meal is simply thick decorticated cake reduced to a coarse powder, and of course has the same composition as the cake from which it is made.

8. The composition, and with it the nutritive value, of different samples of cotton-cake is subject to considerable variation.

9. Decorticated cotton-cake and oil-meal, in comparison with other kinds of artificial food, are decidedly cheap feeding materials, and both, no doubt, ere long, will find that favour with the British farmer which a really valuable and cheap article of consumption is certain to command.

After the foregoing pages were in type, I received a note from Mr. John Fryer, Manor House, Chatteris, enclosing a sample of cotton-cake, and giving a short account of the death of a bullock that had been fed upon the cake and upon mangolds, barley-meal, and clover-hay. Mr. Fryer enclosed the following report of the veterinary surgeon:—

"*Surgeon's Post-mortem Examination.*

"Internal and external appearance healthy, nothing inflammatory. Paunch enormously distended with food. The manifold (I speak as butchers speak) crammed and jammed full of substance like tough dough rolled hard and adhering to the folds. Lower stomach quite empty. The duodenum, for 24 inches in length, entirely blocked up with two or more pounds of the irregular-shapen concave and comminuted husks. Upon comparing them microscopically with the cake before eaten, they were found to be identical."

This report leaves no doubt about the cause of death. The distension of the first bowels was evidently caused by cotton-husks, which, I am informed, were pressed so tightly into the bowel as to give externally the appearance of stones.

On examining Mr. Fryer's cotton-cake, I found it to contain more than half its weight of cotton-husk. I am inclined to think that this cake was prepared by pressing the refuse from the manufacture of decorticated cotton-cake with a small quantity of cotton-seed.

Cakes similar to that forwarded by Mr. Fryer have been lately sent to me for examination. I am glad to have reported them unfit for feeding purposes, having suspected the hard husks of common cotton-cake as likely to do harm. Mr. Fryer's case shows that my suspicion was not altogether imaginary, and confirms the opinion expressed above respecting the feeding value of ordinary cotton-cake.

Royal Agricultural College, Cirencester,
December, 1858.

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and Charing Cross.

ON THE

COMPOSITION AND NUTRITIVE PROPERTIES

OF

MANGOLD-PULP

(THE REFUSE OF BEET-ROOT DISTILLERIES).

By DR. AUGUSTUS VOELCKER.

LONDON:
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ON THE

COMPOSITION AND NUTRITIVE PROPERTIES OF MANGOLD PULP.

IN beet-root distilleries a refuse is obtained, known by the name of Mangold-pulp. According to the method of Leplay, the fermentation is carried on in the sliced roots, and the spirit is separated by superheated steam passed through the mass in closed vessels. The residual matter left in the stills after the process of distillation is completed, is thrown aside in heaps, and the excess of water allowed to drain off, after which it constitutes the mangold-pulp.

The material from which the subjoined analyses were made was obtained from a mangold-root distillery which was established a few years ago at Minety, in Wiltshire, a village about eight miles from Cirencester. This distillery was erected by a company, formed under the Limited Liability Act, which is no longer in being. After a brief period of existence the company were obliged to wind up their affairs, the undertaking having proved a complete failure.

The method adopted by the company was that of Leplay, which method, I believe, has been entirely superseded in France by that of Champonnois. I examined at different times two samples of mangold-pulp, differing, as will be seen by the analytical results, chiefly in the amount of water which they contained respectively. The first sample, on analysis, gave the following results:—

General Composition of Mangold-pulp.

	In Natural State.	Dry.
Water	90·78	..
Soluble organic matter	2·86	30·65
Soluble mineral matter	·56	6·17
Insoluble organic matter	5·26	57·47
Insoluble mineral matter	·54	5·71
	100·00	100·00

Detailed Composition.

	In Natural State.	Dry.
Water	90·78	..
*Soluble protein compounds	·61	6·67
Gum, mucilage, a little sugar, and free acid	2·21	23·98
Soluble mineral matter	·56	6·17
†Insoluble protein compounds	·76	8·25
Crude woody fibre	4·53	49·22
Insoluble mineral matter	·55	5·71
	100·00	100·00
*Containing nitrogen	·09	1·07
†Containing nitrogen	·12	1·32

In the distillation of mangold-spirit a considerable quantity of sulphuric acid is added to the sliced mangolds. The residual pulp consequently has a decidedly acid taste, and, when obtained by Leplay's process, does not readily enter into fermentation, but remains unaltered, and fit for food for a considerable length of time. The second sample had the following composition:—

General Composition of Second Sample of Mangold-pulp.

	In Natural State.	Dry.
Water	91·84	..
Soluble organic matter	2·61	32·07
Soluble mineral matter	·38	4·75
Insoluble organic matter	4·70	57·58
Insoluble mineral matter	·47	5·60
	100·00	100·00

Detailed Composition.

	In Natural State.	Dry.
Water	91·84	..
*Soluble protein compounds	·64	7·87
Gum, mucilage, a little sugar, and free acid	1·98	24·31
Soluble mineral matter	·38	4·75
†Insoluble protein compounds	·69	8·50
Woody fibre	3·99	48·97
Insoluble mineral matter	·48	5·60
	100·00	100·00
*Containing nitrogen	·09	1·26
†Containing nitrogen	·11	1·36

The second sample thus contains about 1 per cent. more of water, but does not otherwise materially differ in composition from the first. Both samples had a greyish-white colour, and presented rather an uninviting appearance. The surface portions of a heap of the pulp turned almost black on lengthened exposure to the air.

Notwithstanding the somewhat disagreeable appearance and acid taste of the pulp, pigs from the first ate it up greedily when it was given to them unmixed with any other food. Cows and sheep at first would not touch it; on mixing the pulp, however, with clover-chaff they did not object to it, and by degrees seemed to acquire a liking for the mess.

I shall presently give an account of some feeding experiments instituted with a view to ascertaining practically the comparative fattening value of the pulp and of fresh mangold-wurzel. But as many persons entertain very erroneous opinions respecting the relative value of the different constituents of food, and their adaptation to particular purposes, and as it may be at all events interesting to most to trace the changes which mangolds undergo in the process of distillation, I shall briefly endeavour to describe these changes. We shall best comprehend this matter by comparing the composition of the pulp with that of the mangold-root from which it is made. Two specimens of yellow-globe mangolds, analysed by me some time ago, were found to contain in 100 parts:—

Composition of Yellow Globe Mangolds.

	1.	2.
Water	87·440	88·450
Sugar, gum, and soluble pectin compounds ..	7·408	7·538
Soluble mineral matters	1·356	·952
*Soluble albuminous compounds	·956	·887
†Insoluble albuminous compounds	·144	·104
Cellular fibre and insoluble pectinous compounds (crude fibre)	2·583	1·995
Insoluble mineral matters	·113	·074
	100·000	100·000
*Containing nitrogen	·153	·142
†Containing nitrogen	·023	·017
Total nitrogen	·176	·159

A comparison of these analyses with the preceding analytical results, representing the composition of pulp, will show—

1. That the proportion of water in the pulp is increased nearly 3½ per cent.;

2. That the sugar has almost entirely disappeared in the pulp;

3. That the proportion of crude woody fibre is very much larger in the pulp than in the root itself;

4. That notwithstanding the larger amount of water in the pulp, it contains more albuminous or flesh-producing matter than the mangold-roots;

5. That the roots contain more soluble albuminous matters than the pulp; and

6. That the proportion of soluble mineral matters is more considerable in the roots than in the pulp.

In short, all the soluble constituents of mangolds, more especially the sugar, are much more sparingly present in the pulp than in the root; and the insoluble matters, especially crude woody fibre, are more abundant in the pulp than in the root itself.

Since there is nearly 3½ per cent. more water in the pulp than in the root, the comparison of the pulp in its natural state with the fresh root does not bring out as strikingly the changes which mangolds experience in the distiller's hands as would be the case if both contained the same amount of water. I have, therefore, calculated the composition of the two mangold-roots in a perfectly dry state, and placed in the subjoined Table the results side by side with those which represent the composition of the two specimens of dried pulp.

Composition of Two Specimens of Mangold-wurzel and Pulp, dried at 212° F.

	Mangolds, Orange Globe.		Pulp.	
	1.	2.	1.[a]	2.[a]
Sugar, gum, and soluble pectin compounds	58·98	65·26	23·98	24·31
Soluble mineral matter	10·79	8·24	6·17	4·75
*Soluble albuminous compounds	7·62	7·68	6·67	7·87
†Insoluble albuminous compounds	1·14	·89	8·25	8·50
Cellular fibre and insoluble pectinous compounds (crude fibre)	20·57	17·28	49·22	48·97
Insoluble mineral matters ..	·90	·65	5·71	5·60
	100·00	100·00	100·00	100·00
*Containing nitrogen	1·22	1·23	1·07	1·26
†Containing nitrogen	·18	·14	1·32	1·36
Total nitrogen	1·40	1·37	2·39	2·62
Equal to protein compounds	8·76	8·57	14·92	16·37

[a] There is scarcely any sugar included in these numbers.

The preceding figures suggest the following observations:—

1. In the same state of dryness mangold-wurzel contains 2½ times as much sugar, gum, and soluble pectinous compounds as the pulp.

The average proportion of these soluble organic matters in the two roots, dried at 212° Fahr., and analysed by me, is 62·12 per cent. In the dried pulp the average of the two samples is only 24·4. There is thus a difference of 37·9, or 38 per cent. in round numbers, in favour of the mangolds.

2. On the other hand, in the same state of dryness, the pulp contains nearly double the quantity of albuminous compounds that is found in the root.

The average proportion of albuminous compounds in the dry mangolds is 8·66; in the pulp it is 15·64—thus leaving a difference of 7 per cent., in round numbers, in favour of the pulp.

3. Mangolds contain much less crude fibre than the pulp, with an equal proportion of water.

The average amount of crude fibre in the two mangolds dried at 212° Fahr. is 18·92; the mean of fibre determinations in the two specimens of pulp, 49·09. We have thus a difference of 30 per cent. of crude fibre in favour of the pulp. Minor differences which will be observed in the composition of the pulp and the root itself may be left unnoticed, for they are less striking in themselves and immaterial in a consideration of the comparative feeding value of the two substances.

A careful consideration of the differences just pointed out in the composition of pulp and roots will enable us to decide with no great difficulty:—

1. That, weight for weight, pulp similar to that analysed by me cannot possibly have the same feeding value as good mangold-wurzels.

2. That such pulp, however, is a refuse material which possesses high feeding properties.

To prove that the pulp examined by me is not equal in nutritive value to the good mangolds, I need only state that the latter were found to contain nearly 3½ per cent. more dry matter than the pulp. In materials containing so much water as exists in mangolds or pulp, this difference alone is sufficient to settle the question, whether a ton of pulp is as nutritious as a ton of mangolds. The average percentage of dry matter in the two mangolds examined by me is 12·05. A ton of mangolds therefore contains 270 lbs. of dry substance in round numbers. On the other hand, the mean of the water determinations in the two specimens of pulp is 91·31, which leaves 8·69 of solid matter in 100 parts of pulp. A ton of pulp accordingly contains 194½ lbs. of solid matter. In 1 ton of mangolds there were thus 76½ lbs. more of solid feeding-matter, or more than one-third more feeding-matter, than in 1 ton of pulp. Unless therefore the dry matters which compose the pulp are greatly superior in feeding properties, mangolds must have a decided advantage over the pulp which I analysed.

It is not difficult to prove that this is not the case. I have just pointed out that mangolds contain 2½ times as much sugar, gum, and soluble pectinous compounds. In the perfectly dry root we have 38 per cent. more of these substances than in the pulp. The latter indeed hardly contains any sugar; and I question much whether the soluble non-nitrogenised substances in the pulp have the same practical feeding value as the sugar and other soluble non-nitrogenised substances in the root itself. However, leaving the question as to the comparative value of the soluble non-nitrogenised matters of the pulp and of mangolds undecided, we have at all events 38 per cent. of fattening and very readily-digestible materials in favour of the roots. But against this must be placed the 7 per cent. albuminous compounds, and the 30 per cent. of crude fibre, which the pulp contains more than the roots. The question, therefore, would appear to resolve itself simply to this: Is 7 per cent. of albuminous compounds, and 30 per cent. of crude pulp-fibre, as valuable as 38 per cent. of sugar? But it is not really quite so simple; for, in comparing the crude fibre of the root with that of the pulp, we have assumed that both have the same feeding value; which is not the case in reality. Of the crude fibre contained in the mangold, a much smaller portion is woody indigestible fibre than in that of the pulp; for it includes insoluble pectinous compounds, which, under the action of sulphuric acid, employed in beet-root distilleries, are readily transformed into sugar, and thus rendered soluble. The fibre of the pulp, after deducting the insoluble albuminous compounds which remain attached to it, consists almost entirely of woody fibre. Weight for weight, therefore, the crude fibre of mangolds is more valuable than the crude fibre of the pulp. But even supposing the crude fibre of the pulp to be equally nutritious with the crude fibre of the root, I am not the less convinced that this 38 per cent. of soluble non-nitrogenous matters (consisting chiefly of sugar) contained in the latter will go farther in producing butcher's-meat than the 7 per cent. of albuminous compounds, together with 30 per cent. of fibre found in the former; and for this reason,—because we have already seen that the mangold in its natural state contains more than a sufficient quantity of flesh-forming or albuminous substances to meet the requirements of the animal system.

It is for these reasons that I consider mangolds more nutritious than pulp. We shall presently see how far these speculations are borne out by actual experience. I may however be permitted to combat in this place the opinion, which appears to be pretty generally entertained by French writers, that little or no feeding value is to be ascribed to sugar, and that, chiefly on this account, the pulp may be considered to be as nutritious as an equal weight of roots. In my opinion the sugar is by far the most important constituent in our root-crops; and those farmers who judge of the quality of their swedes or mangolds by the more or less sweet taste which they possess, may be satisfied that instinctively they rely on a trustworthy test.

I shall now describe the experiments which I instituted with a view of testing *practically* the relative feeding value of mangold and of pulp, the latter being the refuse of a distillery in which Leplay's system was adopted.

Eight Cotswold sheep were divided into two lots. Before the experiment began, one lot was kept for 10 days upon mangold-wurzel, clover-hay, and a little linseed-cake; the second lot was fed for the same period upon mangold-pulp, clover-hay, and a little linseed-cake. This preliminary trial was made to accustom the sheep gradually to their diet. After ten days the sheep were accurately weighed. The sheep in Lot I., fed with pulp, weighed—

Sheep No. 1	124 lbs.
„ 2	151 „
„ 3	146 „
„ 4	137 „
Total weight	558 „

The sheep in Lot II., fed upon mangolds, weighed—

Sheep No. 1	153 lbs.
„ 2	134 „
„ 3	170 „
„ 4	136 „
Total weight	593 „

The experiment began on the 22nd of March, and terminated on the 10th of May, when no more pulp could be obtained, the distillery having stopped its operations.

The first lot received per day 1 lb. of linseed-cake, 4 lbs. of clover-hay chaff, or ¼ lb. of cake, and 1 lb. of hay per sheep, and as much pulp as the sheep felt inclined to eat. The second lot received per day the same allowance of linseed-cake and clover-hay chaff as the first, with as much of sliced mangolds as the sheep could consume. Both lots were fed three times a day. At 7 o'clock in the morning Lot I. got pulp mixed with 2 lbs. of clover-hay chaff; Lot II. got sliced mangolds and 2 lbs. of clover-hay chaff. At 12 o'clock each lot received 1 lb. of crushed linseed-cake—Lot. I. mixed with pulp, Lot II. with sliced roots. The sheep were again fed at 5 o'clock in the evening; Lot I. with 2 lbs. of clover-hay mixed up with pulp; Lot II. with 2 lbs. of clover-hay mixed with sliced mangolds. In mixing the clover-chaff with pulp, sliced roots, and cake, a limited quantity of pulp and roots were used, in order to insure the entire consumption of the hay and cake; care, however, was taken to keep the feeding-troughs constantly supplied with pulp and sliced roots respectively, so that the sheep could help themselves at all times to as much pulp and roots as they liked. The pulp and mangold which were given to the sheep were of course weighed.

The following quantities of food were consumed during the whole experimental period of 7 weeks:—

Lot I., 4 sheep fed upon pulp, consumed 196 lbs. of clover-hay chaff, 49 lbs. of linseed-cake, 34 cwts. 2 qrs. 21 lbs. of mangold-pulp.

Lot II., 4 sheep fed upon mangolds, consumed 196 lbs. of clover-hay chaff, 49 lbs. of linseed-cake, 33 cwts. 1 qr. 19 lbs. of mangolds.

It will be observed that the sheep in the first lot consumed 1 cwt. 30 lbs. more pulp than the quantity of roots eaten by the sheep in the second lot. Each sheep was weighed on the 12th of April, 26th of April, and May 10th. The weight of each sheep at these periods, and their final increase, is given in the subjoined Table:—

TABLE *showing the Weight of each Sheep in lbs. at beginning of Experiment and at different times of Experimental period, and Final Increase.*

LOT. I.—*Four Sheep fed upon Mangold-pulp.*

	Put up on March 22.	April 12.	April 26.	May 10.	Increase.
	lbs.	lbs.	lbs.	lbs.	lbs.
Sheep No. 1 weighed	124	130½	133	138½	14½
,, 2 ,,	151	142	139½	148	– 3
,, 3 ,,	146	152	154½	162½	16½
,, 4 ,,	137	147	143	150	13
Total	558	571½	570	599	41

LOT II.—*Four Sheep fed upon Mangolds.*

	Put up on March 22.	April 12.	April 26.	May 10.	Increase.
	lbs.	lbs.	lbs.	lbs.	lbs.
Sheep No. 1 weighed	153	154½	164	170½	17½
,, 2 ,,	134	136½	145½	151½	17½
,, 3 ,,	170	171	181½	187½	17½
,, 4 ,,	136	140	148½	155	19
Total	593	602	639½	664½	71½

It appears thus that the 4 sheep fed upon mangold gained 30½ lbs. more in weight than the 4 sheep fed upon pulp, although the latter consumed 1 cwt. 30 lbs. more of pulp. One of the sheep in the first lot, it will be noticed, lost 3 lbs. in weight. This is due to the sheep having been affected with scouring after it had been fed for some time upon pulp. The pulp, which is very acid, is apt to produce this disorder. It ought therefore always to be given with a good deal of dry food.

These experiments, though deficient in some respects, I think still confirm sufficiently the theoretical opinion to which I have been led by the analysis of the pulp and of mangold-wurzel.

The linseed-cake used in the experiment was good American barrel-cake, and was found to contain, in 100 parts,—

Moisture	11·56
Oil	11·56
Gum, sugar, mucilage, and digestible fibre	28·47
*Albuminous compounds (flesh-forming matters) ..	26·37
Woody fibre (cellulose)	13·92
Mineral matters (ash)	8·12
	100·00
* Containing nitrogen	4·22

The clover-hay chaff continued 20·12 per cent. of water, 6·89 per cent. of ash, and 1·25 per cent. of nitrogen. Mangolds and pulp had the composition which has been given already in the preceding pages.

Although my analyses and feeding experiments have proved the pulp to be inferior in feeding properties to mangold-wurzel, I am of opinion that the pulp is a very useful feeding material, which, at 10*s.* a ton, the price at which it was sold, is certainly not dear.

I would observe, in conclusion, that more favourable results than mine have been obtained with pulp in numerous experiments carried out in France. It should be borne in mind, however, that in France, Champonnois' method of distillation has almost entirely superseded Leplay's, and that French writers expressly state that the pulp produced by Leplay's process is much inferior to the pulp of distilleries where Champonnois' system is adopted. The differences in the composition of the pulp used in my experiments and that generally produced in France may thus explain discrepancies in the results, and probably justify the opinion of several French authorities, who consider the pulp, weight for weight, to be, if not superior, at least equal in nutritive properties to mangolds.

Royal Agricultural College, Cirencester, June, 1860.

LONDON: PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
AND CHARING CROSS.

ON

THE COMPOSITION

OF

TWO VARIETIES OF KOHL-RABI

AND OF

CATTLE-CABBAGE.

By DR. AUGUSTUS VOELCKER.

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
AND CHARING CROSS.
1860.

FROM THE

JOURNAL OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND,

VOL. XXI., PART I.

ON THE COMPOSITION OF TWO VARIETIES OF KOHL-RABI AND OF CATTLE-CABBAGE.

THERE are two crops which deserve to be more extensively cultivated than they are at present: the one is Kohl-rabi, the other Cattle-cabbage. Both crops have this in common, that they are not injured by frost, provided that the young plants are not planted out too early in the spring, in which case they get over-ripe before the winter sets in, and in a rainy and warm autumn or mild winter are certain to be spoiled. If Kohl-rabi or cabbages, therefore, are intended as winter food for cows or sheep, they should not be planted out too soon, nor should the whole crop be put out at one time. When the seed has been sown and the young plants set out at proper intervals of time, a regular succession of cabbages or Kohl-rabi may be kept up as easily in the field as it is in a vegetable garden, and a supply of very nutritious and wholesome food be secured at periods of the year when other food is scarce.

Kohl-rabi especially stands the frost remarkably well. In Germany, where a small variety is grown in gardens for the table, it is not considered good until it has stood at least a week's hard frost. As food for lambs it far surpasses white turnips, and is equal to any kind of green food with which I am acquainted. With proper management it may be grown so as to come in at the lambing season; and even should the bulbs sprout abundantly and become themselves deteriorated or unfit for food, still I believe that sheep-breeders will not regret having reserved a Kohl-rabi field for the lambing season, instead of one of white turnips, because the tops and sprouts of Kohl-rabi, unlike those of the white turnip, are very nutritious. The Kohl-rabi is a plant which belongs, as most readers of this Journal are aware, to the cabbage tribe. Its leaves consequently resemble in taste, composition, and nutritive properties, those of the cabbage much more than those of the turnip, which latter are more watery and far less nutritious.

I much regret that I had no opportunity last season of obtaining the leaves of Kohl-rabi plants for analysis; but as it is my intention to examine this season a large number of bulbs of Kohl-rabi, I shall at the same time direct my attention to the composition of the leaves.

In the mean time the subjoined analysis of two varieties of

Kohl-rabi may be of some interest to those who intend to grow this crop. The bulbs were kindly supplied to me by Mr. Innes, steward to Colonel North, who was a successful grower of Kohl-rabi last year, and has formed a decidedly favourable opinion of its practical feeding value. The varieties analysed by me are known to seedsmen as the Green-top and Purple-top Kohl-rabi.

Composition of Green-top and Purple-top Kohl-Rabi.

a. *General Composition.*

	Green-top.		Purple-top.	
Water	86·020		89·002	
Substances soluble in water	9·260	Dry matter 13·98	7·588	Dry matter 10·998
Substances insoluble in water	4·720		3·410	
	100·000		100·000	

b. *Detailed Composition.*

	Green-top.	Purple-top.
Water	86·020	89·002
Oil	·227	·177
*Soluble protein compounds	2·056	2·006
Sugar, gum, and pectin..	6·007	4·486
Salts soluble in water	·970	·919
†Insoluble protein compound	·300	·269
Digestible fibre and insoluble pectinous compounds	2·993	1·896
Woody fibre (cellulose)	1·230	1·106
Insoluble mineral matters	·197	·139
	100·000	100·000
*Containing nitrogen	·329	·321
†Containing nitrogen	·048	·043
Total nitrogen	·377	·364
Percentage of ash	1·167	1·058

It must not be inferred from the preceding analytical results that purple-top Kohl-rabi is necessarily more watery than the green-top variety. My observations only apply to those bulbs which I had an opportunity of examining. A series of determinations of water in a larger number of bulbs of each kind probably would have proved that the apparent superiority of the green-top variety is not real, but due entirely to the accidental occurrence of a smaller proportion of water in the root which was submitted to me for analysis.

It is well known that the proportion of water in roots drawn from the same field and growing in close proximity to each other varies much. All that can be said, therefore, is, that the particular specimen of the green-top variety which I analysed was less watery and no doubt also more nutritious than that of the purple-top.

The following table gives the composition of these two varieties of Kohl-rabi in a perfectly dry state:—

Composition of Kohl-Rabi, dried at 212° F.

	Green-top.	Purple-top.
Oil	1·623	1·609
*Soluble protein compounds	14·706	18·239
Sugar, gum, and pectin	42·968	40·789
Salts soluble in water	6·938	8·356
†Insoluble protein compounds	2·145	2·445
Digestible fibre and insoluble pectinous compounds	21·409	17·239
Woody fibre (cellulose)	8·798	10·056
Insoluble mineral matters	1·409	1·263
	99·996	99·996
*Containing nitrogen	2·353	2·918
†Containing nitrogen	·343	·390
Total nitrogen	2·696	3·309
Percentage of ash	8·347	9·619

A comparison of the preceding results with the analyses of swedes, mangolds, and turnips, shows that theoretically Kohl-rabi is much more nutritious than white turnips, and fully equal, if not superior, to swedes and mangolds. These remarks, however, I would remind the reader, apply only to the specimens which I had an opportunity of examining. Future examinations, and, above all, practical feeding experiments, are required to establish fully the comparative feeding value of Kohl-rabi.

I may remark with respect to the Kohl-rabi, that it is an excellent food for milch-cows, inasmuch as it produces much and good milk. The butter made of such milk has a pleasant taste, altogether unlike the disagreeable flavour that characterizes butter made from the milk of cows fed upon turnips.

Composition of Cattle-Cabbage.

As yet not many complete analyses of field-cabbage have been published. I do not recollect having seen any one that could be relied on, with the exception of that by Dr. Anderson published a few years ago in the Highland Society's Transactions. It appeared to me, therefore, desirable to make a full analysis of this useful crop. The specimen examined in my laboratory was grown on the farm attached to the Royal Agricultural College, Cirencester. A preliminary trial showed that the outside leaves contained much less water than the inner, for which reason both were examined separately. The whole cabbage was divided into two parts: the one consisting of the outer green leaves, the other of the heart with the paler inner leaves attached to it.

The following tabular results represent the general composition of both parts of the cabbage:—

Composition of Cabbage-leaves (outside green leaves).

Water	83·72
Dry matter	16·28
	100·00

The Dry matter consisted of:—

		Dry Matter per Cent.
*Protein compounds	1·65	10·19
Non-nitrogenous matter	13·38	82·10
Mineral matter	1·25	7·71
	16·28	100·00
*Containing nitrogen	·26	1·63

General Composition of Heart and Inner Leaves.

	In Natural State.	Dry.
Water	89·42	..
Soluble organic matter	6·20	18·60
Soluble mineral matter	·73	6·89
Insoluble organic matter	3·53	33·36
Insoluble mineral matter	·12	1·15
	100·00	100·00

It will be observed that the outer green leaves contain nearly 6 per cent. less water than the heart and inner leaves.

In the next table the detailed composition of the heart and inner leaves together is stated both in the natural state and when dried at 212° F.:—

Detailed Composition of Heart and Inner Leaves of Cabbage.

	In Natural State.	Dry.
Water	89·42	..
Oil	·08	·75
*Soluble protein compounds	1·19	11·24
Sugar, digestible fibre, &c.	7·01	66·25
Soluble mineral matter	·73	6·89
†Insoluble protein compounds	·31	2·93
Woody fibre	1·14	10·77
Insoluble mineral matter	·12	1·17
	100·00	100·00
*Containing nitrogen	·19	1·79
†Containing nitrogen	·05	·47

Cabbages contain about the same proportions of water, sugar, and protein compound as are found in good swedes. On the whole, I am inclined to think, weight for weight, cabbages and swedes possess nearly the same nutritive value.

In ordinary seasons the average produce of swedes on our poorer fields is about 15 tons per acre. On weighing the produce of an acre of cabbage, grown under similar circumstances, I found that it amounted to 17½ tons per acre in round numbers. On good, well-manured fields, however, we have had a much larger produce.

Royal Agricultural College, Cirencester, June, 1860.

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EXPERIMENTS

WITH DIFFERENT

TOP-DRESSINGS UPON WHEAT.

By DR. AUGUSTUS VOELCKER.

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
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EXPERIMENTS WITH DIFFERENT TOP-DRESSINGS UPON WHEAT.

There is no lack of experiments made with guano, nitrate of soda, soot, shoddy, gas-water, and other nitrogenized substances, which are occasionally used as top-dressings upon wheat. Experience has shown that all these manures may be used, with more or less advantage, for the wheat-crop; and that, generally speaking, they are the more effective the more nitrogen they contain. Thus Peruvian guano or nitrate of soda, which are both very rich in nitrogen, are justly considered more powerful wheat-manures than soot or shoddy—two materials much poorer in this element. Whilst I consider the relative proportions of nitrogen in different fertilizers, intended to be used for wheat or other cereal crops, to be an important element in estimating the comparative commercial and agricultural value of artificial manures, such as Peruvian guano, nitrate of soda, or sulphate of ammonia, I am of opinion that the form or state of combination in which the nitrogen is contained in the manure materially affects its efficacy. Any one who has tried side by side nitrate of soda, Peruvian guano, and shoddy, must have felt surprised at the different degree of rapidity with which the effects of these three fertilizers are rendered perceptible in the field. I have noticed more than once that, under favourable circumstances, the effects of nitrate of soda became visible in the course of three or four days in the darker green colour and more luxuriant appearance of the young wheat, whilst it took eight or ten days in the case of guano to produce a similar effect. On wheat dressed with shoddy no apparent effect was produced even after the lapse of four or six weeks. So slow is the action of the latter that a superficial observer might well doubt the efficacy of shoddy as a wheat-manure, for it often produces no visible improvement in the wheat-crop, and it is only after threshing out the corn that it can be ascertained that shoddy has had some effect upon the yield of corn. These examples appear to indicate that nitrogen in the shape of nitric acid has a different practical value from that which it possesses in the shape of ammonia, and that it has again another value in the form of nitrogenized organic matter. It must be confessed that our knowledge of the comparative efficacy of nitrogen, in its various states of combination, is extremely limited, inasmuch as we scarcely possess any sufficiently accurate and trustworthy comparative field experiments which are calculated to throw light on this subject. As yet the sure foundation on which an explicit opinion as to the relative merits of nitrogen—in the shape of nitric acid, ammonia, or organic matter—can be given, is altogether wanting. It is true the experience of practical men affords certain useful indications to the scientific observer, but nothing more. In the absence of clear, unmistakeable, and sufficiently extensive practical evidence, no definite answer can be given to the question so frequently addressed to the agricultural chemist, Shall I apply nitrate of soda or guano upon my wheat?

We do not know, even in a general way, the comparative efficacy of nitrates and of ammoniacal manures: how is it possible, I would ask, to answer such a question in a particular instance? The importance of this question will be admitted by every one, especially at a time when the price of corn is low, and that of Peruvian guano high. Extensive deposits of nitrates of potash and soda are more likely to be discovered when diligent search is made after them than new and extensive deposits of guano equal to, or approaching in efficacy, Peruvian. Apart from the theoretical aspect, the question as to the relative merits of nitrogen in the shape of nitric acid or ammonia is of great practical interest. Fully impressed with the importance of this subject, I have undertaken, at the request of the Council of the Royal Agricultural Society, a series of field experiments with top-dressings upon wheat, and have now the pleasure of laying before the members of the Society the results of a series of experiments made last season (1859). Similar experiments I hope to continue from year to year; for the longer I am engaged in carrying out experimental trials in the field, the more I am convinced that the experience derived from one, two, or three years' experimenting in the field is alike inadequate to further the progress of scientific agriculture, and to supply the farmer with information from which he can derive practical advantage.

The time has arrived when an extension of field experiments is imperatively demanded. Practical experiments should be instituted in all parts of the country, and tried on every description of soil, and under the most varied conditions. They should be conceived in a philosophical spirit, and carried out with that accuracy and love of truth which ought, and generally does, characterize the labours of the student of natural science. Mere random trials, made without plan or definite object in view, are only calculated to lead astray, and thus do more harm than good. Unfortunately, success in a field experiment cannot be always secured: the disturbing influences which spoil the result are numerous and frequently uncontrollable; and, as the labour, anxiety, and expense which attend field experiments are very great, it can hardly be expected that many agriculturists will engage in this work. After having gone to the trouble of preparing and measuring out the land, selecting the seed, procuring and weighing out the various fertilizers intended for trial, after having them analysed and taken notes from day to day of the progress of the experimental plots, it is a sore trial for the experimentalist to have to report, "Results vitiated by the ravages of the black caterpillar." Indeed any one who is not prepared to meet with more disappointment than success, will be wise to desist from trying his hand at field experiments. I am led to make this remark because only the season before last my experiments upon swedes were entirely spoiled by the black grub. Again last season I instituted an extensive series of experiments with top-dressings upon barley, and, after having incurred considerable expense and taken much trouble, all that I can report is, "Results vitiated by the ravages of the wire-worm."

My experiments upon the wheat-crop, I am happy to say, were unusually successful. No hail, drought, mildew, or rust, interfered with the success of the trials. I was fortunate enough to find a good and most equal plant on a perfectly level and uniform field of the Royal Agricultural College farm. The day on which the top-dressings were applied was calm and cloudy; a moderate rain that fell on the next day washed the various manures into the soil, and secured at once their uniform distribution. The season, on the whole, was favourable to wheat, the weather at harvest time was unusually splendid, and on none of the experimental plots was the crop laid in the slightest degree.

The field on which the experiments were tried is perfectly level, and throughout of uniform depth. Its extent is about 20 acres; and last season the whole was in wheat after seeds; 2 acres covered with a very equal plant were measured out for the experiments and carefully divided into 8 parts of equal length and breadth. Each experimental plot thus occupied the space of ¼ acre. The 2 acres under experiment were surrounded by a considerable breadth of the general wheat-crop, except on one side. Although the headland, and a portion of the rest of the land, separated on that side the experimental plots from the adjoining hedge, it was considered prudent to reject the ¼ acre next to the hedge. Seven plots of ¼ acre each in extent thus were left. These plots were manured as follows:—

To Plot I. was applied 70 lbs. of Peruvian guano; or at the rate of 2½ cwt. per acre.
,, II. ,, 49 lbs. of nitrate of soda; or at the rate of 1¾ cwt. per acre.
,, III. ,, 45 lbs. of nitrate of soda and 42 lbs. of common salt; or at the rate of 1½ cwt. of salt and 180 lbs. of nitrate of soda per acre.
,, IV. ,, 1 cwt. of Proctor's wheat manure; or at the rate of 4 cwt. per acre.
,, V. ,, 1½ cwt. of the same wheat manure; or at the rate of 6 cwt. per acre.

Plot VI. was left unmanured.

To Plot VII. was applied about 1 ton of chalk-marl; or at the rate of about 4 tons per acre.

These quantities of the different fertilizers were obtained in each case at an expense of 1*l.* 12*s.* 6*d.* per acre, except the larger dose of wheat-manure on Plot V., the cost of which was 2*l.* 8*s.* per acre. In this estimation the actual prices paid were taken. Peruvian guano, at the time of application, was 13*l.* per ton; nitrate of soda, 18*l.* 10*s.* per ton; common salt, 1*l.* 10*s.* per ton; wheat-manure, 8*l.* per ton.

The price of the chalk-marl could not be accurately ascertained, and probably 8*s.* per ton will be rather under than above the price at which it was procured. The manures were all finely sifted (except the chalk-marl), mixed with about 10 times their weight of fine soil, and sown broadcast on the afternoon of the 22nd of March, 1859.

The land was clean, in good condition, and moist. A portion of the soil from the experimental field was submitted to a mechanical and to a chemical analysis. It yielded the following results:—

Composition of Experimental Wheat-Field; Field No. 2 of the Royal Agricultural College Farm, Cirencester.

a. *Mechanical Analysis.*

Moisture	4·18
Organic matter and water of combination	9·75
Lime	18·63
Clay	61·76
Sand	5·68
	100·00

It will be seen that there is but little sand or silica, that can be separated by washing, in this soil. Notwithstanding, the straw of the wheat was very stiff.

b. *Chemical Analysis.*

Moisture	4·18
*Organic matter and water of combination	9·75
Oxides of iron and alumina	16·25
Phosphoric acid	·12
Sulphate of lime	·31
(Containing sulphuric acid)	(·18)
Carbonate of lime	18·63
Magnesia	·18
Potash	·41
Soda	·11
Insoluble silicates and sand (chiefly clay)	50·45
	100·39
*Containing nitrogen	·37
Equal to ammonia	·45

In the preceding analysis the phosphoric acid was determined by the molybdate of ammonia process, which furnishes exceedingly accurate results. The proportion of phosphoric acid found (·12) is but small; nor does this soil contain much sulphuric acid or available alkalies. On the other hand, it is rich in lime and clay, and would, no doubt, be much more productive if the field were deeper. Being rather shallow, the agricultural capabilities of the experimental field are naturally below the average.

In shallow, stiff, and retentive soils organic matter accumulates rapidly. Most of the nitrogen indicated in the above analysis is present in the shape of organic matters: *i.e.*, the roots, leaves, and other remains of the preceding crop. A small portion only of nitrogen occurs in this soil in the state of ready-formed ammonia.

Before stating the yield of each experimental plot, I shall notice briefly the appearance of the crop at different times, and give the analysis of the manures employed in the experiments.

PLOT I.—Top-dressed, March 22nd, with Peruvian guano, at the rate of 2½ cwts. per acre, cost, 1*l.* 12*s.* 6*d.* per acre.

On the eighth day after the application of the guano the effects of this fertilizer became slightly visible, on the tenth day they were a little more marked, and, after a fortnight, plainly observable even to a superficial observer. Compared with the unmanured wheat, the colour of the wheat on Plot I., though not so dark-green as on the portion dressed with nitrate of soda, was deeper, and the plants looked altogether more luxuriant than on the unmanured plot. The darker green colour was perceptible for more than six weeks, and then gradually disappeared. At the same time the wheat-plants grew more vigorously, and at harvest time were a good deal higher than the wheat in the surrounding field. On analysis the Peruvian guano gave the following results:—

Moisture	17·12
*Organic matter and ammoniacal salts	51·31
Phosphates of lime and magnesia (bone-earth)	22·55
Alkaline salts	7·94
Insoluble siliceous matter (sand)	1·08
	100·00
*Containing nitrogen	14·64
Equal to ammonia	17·77

These numbers express the composition of a genuine good Peruvian guano.

PLOT II.—Top-dressed, March 22nd, with nitrate of soda, at the rate of 1¾ cwt. per acre, cost 1*l.* 12*s.* 6*d.* per acre.

Already, the fourth day after application, the effects of nitrate of soda became slightly visible, and in the course of a week the dark green colour of the wheat on that plot was unmistakable. The wheat on Plot II. looked remarkably well throughout the season, and at harvest time was as high as the wheat dressed with guano. The nitrate of soda employed in this experiment was very pure, as will be seen by the subjoined analysis:—

Composition of Nitrate of Soda.

Moisture	1·87
Pure nitrate of soda	95·68
Chloride of sodium	·79
Sulphate of soda	1·17
Sand	·49
	100·00

Plot III.—Top-dressed, March 22nd, with nitrate of soda and salt, at the rate of 180 lbs. of nitrate of soda and 1½ cwt. of salt per acre, cost 1*l*. 12*s*. 6*d*. per acre.

The remarks made with respect to Plot II. apply equally well to this plot. There was no visible difference in the appearance and general character of the wheat on Plots II. and III., and at harvest time it was impossible to say which of the two would yield the heavier crop.

Many persons who passed by the wheat-field, which could be overlooked from the turnpike-road, were astonished at the dark-green coloured wheat on the two plots upon which nitrate of soda was put. In comparison with the surrounding wheat, which had received no top-dressing, the two ¼-acre plots looked as if a painter had put an extra layer of green colour on the wheat. The common salt used on Plot III. was ordinary agricultural salt.

Plot IV.—Top-dressed, March 22nd, with wheat-manure (Proctor's), at the rate of 4 cwts. per acre, cost 1*l*. 12*s*. 6*d*. per acre.

The effects produced by this top-dressing were not so soon visible as those produced by nitrate of soda. However, in less than a fortnight the wheat was decidedly improved, and, as far as appearance went, kept pace with the wheat dressed with guano. At harvest time it was impossible to say which of the Plots, No. I., II., III., or IV., was the best. An inspection of the following analysis will show that the wheat-manure used on this and following plot was an excellent fertilizer. It will be noticed that it contained a large quantity of nitrogen, partly as sulphate of ammonia, partly in the shape of soluble and insoluble nitrogenized organic matter. In addition to these important constituents, it contained both soluble and insoluble phosphates, as well as common salt, gypsum, and a few other matters of less value.

Composition of Wheat Manure.

	Moisture	13·60
	*Sulphate of ammonia	10·97
†	Soluble nitrogenized organic matter	8·08
	Insoluble nitrogenized organic matter	14·72
	Bi-phosphate of lime	3·54
	Equal to bone-earth rendered soluble by acid	(5·52)
	Insoluble phosphate of lime (bone-earth)	9·45
	Sulphate of magnesia	·61
	Hydrated sulphate of lime	19·73
	Chloride of sodium (common salt)	16·84
	Insoluble siliceous matter (sand)	2·46
		100·00

*Containing nitrogen	2·32
Equal to ammonia	2·82
†Containing nitrogen	3·53
Equal to ammonia	4·28
Total quantity of nitrogen	5·85
Equal to ammonia	7·10

Plot V.—Top-dressed, March 22nd, with Proctor's wheat-manure, at the rate of 6 cwts. per acre, cost 2*l.* 8*s.* per acre.

During the first three or four weeks there was no difference perceptible in Plots IV. and V., but in the beginning of June it became plain to a careful observer that the wheat on this plot was evidently all the better for the extra dose of manure.

The wheat continued to improve, and took the lead of the experimental plots. At harvest time the wheat on this plot was perceptibly higher in straw than on any of the other plots, and the ears of corn likewise appeared rather longer and better filled than on any of the other portions of the experimental field. The reapers, without exception, pronounced the crop on Plot V. the heaviest of all; and the correctness of their opinion, it will be shown, was fully borne out by the direct weighings of the yield. The contrast in the appearance of this plot and the rest of the general wheat-crop was most striking. Although the wheat on No. V. was high, it stood perfectly erect at harvest, and produced strong healthy straw.

Plot VI.—Left unmanured.

The wheat on this plot was fully three inches lower than on the preceding plot. Although it was not so dark green as the crop on Plots I., II., III., IV., V., it was, nevertheless, healthy-looking, but rather thin.

Plot VII.—Top-dressed with chalk-marl, at the rate of about 4 tons per acre.

There was not the slightest difference perceptible in this and the preceding plot, and it was plain to any one that the marl had had no effect whatever. On analysis this chalk-marl was found to have the following composition:—

Composition of Chalk Marl.

Moisture	2·49
Carbonate of lime	69·23
Oxides of iron and alumina	·36
Phosphate of lime (bone-earth)	·63
Sulphate of lime	trace
Magnesia and alkalies	·45
Soluble silica	8·29
Insoluble siliceous matter (fine sand)	18·55
	100·00

Towards the end of July the crop was nearly ripe; at that time I could not notice any marked difference in the state of ripeness of the crops on the 7 experimental ¼-acres.

The wheat was reaped in the first week of August, and threshed out on the 24th of August, 1859, and the whole of the produce of corn and straw carefully weighed: it was omitted, however, to weigh the chaff and cavings.

The following Table exhibits the yield of corn of each experimental plot, and the produce calculated per acre:—

TABLE *showing the Produce, in lbs. and bushels, of Corn of Experimental Plots of ¼-acre, and Weight and Bushels per acre. (Average weight per bushel, 60 lbs.)*

		Produce in corn per plot.		Produce in corn per acre.	
Plot		lbs.	bushels.	lbs.	bushels.
I.	2½ cwt. guano per acre	601½	10	2406	40⅒
II.	1¾ cwt. of nitrate of soda per acre ..	570	9½	2280	38
III.	180 lbs. of nitrate of soda and 1½ cwt. of salt per acre	609	10	2436	$40\frac{6}{10}$
IV.	4 cwt. of Proctor's wheat-manure per acre	595	10	2370	39½
V.	6 cwt. of ditto per acre	663	11	2652	44⅕
VI.	Unmanured	405	6¾	1620	27
VII.	Chalk-marl, 4 tons per acre	404½	6¾	1618	27

By direct weighings it was found that the weight per bushel was in—

No. I.	60½ lbs.	No. V.	60 lbs.
„ II.	60 „	„ VI.	60 „
„ III.	60¾ „	„ VII.	60½ „
„ IV.	60½ „		

Practically speaking, there was thus no difference in the weight of corn per bushel. Not having had much experience in filling bushels of corn, I found that I could not always fill the bushel-measure so uniformly as not to get a difference of from $\frac{3}{4}$ to 1 lb. in the weight of different bushels of the same corn.

The following table exhibits the produce in straw :—

TABLE *showing the Produce in Straw of each $\frac{1}{4}$-acre Plot, and Produce per acre.*

		Per plot.			Per acre.			
Plot		cwt.	qrs.	lbs.	ton	cwt.	qrs.	lbs.
I.	$2\frac{1}{2}$ cwt. of guano	5	3	0	1	3	0	0
II.	$1\frac{3}{4}$ cwt. of nitrate of soda ..	6	0	2	1	4	0	8
III.	180 lbs. of nitrate of soda and $1\frac{1}{2}$ cwt. of salt	6	0	12	1	4	1	20
IV.	4 cwt. of wheat-manure	5	3	23	1	3	3	8
V.	6 cwt. of wheat-manure	6	3	2	1	7	0	8
VI.	Unmanured	4	1	20	0	17	2	24
VII.	Chalk-marl	4	0	20	0	16	2	24

For the sake of better comparison, the increase per acre in corn and straw over unmanured portions of the experimental field, is stated in the next Table.

TABLE *showing the Increased Produce per acre in Corn and Straw over Unmanured Plot, in lbs. and bushels.*

		Increase in corn.		Increase in straw.		
Plot		lbs.	bushels.	cwt.	qrs.	lbs.
I.	Peruvian guano	786	$13\frac{1}{10}$	5	1	4
II.	Nitrate of soda	660	11	6	1	12
III.	Nitrate of soda and salt	816	$13\frac{6}{10}$	6	2	24
IV.	4 cwt. of Proctor's wheat-manure	750	$12\frac{1}{2}$	6	0	12
V.	6 cwt. of ditto	1032	$17\frac{1}{5}$	9	1	12
		produce.		produce.		
VI.	Unmanured	1620	27	17	2	24
		increase.		decrease.		
VII.	Chalk marl	none		1	0	0

An examination of the preceding results suggests the following remarks :—

1. The plot manured with chalk-marl furnished as nearly as possible the same amount of corn as the unmanured plot, and rather less straw. The produce in the one amounted to 1620 lbs. of corn, and in the other to 1618 lbs.; or each gave 27 bushels of wheat.

In some parts of England chalk-marl is applied with considerable benefit to the wheat-crop, but as the soil of the experimental field contained 18 per cent. of carbonate of lime, it could not be expected that a marl, which owes its fertilizing properties almost entirely to the carbonate of lime and to a little phosphate of lime which it contains, should produce any marked effect upon the wheat-crop. Indeed, I did not expect any increase from the application of this marl, and used it in this experiment chiefly to ascertain the extent of variation in the produce of two separate ¼-acre plots. The result plainly shows that the experimental field was very uniform in its character and productiveness. We may also learn from this result that the efficacy of a manure is greatly affected by the chemical composition of the soil to which it is applied. However beneficial chalk-marl may be in other localities, it cannot possibly do any good on land which contains already an abundance of the same elements which are supplied in the marl.

2. The application of only 1¾ cwt. of nitrate of soda raised the produce in corn to 38 bushels, and that of straw to 1 ton 4 cwt. 8 lbs. We have thus here an increase of 11 bushels of corn, and 6¼ cwt. of straw, at an expense of 1*l.* 12*s.* 6*d.*

3. By mixing nitrate of soda with common salt, the produce in corn was raised to 40 bushels, and that of straw to 1 ton 4 cwt. 1 qr. 20 lbs. It appears thus that the admixture of salt to nitrate of soda was beneficial in this experiment. The quantity of salt used amounted to only 1½ cwt.: notwithstanding, it had a decidedly beneficial effect upon the produce. As salt is cheap, it may be worth while to try in future experiments whether a larger dose of salt mixed with nitrate of soda will be of advantage.

4. Peruvian guano produced very nearly the same quantity of corn as the mixture of nitrate of soda and salt, but somewhat less straw.

5. The smaller dose of wheat-manure gave almost ½ a bushel less increase in corn, and rather more straw, than guano. The difference in the yield of these two plots, however, is trifling.

6. The larger dose of Proctor's wheat-manure (6 cwt. per acre), it will be seen, gave an increase of 17⅕ bushels of corn, and 9 cwt. 1 qr. 12 lbs. of straw, over the yield of the unmanured plot. 4 cwt. of the same wheat-manure gave an increase of 12½ bushels of corn, 6 cwt. 12 lbs. of straw. One-half more of wheat-manure, or 6 cwt., very nearly gave one-half more increase in corn and straw. The chief points of interest which attach to these experiments are:—

1. That nitrate of soda applied by itself materially increased the yield of both straw and corn.

2. That the admixture of salt to nitrate of soda was found to be beneficial.

3. That guano produced as good a result as nitrate of soda.

4. That the increase in corn and straw corresponded with the quantity of the wheat-manure which was used.

5. That ammonia and nitrogenized organic matters—which

proved inefficacious or even injurious in relation to turnips, grown on a similar soil to that on which the wheat was raised—had a most marked and decidedly beneficial effect upon the wheat-crop.

It may not be amiss to contemplate these experiments in an economical point of view, and to ascertain to what extent the different top-dressings have repaid the outlay of money—which, it will be remembered, was 1*l.* 12*s.* 6*d.* per acre in all cases, except in the case of the larger dose of wheat-manure, the application of which entailed an expenditure of 2*l.* 8*s.* per acre. Leaving unnoticed the extra produce of straw, which in some cases was considerable, I shall only take into account the produce in corn. The present average price of wheat of ordinary quality is about 42*s.* per quarter. Taking 42*s.* as the price of wheat per quarter, we obtain the following money-value of the increase in produce, as the clear profit realized by the top-dressings after deducting the expense of the manures:—

TABLE *showing the Money Value of Increase in Corn per acre over Unmanured Plot, and Clear Profit after deducting the price paid for Manures.*

Plot		Money increase in corn.			Cost of Manure.			Clear Profit.		
		£.	s.	d.	£.	s.	d.	£.	s.	d.
I.	Guano	3	8	9	1	12	6	1	16	3
II.	Nitrate of soda	2	17	9	1	12	6	1	5	3
III.	Nitrate of soda and salt	3	11	5	1	12	6	1	18	11
IV.	4 cwt. of wheat-manure	3	5	7	1	12	6	1	13	1
V.	6 cwt. of wheat-manure	4	10	4	2	8	0	2	2	4
VI.	Unmanured	.. ..			.. ..			.. ..		
VII.	Chalk-marl	none			1	12	6	loss. 1	12	6

It will be seen that, with the exception of the chalk-marl, all the top-dressings paid very well, and that the more liberal outlay for manure produced by far the best return in money.

I purpose to note down the relative produce of next season's crop on each of the ¼-acre experimental plots, and hope thus to ascertain whether the efficacy of the various top-dressings was spent in one season or not. In estimating the profits arising from the use of these top-dressings, the condition in which the land is left after the removal of the crop ought, by rights, to be taken into account. It appears to me that the productiveness of the different plots will be found to vary considerably.

In nitrate of soda we have only two constituents, namely, soda and nitric acid. Soda has scarcely any fertilizing value, and in combination with nitric acid it is, moreover, readily removed by the rain into the subsoil or drainage water; for soils do not possess the power of retaining nitrates. Supposing any nitrate of soda to have been left in the soil, it is not likely to produce any effect on the succeeding crop. All the more important mineral constituents which are required for the growth of wheat must be furnished by the soil top-dressed with nitrate of soda. The amount of available mineral fertilizing matters in the soil, therefore, will be less after the removal of the wheat-crop, and the soil will be found, I think, in a poorer condition.

The portions of land top-dressed with guano and wheat-manure, on the other hand, were supplied not only with ammoniacal salts and nitrogenized organic matters, but also with valuable mineral matters—such as phosphoric acid, sulphuric acid, and alkalies. On calculating the proportion of phosphoric acid which is removed in the produce of Plot I., I find that the guano supplies more phosphoric acid than is removed in the produce of corn and straw. After harvest, therefore, the land will actually be richer in this important fertilizing matter than it was before the application of guano. Again, I question very much whether the total amount of nitrogen in guano and in the wheat-manure will be used up in the growth of one wheat-crop. It appears to me more likely that some will remain in the soil, ready to benefit the succeeding crop. However, this point can only be decided by direct experiments. Unlike nitrates, ammoniacal matters are retained in all soils containing a fair proportion of clay, which circumstance is of course in favour of guano and ammoniacal manures in general as top-dressings for wheat.

Since, then, guano and artificial manures, resembling in composition the wheat-manure used in my experiments, supply the wheat-crop with constituents which must be furnished entirely by the soil when nitrate of soda alone is employed as a top-dressing; and since an excess of ammoniacal matter will be retained in the soil, whereas an excess of nitrate is subject to loss; I am inclined to think that the land dressed with guano and Proctor's wheat-manure will be left in a better condition than the plots manured with nitrate of soda. On the whole, I am of opinion that in the recorded experiments the wheat-manure and guano have proved to be preferable as top-dressings to nitrate of soda. However, nitrate of soda is an excellent material for producing a rapid improvement in sickly-looking wheat. We have used nitrate of soda last season with great advantage on our farm. A slight sprinkling with a mixture of nitrate of soda and salt causes a marvellous improvement in poor, thin, yellow-looking wheat. On the thin brashy soils in our neighbourhood the young wheat is apt to turn yellow and sickly in dry springs, especially on the brows of hilly fields: nothing can be better in such a case than a dressing with nitrate of soda and salt. By this means Mr. Coleman, who manages the Royal Agricultural College farm, has been able to grow good crops of wheat on thin brashy and exposed fields, which usually without such a dressing yielded but a scanty produce.

Nitrate of soda and guano often contain hard lumps, which ought to be carefully broken down before application: this is generally neglected, to the great disadvantage of the farmer. It is true there is some difficulty in reducing guano to a fine powder, and there is trouble connected with passing through a fine sieve nitrate of soda or guano; but no trouble or additional expense for labour should deter any one from reducing artificial manures, intended to be used as top-dressings, into a fine powdery condition: for the difference in the efficacy of manures in such a condition, and the same manures applied in a rough state, is much greater than most people believe who have not tried the experiment.

Whilst speaking of the application of top-dressings, I cannot refrain from observing that all artificial manures—such as nitrate of soda, guano, or a mixture of nitrate of soda and salt—should not only be first passed through a fine sieve, but they should also be mixed with three to five times their own weight of fine red ashes, dry soil, or sand, before sowing them broadcast by hand, or, what is much more convenient and better, by the broadcast manure distributor. Chambers' or Reeves' dry manure distributor cannot be too highly recommended for sowing, in a most uniform and expeditious manner, top-dressings of every description.

In conclusion, I beg publicly to thank Mr. Coleman for the obliging manner in which he has assisted me in carrying out the preceding experiments.

Royal Agricultural College, December, 1859.

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AND CHARING CROSS.

ON THE

COMPOSITION

OF

SORGHUM SACCHARATUM

(HOLCUS SACCHARATUS),

OR

NORTH CHINA SUGAR-CANE.

BY DR. AUGUSTUS VOELCKER.

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
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1860.

FROM THE
JOURNAL OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND,
VOL. XX., PART II.

ON THE

COMPOSITION OF SORGHUM SACCHARATUM.

THE cultivation of the North China sugar-cane, sorghum saccharatum (holcus saccharatus), the sorgo sucré of the French, has of late attracted much attention. During the past season it has been grown in many places in England by way of experiment.

This new graminaceous plant appears to be cultivated largely in several parts of North America, where it has attracted much attention on account of the sugar which it contains, and likewise on account of its adaptation to the distillation of spirit and the preparation of fermented liquors. It is a beautiful-lookine grass, resembling in appearance Indian corn. In favourablg climates it comes to maturity in a single season, and reaches e height of from 12 to 16 feet. Sorghum sugar, when refined, is identical in composition and quality with cane-sugar. Sorghum saccharatum is recommended chiefly as a new material for the manufacture of sugar, and likewise as a nutritious and fattening food for horses and cattle.

The sorghum which was used for analysis was grown on the Royal Agricultural College Farm. The seed was drilled on the 13th of May, in rows 14 inches apart, and at a depth of about 3 inches. It came up well and evenly. The plants appeared to grow vigorously throughout the summer, and reached a height of about 5 feet by the beginning of October. A patch of about ¼-acre furnished a good deal of green food to cattle, which seemed not to relish it at first, but towards the end of September grew very fond of it. The soil on which the sorghum was grown was in good condition, of moderate depth, and, like most soils in our neighbourhood, contains a good deal of lime and clay, and scarcely any sand. The preceding crop was potatoes. As this crop had been heavily manured, no farmyard dung was put on the land this season, nor was any other manure employed, except some ashes from burnings of roadside parings and the clippings of hedgerows.

The sorghum was submitted to analysis at two different periods, namely, on the 23rd of August and on the 26th of September, 1859.

Composition of Sorghum, analysed August 23rd.

Water.—At this time the plants had no proper stems. The stalks consisted merely of leaves rolled up, which could be entirely untwisted.

As there was a good deal of adhering water on the leaves, it was necessary to unroll all the leaves, and to dry them with fine blotting paper, before making the water-determination.

Deprived in this way of all accidental water, 1000 grains of the finely cut plant left, on drying in the water-bath, 148 grains of dry matter. The plants consequently contained 85·20 per cent. of water.

In a second determination, 85·15 per cent. of water was found. The mean of the two water determinations is 85·17.

Ash.—18·61 grains of perfectly dry substance gave 1·41 grains of ash, or 100 grains contained 7·57 grains of ash. In the natural state the plants thus contained 1·12 per cent. of ash.

Protein Compounds.—Burned with soda-lime, the dried substance was found to contain 2·75 per cent. of nitrogen, which is equal to 17·18 per cent. of protein compounds. In a second nitrogen combustion, 2·78 per cent. of nitrogen was obtained, which is equal to 17·37 per cent. of protein compounds. The mean of these two nitrogen determinations is 2·76 per cent., equal to 17·27 per cent. of protein compounds. In the natural state sorghum contained, according to the first determination, ·407 per cent. of nitrogen, equal to 2·544 per cent. of protein compounds; and ·412 per cent. of nitrogen, equal to 2·575 per cent. of protein compounds, according to the second determination.

According to these determinations, the general composition of the sorghum on the 23rd of August may be represented as follows:—

	First Experiment.	Second Experiment.	Average.
Water	85·200	85·150	85·175
Nitrogenized organic matters (so called flesh-forming matters)	2·544	2·575	2·559
Substances free from nitrogen, and fitted for the support of animal heat and the formation of fat	11·136	11·155	11·146
Inorganic matters (ash)	1·120	1·120	1·120
	100·000	100·000	100·000

And that of sorghum, dried at 212° F.:—

	First Experiment.	Second Experiment.	Average.
Nitrogenized substances	17·18	17·37	17·27
Non-nitrogenized matters (heat and fat-producing matters)	75·25	75·06	75·16
Inorganic matters (ash)	7·57	7·57	7·57
	100·00	100·00	100·00

I have likewise made a complete proximate analysis of the sorghum; and, with a few modifications, followed the process which will be found described in detail in my Paper on the Composition of Parsnips and Belgian Carrots. (See Journal of the Royal Agricultural Society of England, vol. xiii., part ii.)

The following table contains the results of the detailed proximate analysis of the sorghum :—

Detailed Proximate Composition of Sorghum Saccharatum on the 23rd of August.

	In Natural State.	Dried a 212°.
Water	85·17	..
*Albumen	·36	2·42
Other soluble protein compounds	·90	6·08
Mucilage, pectin, and digestible fibre	6·63	44·71
Soluble mineral matters	·81	5·46
†Insoluble protein compounds	1·25	8·43
Indigestible woody fibre (cellular)	4·57	30·81
Insoluble mineral matters	·31	2·09
	100·00	100·00
*Containing nitrogen	·21	1·71
†Containing nitrogen	·20	1·35
Total quantity of nitrogen	·41	2·76

It will be seen that the sorghum contained a good deal of nitrogenized matter at the time when the analysis was made, but no sugar whatever.

The taste of the plants on the 23rd of August was anything but sweet. I did not expect, therefore, to find much sugar, but I was unprepared to meet with a total absence of sugar. In order to verify this fact, I caused a direct sugar-determination to be made in a fresh and large quantity of the whole plant, but was unable to detect any appreciable quantity of sugar.

Horses and cattle to whom the plants were given, at first refused them altogether, and after some time partook only sparingly of this food. They evidently did not relish it.

There can be but little doubt that the sorghum was quite unripe by the end of August, and was unfit for feeding purposes.

It is worthy of special notice that the plants contained no sugar at that time. Last summer was unusually hot, but, notwithstanding, the plants were quite unfit for feeding by the end of August.

Fortunately, the last week in August and the month of September were warm; the plants therefore continued to grow vigorously, and formed perfect stems, which to the taste were very sweet when examined on the 26th of September.

Composition of Sorghum on the 26th of September.

The plants were cut about 4 inches above the ground. The analysis was made with the whole plant.

a. *General Composition.*

	In Natural State.	Dried at 212°.
Water	81·80	..
Soluble organic matter	8·16	44·83
Soluble mineral matter	·74	4·07
Insoluble organic matter	9·07	49·83
Insoluble mineral matter	·23	1·27
	100·00	100·00

b. *Detailed Proximate Composition of Sorghum Saccharatum, September 26th,* 1859.

	In Natural State.	Dried at 212°.
Water	81·80	..
*Albumen	·37	2·03
*Other soluble protein compounds	1·16	6·36
Sugar	5·85	32·15
Wax and fatty matter	2·55	14·01
Mucilage, pectin, and digestible fibre ..	2·59	14·26
Soluble mineral matters	·74	4·06
†Insoluble protein compounds	·66	3·62
Indigestible woody fibre (cellular)	4·05	22·25
Insoluble mineral matters	·23	1·26
	100·00	100·00
*Containing nitrogen	·245	1·34
†Containing nitrogen	·106	·58
Total quantity of nitrogen	·351	1·92

The sorghum contained, it will be noticed, nearly 6 per cent. of sugar on the 26th of September. Cattle supplied with this grass at that time greedily ate it, and, to all appearance, did well upon it.

The proportion of sugar in the whole plant is about the same as that in carrots.

On examining the stumps which were left in the ground, they were found much sweeter than the upper part of the stems. The difference in the taste was so marked, that I had made two direct sugar-determinations by the fermentation process.

The first determination was made in the stems cut about 2 inches from the ground. It gave 7·65 per cent. of sugar.

The second was made in the upper part of the stems, cut about 12 inches from the ground. It yielded 3·60 per cent. of sugar, or not quite half the quantity which was found in the lower part.

At the same time I determined the amount of crude fibre (the part insoluble in water) in both cases, and found in the lower part of stems 6·50 per cent. of crude fibre, and in the upper part 13·01 per cent.

We have thus—

Proportion of Sugar and Crude Fibre.

	In Stems cut 2 inches above ground.	In Stems cut 12 inches above ground.
Percentage of sugar	7·65	3·60
„ crude fibre	6·50	13·01

This distribution of sugar and fibre in the stems of sorghum is interesting in a physiological point of view. Whilst speaking of the distribution of sugar in sorghum, I may state that Professor Buckman observed last September that, whilst the principal or main stem was quite sweet, the stolons or side shoots were still bitter. It would thus appear that this grass does not ripen together; the central or oldest stem is perfect before the lateral shoots. Fearing the central stems might get so hard and woody as to become useless as a cattle-food if left in the ground until sufficient sugar is developed in the lateral shoots, Professor Buckman recommends that the central stems should be cut down first; the lateral shoots will then make rapid growth and gradually become sweet. By this simple expedient, the full benefits from the whole of the crop may be secured.

A comparison of the analysis made in August with that made in September will show several matters of interest. I notice some of the more striking ones.

1. In August the sorghum was much more watery than in September. In the former month it contained, in round numbers, 85 per cent. of water; in the latter only 81½ per cent.

2. Whilst there was a total absence of sugar in August, the whole plant contained nearly 6 per cent. in September in its natural state, or 32 per cent. when dry.

3. Instead of sugar, the sorghum contained in August chiefly mucilage and pectin, which constituents disappeared to a great extent in September, and gave rise to the formation of sugar.

4. The amount of woody fibre is less in the more matured grass than in the unripe plants analysed in August.

5. The unripe plants contain more mineral matter than the grass in a more advanced state of ripeness.

6. It is particularly worthy of notice to observe the larger amount of nitrogen in the immature grass. In the grass analysed in August there is ·41 of nitrogen, notwithstanding the larger amount of water; whilst in the plants analysed in September, and containing about 3½ per cent. less water, only ·35 of nitrogen was found. It will be seen that the proportion of insoluble protein compounds is considerably diminished in the September

produce. The differences in the relative proportion of nitrogen in the grass analysed at the two periods appear particularly striking, if the compositions of the dried substances are compared with each other. It will then be found that there is nearly 1 per cent. less nitrogen in the plants analysed in September than in the grass analysed in August.

We have here presented to us a fresh proof that the nutritive value of food of the same kind is not regulated by the amount of nitrogen which it contains, but rather by the proportion of sugar. Indeed, I think it may be safely asserted that all green food, and likewise turnips and other roots, are immature, and more or less unfit for feeding, when they are rich in nitrogen. Fully ripe and very nutritious roots and grass always contain less nitrogen than the same food in an immature state, or than food of indifferent feeding qualities.

A single year's trial of course does not entitle me to judge of the agricultural merits of the sorghum saccharatum; but I cannot help thinking that the climate in most parts of England is opposed to its growth in anything like full perfection. Last season we had a fine and warm summer; notwithstanding which, neither the field crop nor an experimental plot in the botanical garden came to full maturity. They scarcely reached 5 feet in height, which is very much lower than the height which this grass is reported to reach in America. I notice in a communication of Dr. Gössman of Philadelphia that in America the sorghum reaches a height of 12 to 16 feet, and that it furnishes 70 to 75 per cent. of juice, from which Dr. Gössman obtained 6 to 7 per cent. of good crystallized sugar, besides a quantity of molasses. It appears to me more than doubtful that the sorghum will grow to this height in many parts of England; nor do I think the cultivation of sorghum in England will be remunerative in furnishing the raw material for the manufacture of sugar or the distillation of spirits. However, repeated trials are needed before we can finally pronounce on the value of sorghum for the manufacture of sugar, or on its merits as a feeding stuff.

For the benefit of those who are inclined to give this new grass a trial next season, I append the following remarks on its culture by Professor Buckman, who says:—

> "The seed was obtained from Messrs. Sutton, Reading, and sown in the beginning of May. The distance apart was 20 inches; depth (at which seed was sown), not more than 3 inches. It came up soon, and for the first month did not at all promise the fine aspect it afterwards showed; but as soon as the warm nights came it made rapid growth, and we were thus led to infer that too early sowing is by no means a saving of time, though we are not quite sure whether getting strong plants early, by germinating in a hothouse or under glass with artificial heat, and gradually exposing them to harden before transplanting, would not be advisable, especially where the growth of

holcus is attempted in cold, exposed, or late-growing situations; and, in this case, of course the operation of transplantation should be done in wet weather, the saving of seed, and the ensuring of a well-regulated equidistant plant, being taken as no bad equivalent for the extra labcur and expense. In this case the crop was hoed, but this is a delicate operation with the sorghum, as it sends out adventitious roots from the joint immediately above the ground, which dip into the soil, and, if not interfered with, aid immensely in forwarding the growth and developmemt of the plant. Hoeing, then, before this process commences encourages it, but by no means can it be properly done when this is in progress. When, however, the new roots are fully established, a careful stirring of the ground between the rows (not between the individual plants) appears very much to facilitate a larger and, what is more important, a quicker growth."

Royal Agricultural College, *Cirencester*,
Dec. 1859.

The foregoing article by Dr. Voelcker contains some curious and instructive facts. That the specimens of sorghum examined by him should have contained no sugar at the end of August, and up to that time should have been unpalatable to horses and cattle, are circumstances which not only have an important bearing on the probable value of the sorghum as a fodder plant in this climate, but they show what great changes may take place in a growing plant without any external difference being perceptible. This clue if properly followed up is very likely to lead to the right explanation of many apparent contradictions in the experience of practical men as to the value of any particular root or plant as food for stock, and it appears to me highly desirable that an extensive series of observations should be made on the changes which take place from time to time in the constituents of our root and fodder crops during their whole period of growth, but especially at the time of their approach towards maturity. The inquiry whether any material alteration takes place either for better or worse in the juices or tissues of a swede or a mangold at the fall of the leaf, or shortly before or after that time, or whether our natural or artificial grasses vary much in their composition and consequent value during the successive months of spring and summer, involves questions of first-rate interest to the farmer, and might materially assist him in fixing the time for mowing his meadows or storing his roots. I may perhaps be considered over sanguine for seeking to connect with such an investigation questions of a still more extensive character, but it certainly appears to me probable that a sufficiently extended scientific inquiry of the kind above named would throw considerable light on the whole question of manures, and their effect on the composition as well as the growth of plants. But whether these ultimate results be realised or not, the direct and immediate objects to be obtained by such an examination of our cultivated crops are so full of interest that I venture to express the hope that Dr. Voelcker will closely follow up what he has so hopefully inaugurated in the short paper before us.

One point in Dr. Voelcker's trial of the sorghum requires special attention on the part of future experimenters, viz. the period at which the plant begins to be palatable to live stock. A small plot of it sown here (West Riding of Yorkshire) last April in a well-sheltered garden grew vigorously and produced a large amount of both leaves and stems, the latter fully six feet high ; both were greedily eaten by horses and cattle as early as the month of July, and from that time until the end of October, when it was cut down by frost. No special manure was applied to this plot, but the land was in the high condition which is usual in the case of garden ground.

From the late period at which its growth commences, it is not probable that the sorghum will be able to compete with our clovers, &c., as a general crop for soiling, but two points are already ascertained beyond doubt, viz., that a small piece of land devoted to this plant will raise a large amount of produce, and that at a certain period (to be hereafter ascertained) this produce acquires considerable feeding value.

If it should be generally found to be as palatable to stock in July, as it was here, it will be very useful for soiling during the months of August and September; if, however, like Dr. Voelcker's, it should in most cases be unfit for cattle food until late in September, it would still be worth while to try whether it might not be made into valuable hay, either by cutting it in autumn when the saccharine matter was fully developed, or by cutting earlier and stacking it sufficiently green to induce considerable fermentation in the stack. The sorghum is naturally a plant of rapid growth, and it is possible that heavy doses of guano or other highly concentrated manure might force on its growth sufficiently to obtain not only a greater weight of produce but earlier maturity. At all events those stockmasters who, like myself, often experience a lack of material for soiling for a few weeks after harvest, would do well to try experiments on a limited scale with the sorghum, which is evidently a plant of great capabilities.

H. S. THOMPSON.

ON THE

CHEMICAL PROPERTIES OF SOILS.

BY DR. AUGUSTUS VOELCKER.

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ON THE

CHEMICAL PROPERTIES OF SOILS.

THERE are many persons who, on reading the papers which from time to time appear in our chemical and agricultural journals on the powers of soils to absorb manuring matters, receive the impression that sandy soils have not the power of retaining ammonia, whilst clay soils are imbued with this property in so eminent a degree, that no amount of rain is capable of removing any of the ammonia absorbed by them.

These impressions, though natural, are not founded on fact. It will be one of the objects of this communication to show by many experiments the fallacy upon which these erroneous impressions are based.

If soluble fertilizing matters were rendered completely insoluble when brought into contact with the soil, it would indeed be difficult to understand the use of soluble manuring matters, or to doubt the policy of resorting to mechanical means of cultivation, such as subsoiling, stirring, &c., which have the effect of rendering soluble mineral matters contained in the soil in an insoluble state. But does not daily experience teach us that such fertilizers are much more effective than the same materials in an insoluble or partially soluble condition?

It has indeed been stated by a high authority, that since soluble fertilizing matters are rendered insoluble in contact with soil, plants must have the power of taking up their food from the soil in some other form than that of simple solution. It is here taken for granted that soluble matters become quite insoluble in contact with soil. Many people, on being told that plants do not take up their food from the soil in the state of simple solution, assume that they take it up in a solid form.

On the Chemical Properties of Soils.

It is not my intention to expound in this place Baron Liebig's views on the assimilation of the food derived by plants from the soil. The changes which fertilizing matters undergo in contact with soil are, as we know, so numerous and so little understood, and the precise combinations in which mineral food is taken up by plants so little known, that it would be extremely hazardous to propound in detail a new theory respecting the assimilation of mineral food by plants. Baron Liebig, therefore, wisely refrained from expressing his views on this subject in that clear and precise manner which generally distinguishes his writings, and very properly contented himself with indicating that our present views respecting the absorption of mineral matters by plants are not quite correct.

Professor Way's and my own researches certainly have shown that manuring matters in contact with soil undergo remarkable changes, and fully justify the statement that plants do not take up mineral food in the simple state of solution in which we add it to the soil in the shape of manure, but in totally different states of combination.

Again, if sandy soils had not the power of retaining soluble fertilizing matters, it would be difficult to comprehend how, notwithstanding the occurrence of heavy thunderstorms or long-continuing rains, the effects of superphosphate or guano, or even sulphate of ammonia, are clearly seen in the increased produce raised on such soils by the aid of these manures.

The quantity of water running through the soil at such times, is amply sufficient completely to dissolve the soluble manuring matters. If it were, therefore, quite correct that sandy soils had not in any degree the power of absorbing soluble manuring matters, they would be removed by the rain into the subsoil, neighbouring ditch, or drain, and could scarcely produce any effect upon vegetation.

Experience teaches us that the same kinds of manure produce very different practical results upon different soils. It must be admitted that the composition of different soils varies considerably, and that this circumstance, no doubt, accounts to some extent for the variations in the practical results.

There are, however, many apparently similar soils, that is to say, soils in which the analysis shows like quantities of the same constituents, such as potash, soda, lime, magnesia, phosphoric, sulphuric and silicic acid, and all the elements present in the ashes of plants, in which, notwithstanding, the same kind of manure produces a different practical result. This appears to me to indicate that the analysis of soils, as usually performed by chemists, does not afford in all cases a sufficient guide to estimate their agricultural capabilities, nor to point out the kind of manure which is particularly well adapted for the special crop which we wish to raise. Even a detailed analysis of a soil gives only the proportions of the different soil-constituents, but generally without reference to the states of combination in which they exist in the soil; and is altogether silent on the property possessed by all soils, in a higher or lower degree, of effecting striking and important changes in the manuring matters which are placed upon the land.

That this property belongs to every soil has been recently shown by me and others who have investigated this subject. It has likewise been shown that some soils possess the power of modifying the composition of manures much more thoroughly than others. It is, therefore, reasonable to connect the agricultural capabilities of soils in a great measure with their power of retaining certain fertilizing matters with avidity, and of modifying others in a most interesting and unexpected manner.

It is hardly necessary to dwell upon the importance of an accurate knowledge of the inherent capacity of soils to work up, so to speak, the crude fertilizing matters into new combinations; to allow the free percolation of other—it may be less needful—substances, and to provide for a constant supply of food which is neither so soluble as to injure the produce, nor so insoluble as to remain inactive.

The investigation of the exact circumstances under which these properties manifest themselves demands our serious and immediate attention. We stand on the threshold of a wide and fertile field of research, and cannot hope to make any material progress in the practical cultivation of soils and the economy of manures until this subject has been to some extent investigated in a truly scientific manner, independently of all direct application. Useful applications will as assuredly follow from the sure establishment and clear recognition of scientific principles, as good works from the principle of Christian love deeply engraven in the heart of man.

It must, therefore, ever be the primary object of every student of nature to increase our knowledge of scientific facts, and thus to furnish the materials from which principles can be deduced. and upon which rational theories can be built. Perhaps no theory in physical science is absolutely true; nevertheless if it fulfil the chief purpose of every good theory, that is, the arrangement of existing scientific facts in a comprehensive form, and their preservation as a common inheritance to mankind, and so leads to an extension of our knowledge of material things, no theory, however erroneous subsequent researches may prove it to be, can be called vain.

No one who has carefully examined the curious and mysterious properties of soils in relation to manuring matters will hastily propound a new theory on the nutrition of plants whilst our range of observation is as limited, and our chemical facts as imperfectly ascertained, as is now the case. Such presumption would, in the end, only bring discredit upon the author.

The description of chemical facts and the proofs upon which they rest is necessarily a hard and dry subject to the uninitiated. It is nevertheless of great consequence to preserve in a Journal like that of our great national Agricultural Society faithful accounts of original researches in agricultural chemistry, however uninteresting and abstruse they may appear to the practical man.

The present communication deals chiefly with chemical facts, having a more remote but nevertheless important bearing upon practical agriculture. I wish it to be regarded as the first instalment of a series of similar researches, which will probably occupy me for the rest of my life, however long I may be permitted to retain my energies and zeal for the promotion of agricultural progress.

FIRST SERIES OF EXPERIMENTS ON THE ABSORPTION OF CAUSTIC AMMONIA.

The object I had in view in instituting this first series of experiments was simply to ascertain the quantity of ammonia which a given quantity of different soils of known composition removed from a weak solution of caustic ammonia prepared with distilled water, and to compare the results with those obtained by other observers from similar experiments on other soils.

The ammonia solution used in the subsequent experiments was of the same strength as that before used, and contained 23·24 grains of ammonia ($N\ U_3$) in the gallon, or ·332 grains of ammonia in 1000 grains of liquid.

The soils employed in these and all following experiments were:—

1. A calcareous clay.
2. A fertile loam, containing a little lime, mixed in equal proportion with the clay subsoil on which it rests.

3. The surface and subsoil of a heavy clay field, containing scarcely any sand.
4. A sterile sandy soil, containing much organic matter, and scarcely any lime.
5. Pasture land, being a vegetable mould containing abundance of organic matter and a fair proportion of sand and clay.

These soils were preferred to others for experimental purposes on account of their widely differing physical and chemical properties. They afford good examples of some of the more frequent and important varieties of British soils.

First Experiment, on Calcareous Clay.

The soil used in the first experiment contained, in 100 parts:—

Moisture	1·51
Organic matter and water of combination	11·08
Oxides of iron and alumina	14·25
Carbonate of lime	10·82
Sulphate of lime	·71
Magnesia	·51
Potash (in acid solution)	·32
Soda (in acid solution)	·05
Phosphoric acid	·10
Insoluble silicates and sand (chiefly clay)	60·65
	100·00

Submitted to a mechanical analysis it yielded:—

Moisture	1·51
Organic matter and water of combination	11·08
Carbonate of lime	10·82
Clay	52·06
Sand	24·53
	100·00

3000 grains of this soil were shaken up in a glass-stoppered bottle with 14,000 grains of ammonia solution, containing 23·24 grains of caustic ammonia in the imperial gallon. In the course of the day the bottle was repeatedly shaken, and the liquid then left to subside. After standing for three days the soil had all settled to the bottom, and the greater part of the liquid could be drawn off in a perfectly clear condition. This liquid was slightly tinged with yellow.

2000 grains of this clear liquid were then carefully neutralised with a standard solution of sulphuric acid of known strength. It being known how much of the test acid was required to neutralise the ammonia solution before contact with soil, the amount of ammonia retained in the soil could be readily calculated:—

	Ammonia. Grains.
Before contact with the soil the solution contained in 1000 grains	·332
After contact	·135
Difference	·197

·197 grains of ammonia were thus removed from each 1000 grains of solution, consequently 2·758 grains of ammonia were removed from 14,000 grains of solution and retained in 3000 grains of soil.

In this experiment accordingly 1000 grains of soil absorbed ·9193 grains of ammonia. A repetition of the same experiment gave precisely the same results. The clear liquid poured off the soil being slightly yellow, it occurred to me that the organic matter (humus acids) in the soil possibly might have neutralised a small portion of the free ammonia of the ammoniacal liquid employed in the experiment. As the test-acid cannot indicate any ammonia when previously neutralised by the organic acids of the soil, the proportion of ammonia retained by the latter may be stated rather too high. In order to verify this supposition, I distilled some of the yellow-coloured liquid with caustic potash, in an apparatus which was so constructed that all chance of traces of potash being carried over with the distillate was entirely avoided. The distillate was collected in a measured quantity of acid of known strength, and the amount of ammonia distilled over, carefully determined.

Proceeding in this manner, 1000 grains of liquid, after contact with soil, contained ·143 of ammonia. Before contact with soil it contained ·332 grains. Consequently ·189 were removed from every 1000 grains of liquid, or 2·646 were removed from the whole quantity of liquid employed in the experiment, and retained by 3000 grains of soil, or 1000 grains of soil absorbed ·882 grains of ammonia. Not taking into account the amount of free ammonia neutralised by the organic acids of the soil, 1000 grains of the latter, as we have seen, absorbed ·9193 grains of ammonia. The difference between ·9193 grains and ·882 grains is ·0373 grains, and represents the quantity of ammonia neutralised by the organic matters contained in 1000 grains of the soil. This difference is very small, but it nevertheless confirms my supposition, and at the same time affords a good proof of the delicacy of the method employed in these experiments.

Second Experiment, on Fertile Loamy Soil.

Equal parts of surface and subsoil were mixed together. The surface soil is a friable sandy loam; the subsoil is stiffer, containing less sand and more clay.

The mechanical analysis of this soil and its subsoil gave:—

	Surface-soil.	Subsoil.
Sand	76·16	55·15
Clay	18·09	41·79
Lime, magnesia, &c.	1·37	·47
Organic matter	4·38	2·59
	100·00	100·00

Submitted to detailed chemical analysis, the soil and subsoil were found to contain in 100 parts:—

	Surface-soil.	Subsoil.
Organic matter and water of combination	4·38	2·59
Alumina	2·15	5·39
Oxide of iron	3·15	7·16
Lime	·77	·26
Magnesia	·13	1·22
Potash	·49	·88
Soda	·13	·28
Phosphoric acid	·12	·19
Chlorine	trace.	trace.
Sulphuric acid	·06	·02
Carbonic acid	·31	1·79
Insoluble silicate and sand	88·31	80·24
Consisting of:—		
Silicic acid	85·11	62·61
Alumina	2·36	14·55
Lime	....	·85
Magnesia	·50	·23
Potash	·25	1·77
Soda	·09	·21
	100·00	100·00
* Containing nitrogen	·182	·09
Equal to ammonia	·220	·11

3500 grains of this soil and subsoil were mixed with 14,000 grains of the above ammonia solution, and, after repeated shakings in a well-stoppered bottle, allowed to settle for three days, by which time the liquid became perfectly clear. The greater portion of the clear solution was then drawn off, and the ammonia contained in it determined in precisely the same manner as in the preceding experiment.

	Ammonia. Grains.
Before contact with soil the solution contained in 1000 grains	·332
After contact	·115
Difference	·217

Thus we see that 217 grains were removed from each 1000 grains of liquid, or 3·038 grains from the whole liquid, and retained by 3500 grains of soil. 1000 grains of soil therefore absorbed ·868 of ammonia. By distillation the amount of ammonia in the liquid after contact with soil was found to be ·131 grains, in 1000 grains of liquid, or 2·814 grains from the whole liquid. Accordingly 1000 grains of soil absorbed ·804 grains of ammonia.

Third Experiment, on Stiff Clay Land.

The mechanical and chemical analysis of the soil and its subsoil furnished the following results:—

Mechanical Analysis.

	Subsoil.	Surface soil.
Moisture	9·46	3·91
Organic matter and water of combination ..	4·87	4·80
Sand	9·26	10·97
Lime	1·12	2·19
Clay	75·29	78·13
	100·00	100·00

Chemical Analysis.

	Subsoil.	Surface soil.
Moisture	9·46	3·91
Organic matter and water of combination ..	4.87	4·80
Oxides of iron and alumina	17·38	7·85
Phosphoric acid	·06	·04
Carbonate of lime	1·02	2·08
Sulphate of lime	·13	·15
Magnesia	·92	·32
Alkalies and loss	·45	
Insoluble siliceous matter (chiefly clay) ..	65·71	80·85
	100·00	100·00

Equal parts of soil and subsoil were mixed together, and 3500 grains of the mixture shaken up with 14,000 grains of ammonia solution, and treated as before mentioned:—

	Ammonia. Grains.
Before contact with soil the solution contained in 1000 grains	·332
After contact	·143
	·189

Consequently ·189 grains of ammonia were removed from every 1000 grains of solution, or 2·646 grains from the whole solution; 1000 grains of soil therefore absorbed ·7543 grains of ammonia.

Fourth Experiment, on Sterile Sandy Land.

100 parts of the soil, dried at 212° Fahr., contains:—

Oxide of iron and a little water of combination	5·36
Oxides of iron and alumina	5·70
Carbonate of lime	·25
Alkalies and magnesia	·49
Phosphoric acid	trace.
Sulphuric acid	·08
Soluble silica	1·01
Insoluble siliceous matter (sand)	87·11
	100·00

It will be seen that this soil hardly contains any lime and abounds in sand. It contains a good deal of organic matter, but very little clay, which will be seen by the subjoined mechanical analysis:—

Organic matter	5·36
Clay	4·57
Lime	·25
Sand	89·82
	100·00

3500 grains of this soil were mixed with 14,000 grains of ammonia solution and left to settle for three days, when the following results were obtained:—

Before contact with soil 1000 grains of ammonia solution contained	·332
After contact with soil 1000 grains contained	·063
	·269

Consequently ·269 grains were removed from every 1000 grains of solution, or 3·766 grains from whole solution.

1000 grains of soil therefore absorbed 1·076 grains of ammonia.

In a second experiment, in which the ammonia was determined by a standard solution of test-acid, in the same manner as in the first experiment, 1000 grains of soil were found to have absorbed 1·136 grains of ammonia.

In both experiments the solution, after remaining in contact with the sandy soil, had a deep yellow colour. The caustic ammonia evidently dissolved a good deal of the organic matter of the soil. The ulmic and humic acids in the soil, in uniting with ammonia, form salts, which are soluble in water, and of a brown colour. A brown coloured solution thus indicates that some of the ammonia has become neutralised by the organic matters in the soil.

The deeper coloured the ammonia solution after contact with soil, the greater will be the error which will be made if the amount of ammonia is determined in the brown-coloured liquid in a direct manner by the alkalimetrical process. Whenever the solution is distinctly coloured yellow or brown, it should be first distilled with caustic potash, in a properly-constructed apparatus, and the free ammonia be determined in the distillate.

Thus the same ammonia solution which yielded to 1000 grains of this sandy soil, according to the direct process of neutralisation, 1·076 grains of ammonia in one experiment, and 1·136 grains of ammonia in a second experiment, after distillation with caustic potash was found to contain in 1000 grains of liquid ·119 grains of ammonia; consequently, subtracting as before ·119 from ·332 grains, ·213 grains are removed from every 1000 grains of liquid, or 2·982 grains from the whole solution.

	Ammonia. Grains.
In a second distillation :—	
1000 grains of liquid were found to contain	·111
Before contact with soil the solution contained	·332
	·221

Therefore ·221 grains of ammonia were removed from every 1000 grains of liquid, or 3·094 grains from the whole quantity.

	Ammonia. Grains.
According to the first distillation :—	
1000 grains of soil absorbed	·852
According to the second distillation :—	
1000 grains of soil absorbed	·884
The mean of the two direct determinations is	1·101
The mean of the two determinations by distillation is	·868
Difference	·233

An error, amounting to one quarter of the whole of the ammonia absorbed by the soil, would therefore have been committed had the determination not been made after distilling the liquid with caustic potash.

Fifth Experiment, on Pasture Land.

The mechanical analysis of this soil yielded the following results :—

Moisture	2·42
Organic matter	11·70
Lime	1·54
Clay	48·39
Sand	35·95
	100·00

Submitted to chemical analysis it yielded:—

Moisture	2·420
Organic matter	11·700
Oxides of iron and alumina	11·860
Carbonate of lime	1·240
Sulphate of lime	·306
Phosphoric acid	·080
Chloride of sodium	·112
Potash (soluble in acid)	·910
Soluble silica	4·090
Insoluble siliceous matters	67·530
	100·248

3500 grains of this soil were shaken up in a stoppered bottle with 14,000 grains of ammonia solution, and the operation conducted in every respect in the same manner as in the preceding experiments:—

	Ammonia. Grains.
Before contact with soil 1000 grains of solution contained	·332
After contact with soil 1000 grains contained	·071
	·261

Thus, ·261 grains apparently were removed from every 1000 grains of liquid, or 3·654 grains from the whole solution. Accordingly 1000 grains of soil would have absorbed 1·044 grains of ammonia. But in reality the amount of ammonia absorbed by this soil is not so large.

A glance at the foregoing composition of the soil shows that it is rich in vegetable matter. This fully accounts for the deep brown colour which the ammonia solution assumed after contact with the pasture land. It became thus necessary to distil the liquid before determining the ammonia. The following result was obtained by distillation:—

	Ammonia. Grains.
Before contact with soil 1000 grains of liquid contained	·332
After contact " " "	·188
	·144

Therefore ·144 grains of ammonia were removed from every 1000 grains, or 2·016 from the whole solution, and taken up by the soil. 1000 grains of soil accordingly absorbed only ·576 grains of ammonia.

In the preceding experiments the following quantities of ammonia were thus absorbed by 1000 grains of—

	Ammonia. Grains.
1. Calcareous soil	·882
2. Fertile loamy soil and clay subsoil	·804
3. Heavy clay soil	·754
4. Sterile sandy soil	·868
5. Pasture land	·576

It is worthy of notice that the sterile sandy soil absorbed as much ammonia as the calcareous clay, and even rather more than the heavy clay soil, thus proving that the property of absorbing ammonia is not confined to clay soils, but that it is shared by light sandy soils.

It has been too generally assumed that sandy soils do not possess the power of retaining any ammonia; but the preceding experiments show unmistakably that this opinion is not founded on fact. If soluble manuring matters were indeed very readily washed out of sandy soils, it is certain top-dressing with nitrate of soda, or sulphate of ammonia and other soluble manures, in nine cases out of ten, would produce little or no effect upon them; for these top-dressings are usually applied at a period of the year when rain falls in abundance, and every facility is afforded for the removal of these soluble matters. Experience, however, teaches us that such top-dressings are particularly valuable on sandy soils, which could not be the case if these did not possess a power ascribed by many persons solely to clay soils. Although it is no doubt the case that heavy rains wash into the drains useful manuring matters, and that clay soils possess in a higher degree the power of retaining fertilizing substances than sandy soils, nevertheless we need not, on the approach of a heavy thunderstorm, be apprehensive that all the sulphate of ammonia or guano which may have been applied to some light sandy land only a few days ago, will be entirely washed away.

Again it may be noticed that the soil taken from the pasture, which abounds in vegetable matter, absorbed the least ammonia. The question naturally arises, Is the cause of this difference due to the presence of organic matter, or to any other peculiarity in this soil? I am unable to answer this question at present, but think it possible that the presence of a large quantity of organic acids in a soil may be unfavourable to the retention of ammonia. Future and extended experiments are needed to confirm or refute this supposition. In the mean time I may direct attention to the well-known fact, that on certain old pasture land ammoniacal manures produce little effect, whereas these manures generally increase the produce of grass in a remarkable manner. In all specimens of soil taken from old pastures, upon which ammoniacal manures have little or no effect, I find a large excess of organic matter. It is just possible that this excess of organic matter prevents the retention of ammonia by the soil; but I have no opinion at present as to the precise mode in which this is effected.

I would also notice specially that the soil employed in the third experiment was the same heavy clay soil which Mr. Mechi kindly sent to me for experimental purposes, and with respect to which I have published some filtration experiments in Part I., vol. xx. of this Journal. For the latter experiments I used liquid manure, which, in addition to a great number of chemical fertilizing matters, contained only 3·36 grains of ammonia in the imperial gallon. It might certainly have been expected that 20,000 grains of soil would have absorbed this small quantity of ammonia, the absorption even then being only at the rate of ·168 grains of ammonia to 1000 grains of soil. Notwithstanding the large quantity of clay in Mr. Mechi's soil, and the small quantity of ammonia in his liquid manure, only 1·81 grains of ammonia were absorbed by 20,000 grains of soil, and 1·55 grains remained in the liquid after three days' contact with it. In this experiment 1000 grains of soil thus absorbed only ·0905 of a grain of ammonia.

In my remarks on this experiment, I express the opinion that a stronger solution of ammonia passed through Mr. Mechi's soil would have parted with a much larger proportion of ammonia than in this experiment. The proof of this is now given. In the former experiment 1000 grains of this clay soil removed only ·0905 of a grain of ammonia from a very dilute ammoniacal liquid; in the present experiment the same quantity of the same soil absorbed about eight times as much, or ·754 grains of ammonia from the stronger solution, containing 23·24 grains of ammonia per gallon.

It must, however, be remembered, that whereas I employed in my former experiments highly complex liquids, in my present trials simple solutions of caustic ammonia were used. The quantity of ammonia which a soil is capable of absorbing must no doubt depend in some degree on the conditions under which the ammonia is present in the liquid. The preceding experiment is, therefore, not quite conclusive. In order to satisfy myself beyond doubt whether more ammonia is really removed from a stronger than from a weaker solution or not, I instituted a second series of experiments, which I must briefly describe.

SECOND SERIES OF ABSORPTION EXPERIMENTS WITH STRONGER AMMONIA SOLUTIONS.

A solution of ammonia in distilled water was prepared, containing about twice as much ammonia as that used in the first series. To speak more exactly, this stronger solution contained 47·11 grains of ammonia per gallon, or ·673 grains of ammonia in 1000 grains of liquid.

The clear ammoniacal solution having been poured off the soil as completely as was possible in each of the five experiments of the first series, the liquid remaining with the soils in the bottles was weighed, and the amount of ammonia contained in this liquid ascertained in each case by calculation:—

14,000 grains of the stronger solution, containing ·673 grains of ammonia in 1000 of liquid, were now added, and the bottle well agitated several times during the first day, the liquid being afterwards allowed to subside. After three days it became clear. A quantity sufficient for making three or four ammonia determinations was then drawn off in a perfectly clear state.

The amount of ammonia contained in the remainder of the solutions left in the soils from the first series of experiments being known, and likewise the quantity of ammonia added in the stronger solution, the ammonia in the liquid after contact with the soil determined the proportion absorbed from the stronger ammoniacal liquid.

The same plan was adopted in all five experiments, and in each experiment the same quantity of ammonia solution was used.

First Experiment (Calcareous Soil).

	Ammonia. Grains.
Quantity of ammonia left in bottle	·732
,, ,, in 1400 grains of fresh liquid ..	9·422
	10·154

1000 grains of mixed liquid contained ·531 grains of ammonia.

	Ammonia. Grains.
After contact with soil the solution contained in 1000 grains	·431
Before contact with soil it contained	·531
	·100

Consequently ·100 grains were removed from each 1000 grains of liquid, or 1·9120 grains from the entire solution employed in the experiment, and taken up by 3000 grains of soil.

1000 grains of soil thus absorbed ·6373 grains of ammonia, in addition to ·882 grains of ammonia absorbed in the 1st Experiment with a weaker solution.

The total quantity of ammonia taken up by 1000 grains of the soil in the two experiments thus amounts to 1·5193 grains.

Second Experiment (Fertile Loamy Soil).

	Ammonia. Grains.
Quantity of ammonia left in bottle	·437
,, ,, added in fresh solution	9·422
	9·859

1000 grains of mixed solution contained ·554 grains of ammonia.

After contact with the soil the solution contained in 1000 grains ·410 grains, therefore ·144 grains were removed from every 1000 grains of liquid, or 2·5632 grains from the entire solution used in the experiment, and absorbed by 3500 grains of soil; or 1000 grains of soil absorbed ·7323 grains of ammonia, in addition to ·804 grains of ammonia absorbed in the 1st Experiment, thus giving a total of 1·5363 grains of ammonia in both trials.

Third Experiment (Heavy Clay Soil).

	Ammonia. Grains.
Quantity of ammonia left in bottle	·846
,, ,, added in fresh solution	9·442
	10·288
1000 grains of mixed solution contained	·515
After contact with soil 1000 grains of solution contained	·450
	·065

Therefore ·065 grains were removed from every 1000 grains of liquid, or 1·294 grains from the entire solution, and absorbed by 3500 grains of soil.

	Ammonia. Grains.
1000 grains thus absorbed in the 2nd Experiment ..	·3697
And in the 1st Experiment	·7543
Or in both Experiments	1·1240

Fourth Experiment (Sterile Sandy Soil).

	Ammonia. Grains.
Quantity of ammonia left in bottle	·414
,, ,, added in fresh solution	9·442
	9·856
For 1000 grains of mixed solution there was	·562
And after contact with soil	·431
	·131

Thus ·131 grains were removed from every 1000 grains of solution, or 2·290 grains from the entire solution, and taken up by 3500 grains of soil.

	Ammonia. Grains.
1000 grains of soil, therefore, absorbed in 2nd Experiment	·654
And in 1st Experiment	·868
Or in both Experiments	1·522

Fifth Experiment (Pasture Land).

	Ammonia. Grains.
Quantity of ammonia left in bottle	·926
,, ,, added in fresh solution	9·422
	10·348
1000 grains of mixed solution contained	·546
And after contact with the soil	·370
	·176

Therefore ·176 grains were removed from every 1000 grains of liquid of 3·331 grains from the entire quantity of liquid used in the experiment and absorbed by 3500 grains of soil.

	Ammonia. Grains.
1000 grains of this soil thus absorbed in the 2nd Experiment	·9457
After having taken up in the 1st Experiment	·576
Or in both experiments 1000 grains of soil absorbed ..	1·5217

Thus in each case the soils absorbed a considerable quantity of ammonia from the stronger solution with which they were brought into contact after having taken up a certain variable quantity from a weaker solution.

It is singular that whilst the proportion of ammonia removed by each of these five soils varied considerably in the first series of experiments with the weaker ammonia solution, the total quantity of ammonia absorbed by 1000 grains of soil in both experiments is almost identical in four of the soils, and but little less in the remaining one. Thus the total amount of ammonia absorbed by 1000 grains of soil was in the case of the—

	Ammonia. Grains.
1. Calcareous soil	1·5193
2. Fertile loamy soil	1·5363
3. Clay soil	1·1240
4. Sterile sandy soil	1·5220
5. Pasture land	1·5217

It will be seen that the soil from a permanent pasture absorbed much more ammonia in the 2nd Experiment than in the first, so that the total quantity of ammonia absorbed in the two together is nearly identical with that absorbed by the other soils.

I have shown that this soil contained much organic matter (humic acids), and that a portion of this organic matter united with ammonia passed into solution in the 1st Experiment, imparting to it a deep yellow colour. In the 2nd Experiment with a stronger ammonia solution the liquid was but little coloured. It appears thus that, comparatively speaking, little ammonia was fixed in the soil in the 1st Experiment, because the organic acids in this soil uniting with the ammonia of the weaker solution, produced soluble combination before insoluble compounds of ammonia could be formed in the soil in as large a proportion as in the other soils containing much less organic matter.

The organic acids of the pasture soil were apparently removed in the 1st Experiment, and thereby the soil acquired increased powers of absorbing ammonia from the stronger solution used in the 2nd Experiment.

THIRD SERIES OF EXPERIMENTS.

Although the preceding experiments show distinctly that soils, no matter of what character, absorb more ammonia from strong than from weak solutions, and that however weak the solution may be, the total amount of ammonia which it may contain is never wholly absorbed by the soil, it appeared to me desirable to place these facts beyond a doubt by further experiments. I therefore instituted a fresh series, in which one and the same soil was used throughout. This soil was found, on analysis, to contain in 100 parts:—

	Ammonia. Grains.
Moisture	4·72
Organic matter and water of combination	11·03
Oxides of iron	9·98
Alumina	6·06
Carbonate of lime	12·10
Sulphate of lime	·75
Alkalies and magnesia (determined by loss)	1·43
Soluble silica (soluble in dilute caustic potash)	17·93
Insoluble siliceous matter (chiefly clay)	36·00
	100·00

An inspection of the analysis shows that this soil contains a good deal of clay and of carbonate of lime. It is in fact a calcareous clay, of a moderately stiff and retentive physical character.

Four solutions of caustic ammonia in distilled water were carefully prepared:—

	Grains of Ammonia per Gallon.		Per 1000 Grains.
Solution No. 1 contained	44·38	or	·634
,, No. 2 ,,	21·28	or	·304
,, No. 3 ,,	12·32	or	·176
,, No. 4 ,,	6·16	or	·088

In each experiment 7000 grains of the respective liquids were repeatedly agitated in a tight-fitting glass-stoppered bottle, with ¼ lb. of soil. The liquid was then allowed to subside for four days, after which time it became perfectly clear. The ammonia in the clear liquids was then determined by the process described in the preceding pages, and the following results were obtained:—

1.—*Experiment with Solution No.* 1.

	Ammonia. Grains.
Before contact with soil the solution contained	4·438
After contact ,, ,, ,,	2·128
	2·310

Therefore 2·310 grains of ammonia were absorbed by 1750 grains of soil, or 1000 grains absorbed 1·32 grains of ammonia.

2.—*Experiment with Solution No.* 2.

	Ammonia. Grains.
Before contact with soil the solution contained	2·128
After contact ,, ,, ...	1·008
	1·120

Therefore 1·120 grains of ammonia were absorbed by 1750 grains of soil, or 1000 grains absorbed ·64 grains of ammonia.

3.—*Experiment with Solution No.* 3.

	Ammonia. Grains.
Before contact with soil the solution contained	1·232
After contact ,, ,, ...	·777
	·455

Thus ·455 grains of ammonia were absorbed by 1750 grains of soil, or 1000 grains absorbed ·26 grains of ammonia.

4.—*Experiment with Solution No.* 4.

Before contact with soil the solution contained	·616
After contact ,, ,, ...	·441
	·175

Therefore ·175 grains of ammonia were absorbed by 1750 grains of soil, or 1000 grains of soil absorbed ·100 grains of ammonia.

According to the strength of the different solutions 1000 grains of soil thus absorbed in—

	Ammonia. Grains.
No. 1	1·32
No. 2	·64
No. 3	·26
No. 4	·10

Not only is the absolute quantity of ammonia which this soil absorbs from an ammoniacal solution larger as the solution employed is stronger; but very dilute solutions are relatively less exhausted by it than stronger ones.

Thus, whilst in the two first experiments, in round numbers, one-half of the ammonia contained in the solutions was absorbed, in the 3rd Experiment about one-third, and in the 4th only about one-fourth of the ammonia was retained by the soil.

In the next place I made some additional experiments for the purpose of ascertaining whether this soil, after having taken up as much ammonia as it will from a weaker solution, would take up more from a stronger one.

Experiment 5.

The solution left in the bottle from Experiment No. 2 was drawn off as much as possible, the liquid remaining with the soil was ascertained by weighing, the amount of ammonia in it calculated, and 7000 grains of solution No. 1, containing 4·438 grains of ammonia added.

The quantity of liquid left in the bottle was 2070 grains, and contained ·298 grains of ammonia, the fresh quantity of stronger solution added 7000 grains, containing 4·438 grains.

The total solution weighed 9070 grains, and contained 4·736 grains of ammonia; 1000 grains of this solution, therefore, contained ·522 grains of ammonia. After standing for four days, the liquid was drawn off and the strength determined as before. This solution contained ·320 grains of ammonia.

	Ammonia. Grains.
Before contact with soil 1000 grains of solution contained	·522
After contact ,, ,, ,, ..	·320
	·202

Thus ·202 grains of ammonia were removed from every 1000 grains of solution. From the whole solution (weighing 9070 grains) consequently 1·83214 were removed and retained by the soil (1750 grains), which had already taken up 1·120 grains from the weaker solution.

	Ammonia. Grains.
1000 grains of soil therefore absorbed in the 2nd Experiment	1·047
And had previously absorbed	·640
	1·687

Or 1000 grains of soil absorbed from both solutions 1·687 grains of ammonia.

In a similar manner the following experiments were made:—

Experiment 6.

There was added to the contents of the bottle used in Experiment No. 3, 5000 grains of solution No. 2, containing ·304 grains ammonia in 1000 of liquid.

	Ammonia. Grains.
Before contact with soil 1000 grains of the mixed solutions contained	·237
After contact with soil 1000 grains of the solution contained	·127
	·110

Therefore ·110 grains were removed from every 1000 grains of liquid, or ·836 grains from entire solution, and retained by 1750 grains of soil, which had already taken up ·455 grains from the weaker solution. 1000 grains of soil therefore absorbed in 2nd Experiment ·477 grains, in addition to ·260 grains absorbed from the weaker solution, or from both solutions ·737 grains of ammonia were removed and retained by 1000 grains of soil.

Experiment 7.

The solution left in the bottle from Experiment No. 4 was drawn off as thoroughly as possible; 7000 grains of solution No. 3, containing ·176 grains of ammonia in 1000 of liquid, were then added, and after repeated shakings the whole was left to settle for four days.

	Ammonia. Grains.
Before contact with soil 1000 grains of the mixed solutions contained	·147
After contact with soil 1000 grains of the solution contained	·096
	·051

Therefore ·051 grains of ammonia were removed from every 1000 grains of liquid, or ·480 grains from the whole solution, and retained by 1750 grains of soil, which had already taken up ·175 grains of ammonia from the weaker solution.

	Ammonia. Grains.
1000 grains of soil thus absorbed from the weakest solution	·100
From the stronger solution	·274
	·374

Or in both experiments ·374 grains were removed and retained by 1000 grains of soil.

Thus in all cases much more ammonia was removed from the stronger solutions than from the weaker, and was retained by the soil in addition to the quantity previously absorbed from the weaker solution. Thus the total amount of ammonia absorbed by 1000 grains of soil was in—

	Ammonia. Grains.
Experiment No. 5	1·687
,, No. 6	·737
,, No. 7	·374

It will be observed that in Experiment No. 1, 1000 grains of soil removed 1·32 grains of ammonia from the strongest solution. The same solution, taken in the same quantity as in Experiment No. 1, and left in contact with soil which had already absorbed ·64 grains of ammonia, removed an additional quantity of 1·047 grains, or altogether 1·687 grains.

It thus appears not only that the strength of the solution influences the amount of ammonia which can be retained by the soil, but likewise that the quantity of liquid which is passed through a soil will affect the proportion which a soil is capable of abstracting from a given solution.

From a *large quantity* of an ammoniacal liquid it appears to me likely that a definite quantity of soil will remove more ammonia than from a smaller amount of liquid of the same strength.

I have not, as yet, made many experiments in this direction. These are urgently needed, for it is clear that we cannot calculate with any degree of certainty the amount of loss in ammonia to which ammoniacal manures are subject in contact with soil, as long as we are not fully acquainted with the exact conditions under which this most interesting chemical property of soils manifests itself.

FIFTH SERIES.—AMMONIA RETENTION EXPERIMENTS.

In the preceding experiments it has been shown that all the soils experimented upon possess the power of absorbing ammonia; further, that all the soils absorbed more ammonia from a more concentrated than from a weaker solution; and, lastly, that in no instance was the ammonia entirely removed from a solution brought into intimate contact with soil. Even in the case of heavy clay soils, and when very dilute ammoniacal solutions were employed, ammonia invariably remained in solution. These facts not only explain the different results which must be obtained in experimenting upon the same kind of soil with solutions of different strength, but they also prove incontestably that the compounds which, no doubt, are produced in almost every description of soil, when ammoniacal solutions are brought into contact with them, are not entirely insoluble, as has been supposed, but sufficiently soluble in water to benefit the growing crops, which we have no reason to suppose take up food from the soil in any other than a soluble state.

Notwithstanding the power of soils to absorb ammonia, this fertilizing constituent is not fixed by the soil so completely or permanently as to be of no avail to the growing plant. The possibility also exists that long-continued and heavy rains may wash out more or less completely the ammonia previously absorbed by soils. Hence the invariable presence of ammonia in spring waters.

An important question is naturally started by these curious properties of soils. It is this: Is the power of soils to retain ammonia greater, and if so to what extent, than the tendency to yield it again to water passed through the soil?

In order to facilitate the solution of this question I instituted a Fifth Series of Experiments, which, under the title of "Ammonia Retention Experiments," I shall now endeavour briefly to describe.

The soil used in these experiments was the same as that employed in the Fourth Series.

1*st Experiment.*—A strong solution of pure ammonia in distilled water was prepared, and its strength accurately determined. An imperial gallon contained 194·39 grains of ammonia, or 1000 grains 2·777 grains. ¼ lb. soil (1750 grains) was placed in a well-stoppered bottle, and 7000 grains of the ammonia solution of the above strength were added. The bottle and contents were repeatedly shaken, and then the whole left to subside for three days. The clear liquid was drawn off and weighed, and its strength determined in the usual way.

	Ammonia. Grains.
Before contact with the soil 1000 grains of the solution contained	2·777
After contact	2·112
	·665

Thus ·665 grains of ammonia were removed from every 1000 grains of solution, or 4·655 grains were removed from the whole solution employed (7000 grains) and retained by 1750 grains of soil. 1000 grains of soil consequently absorbed 2·66 grains of ammonia. The quantity of liquid drawn off weighed 4916 grains, and contained 10·382 grains of ammonia.

The residue in the bottle was next shaken up with 7000 grains of distilled water; after three days the clear liquid was drawn off, weighed, and its strength determined as before. 1000 grains of the liquid were found to contain ·510 grains of ammonia. The amount of liquid left in the bottle before the addition of 7000 grains of water, and its strength, being known, this result will show whether or not the addition of water has had any effect upon the ammonia retained by the soil from a strong ammoniacal solution.

Had the effect of the water simply resulted in the dilution of the ammonia-solution, which could not be poured off from the soil in a clear state, its strength would have been ·484 grains of ammonia in every 1000 grains; but it was ·510 grains of ammonia, consequently ·026 grains of ammonia were removed by every 1000 grains of liquid, or ·236 grains by the whole quantity of liquid employed in the experiment, from 4·655 grains of ammonia previously absorbed by ¼ lb. of soil.

2*nd Experiment.*—7000 grains of distilled water were added to the residue in the bottle from the preceding experiment, and after three days the clear liquid was drawn off, weighed, and the strength determined. 1000 grains of liquid contained ·192 grains. If this second addition of water had not acted upon the ammonia absorbed by the soil in the preceding experiment, 1000 grains of liquid would have contained ·121 of ammonia; consequently ·071 of ammonia were extracted by every 1000 grains of liquid, or ·642 grains by the whole liquid, from the ammonia which the soil retained after having been once washed with 7000 grains of water.

3rd Experiment.—7000 grains of distilled water were added to the residue left in bottle from the 2nd Experiment, and treated as before. 1000 grains of clear liquid contained ·111 grains of ammonia. If no ammonia had been extracted by this third addition of water, 1000 grains of liquid would have contained ·044 of ammonia, instead of ·111 grains; consequently ·067 grains of ammonia were extracted by every 1000 grains, or ·61 grains by the whole liquid from the soil, after having been washed twice before with water.

4th Experiment.—To the residue left in bottle from 3rd Experiment 7000 grains of distilled water were again added, and the bottle put aside for two months. After that time the clear liquid was drawn off, weighed, and its strength determined. 1000 grains of liquid contained ·096 grains of ammonia. Had no ammonia been extracted from the soil it would have contained ·037 grains of ammonia in 1000 grains; accordingly ·059 of ammonia were extracted by every 1000 grains of liquid, or ·622 grains by the entire liquid. This quantity, it will be observed, is almost identical with that extracted in the 3rd Experiment.

5th Experiment.—After a fresh addition of 7000 grains of distilled water, 1000 grains of liquid contained ·040 grains of ammonia. Had no ammonia been extracted from the soil it would have contained ·028 grains; therefore ·012 grains were extracted by every 1000 grains of liquid, or ·120 grains by the entire solution.

6th Experiment.—After a fresh addition of 7000 grains of distilled water 1000 grains of liquid contained ·029 grains of ammonia. If no ammonia had been extracted 1000 grains of liquid would have contained ·006 grains; therefore ·023 grains of ammonia were extracted by every 1000 grains, or ·193 grains by the entire quantity of liquid.

7th Experiment.—7000 grains of distilled water were, for the seventh time, added to the residue left in the bottle from the 6th Experiment, and treated as before. 1000 grains of liquid contained ·031 grains of ammonia. Had no ammonia been extracted they would have contained ·005 grains of ammonia; thus ·026 grains of ammonia were extracted from the soil by every 1000 grains, or ·228 grains from the entire liquid.

Let us then add up the quantities of ammonia removed by these successive washings with water:—

Experiment.			Ammonia. Grains.
1st.	Removed by 7000 grains of water	.. ..	·236
2nd.	,, ,,	.. ..	·642
3rd.	,, ,,	.. ..	·610
4th.	,, ,,	.. ..	·622
5th.	,, ,,	.. ..	·120
6th.	,, ,,	.. ..	·193
7th.	,, ,,	.. ..	·228
	Total	.. ..	2·651

Thus ·2651 grains of ammonia were removed by 49,000 grains of water from ¼ lb. of soil. This quantity of soil absorbed from a strong ammoniacal solution 4·655 grains of ammonia. By deducting 2·651 grains of ammonia, *i. e.* the amount washed out by seven successive washings, with 7000 grains of water each, we obtain 2·004 as the quantity of ammonia which was retained by the soil, after all the washings with water.

More than half the ammonia originally absorbed by the soil was thus again removed by washing with water.

It appears thus distinctly that the *power of soils to remove ammonia from solutions is very much greater than their property of yielding it again to water.*

Indeed even a very much larger quantity of water than that which falls annually upon our fields in the shape of rain is incapable of washing out of the soil such a proportion of ammonia, as can be of any account in relation to the quantities incorporated with it in the shape of natural or artificial manures. In the experiments before us the weight of water which was passed through the soil was twenty-eight times as large as the weight of the soil, and yet little more than half the quantity of ammonia absorbed by the latter was extracted by this immense amount of water. In nature such excessive washings by rain are not likely to occur; we need not therefore fear that the ammonia absorbed by the soil we cultivate will be removed by the most heavy rain-storms to anything like the extent in which it was removed in my experiments.

At the same time it is well to remember that each shower of rain renders soluble some ammonia which may have been previously absorbed by the soil. The best fertilizing matters, if presented to plants in great abundance, exercise an injurious effect upon their growth, or, at any rate, favour an unhealthy development of one part of the vegetable organism at the expense of another. Thus wheat or barley grown on a dung-heap becomes rank and attains a great size, but will hardly flower, and never produce any grain. This is accounted for by the fact that farm-yard manure contains far too much soluble manuring matters to be beneficial to the healthy development of the crops which we cultivate.

It is one of the functions of soils to check the accumulation of soluble fertilizing matters, and this function it performs in many instances by rendering insoluble, or, to speak more correctly, by greatly reducing the solubility of those important fertilizing matters which would otherwise induce an unhealthy or abnormal growth of plants. Considering the structure of the spongioles of the roots of plants we readily comprehend how important it is that such matter should be able to find its way into the vegetable organism. Whilst thus it is the particular function of the soil to prevent the loss of ammonia from manures, such as guano, sulphate of ammonia, &c., which we are in the habit of applying to the land, provision is made that the ammonia, when it becomes fixed by the soil, should not be rendered so entirely insoluble as to be of no direct benefit to plants.

In short, all soils, clay as well as sand, store up ammonia with great eagerness, and part with it reluctantly.

SIXTH SERIES.—ABSORPTION OF AMMONIA FROM A SOLUTION CONTAINING CHLORIDE OF AMMONIUM.

In this series of experiments I endeavoured to ascertain the amount of ammonia which soils of known composition absorb from a standard solution of sal-ammoniac in water.

The solution used in the following experiment contained 79·80 grains of chloride of ammonium in the imperial gallon, or 25·20 grains of ammonia; or 1000 grains of this solution contained 1·14 grains of chloride of ammonium, or ·36 grains of ammonia.

The soils experimented upon were the same as those used in the First Series of Experiments, namely :—

1. A calcareous clay.
2. A fertile loam.
3. Stiff clay soil.
4. Sterile sandy soil.
5. Pasture land.

In each case 3500 grains of soil were mixed with 14,000 grains of a solution of chloride of ammonium, containing ·36 grains of ammonia in 1000 grains of liquid. After standing three days the clear liquid was drawn off, and the ammonia contained in it obtained by distillation with caustic potash. The operation was conducted in each case alike, and the following results were obtained :—

		Ammonia. Grains.
No. 1.	1000 grains of soil absorbed	·68
No. 2.	,, ,, ...	·76
No. 3.	,, ,, ...	·80
No. 4.	,, ,, ...	·16
No. 5.	,, ,, ...	·64

It will be noticed that the proportions of ammonia which are absorbed by the five different soils from a solution of sal-ammoniac, containing 79·80 grains of this salt in an imperial gallon, vary considerably.

In the case of the sandy soil very little ammonia indeed was absorbed. This is rather singular, since the same sandy soil absorbed a good deal of ammonia on being brought into contact with a dilute solution of free ammonia.

We thus see that a soil may absorb free ammonia in considerable quantities, and yet not have the power of separating and fixing ammonia from an ammoniacal salt, such as sal-ammoniac.

SEVENTH SERIES.—ABSORPTION OF AMMONIA FROM A SOLUTION OF SULPHATE OF AMMONIA.

A solution of sulphate of ammonia was prepared, containing 77·70 grains of sulphate of ammonia per imperial gallon, or 20·16 grains of ammonia. 1000 grains of liquid therefore contained ·288 grains of ammonia. The same soil was used in this as in the preceding Series of Experiments. In each case 3500 grains of soil were shaken up in a well-stoppered bottle with 14,000 grains of the solution of the above strength. In these experiments—

		Ammonia. Grains.
No. 1.	1000 grains of soil absorbed	·608
No. 2.	,, ,, ...	·640
No. 3.	,, ,, ...	·576
No. 4.	,, ,, ...	·256
No. 5.	,, ,, ...	·448

Here again the sandy soil absorbed but very little ammonia. There seems thus to be something or other wanting in this soil which prevents it from exercising a decomposing influence upon ammoniacal salts similar to that manifested by the four other soils. I am informed that farmyard manure, guano, and other fertilizers of recognized value, produce little effect upon the crops growing on this sterile sandy soil.

EIGHTH SERIES.—RETENTION OF AMMONIA FROM A SOLUTION OF SULPHATE OF AMMONIA.

In the Fifth Series of experiments I have shown that a soil which absorbed a certain quantity of free ammonia from a tolerably strong solution with which it was brought into contact, again yielded small quantities of ammonia to repeated washings of distilled water.

It appeared to me desirable to ascertain whether similar results would be obtained on washing a soil which had absorbed a certain quantity of ammonia from a solution of sulphate of ammonia.

To this end, I prepared a solution of sulphate of ammonia, which contained 188·720 grains of ammonia in the gallon, or 2·696 grains of ammonia in 1000 grains of liquid. ¼ lb. (1750 grains) of calcareous soil used in First Series was mixed in a stoppered bottle with 7000 grains of this solution, then left at rest for three days, after which the clear liquid was drawn off, and the ammonia contained in it determined by distillation :—

	Ammonia. Grains.
Before contact with soil 1000 grains of solution contained ..	2·696
After contact ,, ,, ,,	2·000
	·696

Therefore ·696 grains of ammonia were removed from every 1000 grains of liquid, or 4·872 grains were removed from the whole solution, and retained by 1750 grains of soil; 1000 grains of soil thus absorbed 2·784 grains of ammonia.

A comparison of this result with the amount of ammonia absorbed from sulphate of ammonia in the preceding experiments, shows that much more ammonia is removed by soil from the stronger ammoniacal solution than from the weaker one.

The liquid was drawn off as much as possible, and the amount of that which could not be removed ascertained by weight; 7000 grains of pure distilled water were next added; after three days the clear liquid was drawn off and weighed, and the ammonia in it determined by distillation in the usual way.

Proceeding in this manner, the soil which had absorbed 4·872 grains of ammonia from a strong solution of sulphate of ammonia was washed five times with 7000 grains of water each time :—

	Ammonia. Grains.
The first washing removed	·278
The second ,, ,, ...	·633
The third ,, ,, ...	·813
The fourth ,, ,, ...	·416
The fifth ,, ,, ...	·242
	2·382

35,000 grains of water, or ½ gallon, thus removed 2·382 grains of ammonia from the soil, which had absorbed 4·872 grains of ammonia. At the conclusion of the experiment the quantity of ammonia which remained in ¼ lb. of soil amounted to 2·490 grains, or very nearly half the quantity which it absorbed in the first place.

These results are conformable with those obtained in the Retention Experiments, where a solution of free ammonia was employed.

NINTH SERIES.—RETENTION OF AMMONIA FROM A SOLUTION OF CHLORIDE OF AMMONIUM.

The soil used in this series of experiments was the same as that employed in the Third Series.

The solution of sal-ammoniac contained 211·40 grains of ammonia in the gallon, or 3·02 grains in 1000 of liquid. ¼ lb. of soil and 7000 grains of solution of sal-ammoniac of this strength, were mixed together, and the amount of ammonia absorbed by the soil ascertained as before. The whole quantity of soil absorbed in this experiment 5·60 grains of ammonia. 1000 grains thus separated 3·20 grains of ammonia from the solution of sal-ammoniac.

Here again we observe that the amount of ammonia which a soil is capable of removing from solutions of ammoniacal salts depends upon the strength of the liquid with which it is brought into contact.

The soil was next washed four times with 7000 grains of water, and the proportion of ammonia removed in each washing determined as before:—

	Ammonia. Grains.
The first washing removed	·409
The second ,, ,, ...	·646
The third ,, ,, ...	·811
The fourth ,, ,, ...	·499
	2·365

28,000 grains of water thus removed 2·365 grains of ammonia from ¼ lb. of soil, which in the first place absorbed 5·60 grains of ammonia from a strong solution of sal-ammoniac. After washing with a considerable quantity of water, the soil thus retained 3·235 grains of ammonia, instead of 5·60 grains.

Thus,whether a soil has absorbed free ammonia, or ammonia from a solution of sulphate of ammonia or sal-ammoniac, water passed through it will wash out a certain quantity of ammonia. But in each case the power of a soil to retain ammonia is very much greater than its inclination to yield it again to water.

It is hardly necessary to remind the reader that in the absorption experiments with salts of ammonia the acid of the salt passes through the soil in combination with lime or other mineral matters of the soil, whilst the ammonia alone is retained. I may notice, however, that the watery liquid which passes through a soil when solutions of ammoniacal salts are filtered through it, contains a larger quantity of *mineral* matters than is the case when *pure* water is filtered through the soil. It would thus appear that ammoniacal salts have the property of rendering the mineral matters of the soil soluble. But the details of experiments on this subject, and an account of their bearing on agriculture, must be reserved for a future communication.

In conclusion, the more prominent and practically interesting points which have been developed in the preceding pages may be briefly stated in the following

SUMMARY.

1. All the soils experimented upon have the power of absorbing ammonia from its solution in water.

2. The sandy soil absorbed as much ammonia as the clay soil.

3. The pasture land, and probably many other soils rich in organic matter, retain less ammonia than soils in which organic matter does not occur in excess.

4. The differences between sandy, calcareous, and clay soils, in their power of absorbing ammonia, is not so great as is generally believed.

5. Ammonia is never completely removed from its solution, however weak it may be. On passing a solution of ammonia, whether weak or strong, through any kind of soil, a certain quantity of ammonia invariably passes through. No soil has the power of fixing completely the ammonia with which it is brought into contact.

6. In the preceding experiments all the soils absorbed more ammonia from the stronger than from the weaker solution; that is to say, the absolute quantity of ammonia which is absorbed by a soil is larger when a stronger solution of ammonia is passed through it. But, relatively, weaker solutions are more thoroughly exhausted than stronger ones.

7. Soils containing much organic matter (humic acids) at first absorb less ammonia from weak solutions than others poor in vegetable matter. But subsequently they take up more ammonia if it is presented to them in stronger solutions.

8. A soil which has absorbed as much ammonia as it will from a weak solution, takes up a fresh quantity of ammonia when it is brought into contact with a stronger ammoniacal solution.

9. All the soils not only absorbed free ammonia, but likewise removed a certain quantity from solutions of ammoniacal salts.

10. In passing sulphate of ammonia or sal-ammoniac through a soil, the ammonia alone is absorbed, and the acids pass through in combination with lime or other mineral matters.

11. A larger proportion of mineral matter is dissolved in a soil when dilute solutions of ammoniacal salts are filtered through it than is the case with pure water.

12. Soils absorb more ammonia from stronger than weaker solutions of sulphate of ammonia and chloride of ammonium.

13. Not only the *strength*, but likewise the *quantity* of the ammoniacal solution which is brought into contact with a soil,

appears to influence the amount of ammonia which the latter is capable of retaining.

14. In no instance is the ammonia absorbed by soils from solutions of free ammonia, or from ammoniacal salts, so completely or permanently fixed, as to prevent water from washing out appreciable quantities of the ammonia.

15. The proportion of ammonia, however, which is removed in the several washings, is small in proportion to that retained by the soil.

16. *The power of soils to absorb ammonia from solutions of free ammonia, or from solutions of sulphate of ammonia or chloride of ammonium, is thus greater than the power of water to redissolve it.*

17. In practice no fear need be entertained that in ordinary years heavy showers of rain will remove much ammonia from ammoniacal top-dressings, such as sulphate of ammonia, soot, guano, and similar manures, which are used by farmers for wheat, barley, and oats.

18. On the other hand, in very rainy seasons, appreciable quantities of ammonia may be removed from land top-dressed with ammoniacal manures, even in the case of stiff clay soils.

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ON THE COMPOSITION

OF

PURTON SALINE WATER.

BY AUGUSTUS VOELCKER, PH. D.

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NOTICING that Dr. Noad intends reading on the 17th December, 1860, a paper on the analysis of Purton saline water, I beg likewise to communicate an analysis of that water, which I made for the proprietor in October, 1859.

The following are the direct results of the analysis. An imperial gallon contains:—

	Grains.
Organic matter and water of combination (being loss obtained on heating residue, dried at 320°F)	8·750
Lime	34·536
Magnesia	25·736
Oxides of iron and alumina, with traces of phosporic acid	·280
Potash	20·707
Soda	49·006
Chloride of sodium	34·297
Sulphuric acid	165·074
Soluble silica	1·280
Iodine	0·056
Bromine	·080
Carbonic acid	33·090
Sulphuretted hydrogen	traces
Specific gravity of water	1·0045

These constituents arranged into compounds give the following results:—

	Grains per imp. gal.
Organic matter and water of combination (loss on drying residue at 320°F)	8·750
Sulphate of soda	112·239
Sulphate of magnesia	77·208
Bromide of magnesium	·092
Iodide of sodium	·066
Chloride of sodium	34·297
Sulphate of lime	83·873
Sulphate of potash	1·916
Carbonate of potash	28·880
Oxides of iron and alumina with traces of phosphoric acid	·280
Silica	1·280
Solid residue, dried at 320°F per imperial gallon	348·881
Free carbonic acid	23·820

Dr. Noad has communicated his results to me. They differ materially from mine. But the fact that the water analysed by Dr. Noad contains a great deal more solid matter than the water analysed by me, shows sufficiently that we examined two different specimens of Purton water. I have determined at various times the amount of residue which is left on evaporation, and find great differences in the total amount of total saline matters. Probably the composition of the saline residue varies at different seasons, and the water, like other saline waters obtained only in limited quantities, is not always of the same composition.

With respect to the arrangement of the direct results of the analysis into compounds, I beg to observe that I have purposely united carbonic acid with potash and not with lime. In his arrangement of results, Dr. Noad does not give any alkaline carbonates. The Purton water, which I examined, however, contains alkaline carbonates, for it exhibits a strong alkaline reaction to litmus paper, even before evaporation.

It is of course impossible to say what proportions of the carbonic acid and sulphuric acid are united with lime and the alkalies, and I have deviated from the ordinary mode of uniting acids and bases together, because the Purton water in its natural condition really contains alkaline carbonates.

ON THE

COMPOSITION OF THE YELLOW LUPINE,

AND A

SOIL SUITABLE TO ITS CULTURE.

BY DR. AUGUSTUS VOELCKER.

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1861.

FROM THE

JOURNAL OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND.

VOL. XXI., PART II.

ON THE

COMPOSITION OF THE YELLOW LUPINE, &c.

The yellow lupine (*Lupinus luteus*), a well-known ornamental plant of our flower-gardens, is now extensively cultivated as a field-crop in several parts of Germany, France, and Belgium; more especially it is largely seen in the sandy districts of Northern Germany and Prussia, where it is considered a very important crop to the farmer, inasmuch as it will thrive luxuriantly on poor, blowing sands, upon which no other leguminous crop can be grown.

A short account of the manner in which this new field-crop is grown in Germany will be found in vol. xx. (1859) of the R. A. S. Journal. It appears from this account, given by Baron Herman von Nathusius, of Hundisburg, near Magdeburg, that two distinct species of lupine, the yellow and the blue, are grown in Prussia. The yellow lupine (*Lupinus luteus*), being more succulent and covered with more and larger leaves than the blue (*Lupinus angustifolius*, Linn.), is generally preferred to the latter, especially if grown as green food, and not for seed.

Lupines are grown in Germany principally for the sake of the seeds, which, like those of all leguminous plants, constitute a very nutritious food, and in their composition and nutritive qualities, as far as these have been ascertained, do not differ much from peas and lentils.

Occasionally the yellow lupine is grown as a green manure. It is considered very useful for that purpose.

More rarely lupines are grown in Germany for the sake of affording green food to sheep and cattle. For this latter purpose I think, however, the yellow lupine is well adapted. If I am not mistaken, the field-culture of lupines will, if at all practicable in this country, be found chiefly valuable as a source of green nutritious food for sheep and cattle, on soils upon which clover and the finer and more nutritious kinds of grasses either refuse to grow altogether, or only furnish a scanty supply of inferior green food.

The English agricultural community is indebted to Mr. Thomas Crisp, of Butley Abbey, for the publication of Baron Nathusius' account respecting the cultivation of lupines in Germany. This gentleman, as far as I know, was the first who, in 1858, successfully attempted their introduction as a field-crop in this country. Mr. Crisp speaks very highly of their importance to the farmer, and strongly commends their cultivation to the notice of the occupiers of light sandy soils. This recommendation has not been made in vain; and I have now the pleasure of communicating the results of an experimental trial undertaken by my friend and former pupil, Mr. James Kimber, of Tubney Warren, Oxfordshire.

At my request, and in answer to many questions relating to the cultivation, and practical feeding value of lupines, the character of his land, &c., Mr. Kimber has kindly addressed to me a letter, which contains much valuable information on these and a few other topics interesting to the practical agriculturist.

I make no apology for appending to this paper Mr. Kimber's interesting communication, assured that it will be read with pleasure and profit by many who have to deal with poor, sandy land, on which clover will not grow even once in eight years, turnips either fail altogether or become affected by anbury and fingers-and-toes, and on which it is next to impossible to grow a fair average corn-crop.

The detailed account given by Mr. Kimber relieves me of the necessity of myself describing the experimental trial. But I may observe that the trial was intended to test the comparative merits of lupines as a green food and as a crop grown for the sake of its seed.

Unfortunately the dry weather at the time of sowing in the spring, and the subsequent cold and wet summer, so much retarded the blossoms that all hope of carrying out the experiments as originally intended had to be given up. The seeds of the lupine ripen very unequally, especially in wet seasons, when it is not unusual to see almost ripe seed-pods and yellow blossoms on the same plant. Though a quantity of ripe seed-pods were gathered, yet by far the larger portion of the plants did not ripen their seed this season, and therefore the experiment was necessarily confined to testing the feeding value of the green lupines, as well as this could be done in one season, by weighing the produce in green food, and ascertaining its chemical composition.

The lupine plants submitted to analysis were cut down on the 24th of September. They were nearly 4 feet high and full of yellow blossoms. The lower part of the central stem was hard and woody, so much so that sheep would not have eaten it. The tops were quite soft and succulent, and there were plenty of leaves and tender side-shoots on the central stems.

It appeared to me desirable to ascertain by weight the portion of the plants which would probably be rejected by animals, and that likely to be consumed by them.

I therefore detached the leaves and soft tops from the woody stems, taking about 6 inches of tops, and thus separated the green plants into :—

	Parts.
Woody stems	29·5
Leaves and soft tops (6 inches)	70·5
	100·0

If anything, the proportion of woody stems is rather over than under estimated, for, as stated, only 6 inches of the top were cut off; I think it likely, therefore, that some of the woody stems would be eaten by sheep or cattle.

A water-determination of the green lupine plants gave 89·20 per cent., and an ash-determination, 80 per cent. of ash on an average.

The amount of nitrogen in the green plants was found to be ·38 per cent. Accordingly lupine plants, cut down green, consist, in 100 parts, of :—

	In Natural State.	Dried at 212° F.
Water	89·20	..
Dry matter :—		
*Organic	10·00	92·58
Inorganic	·80	7·42
	100·00	100·00
*Containing nitrogen	·38	3·51
Equal to albuminous compounds	2·38	22·03

In cabbages analysed last year I found the average proportion of water 89·5 per cent. There is thus about as much water in lupines, cut down green, as in the cabbages, the analysis of which I published some time ago; the amount of mineral matter is likewise nearly the same in both, but the proportion of albuminous or flesh-forming matter is more considerable than in cabbages.

The greater portion of the dry matter in lupines I found insoluble in water, as will be seen by the following results, representing the general composition and proportion of juice and crude fibre in the plants analysed in my laboratory :—

General Composition of Yellow Lupines (cut down in a green state).

		In Natural State.		Calculated Dry.
Water	..	89·20	..	..
Soluble organic matters ..	Juice 93·10	3·29		30·46
Soluble mineral matters ..	..	·61	Juice 36·13	5·67
Insoluble organic matters ..	..	6·71	..	62·12
Insoluble mineral matters ..	crude fibre 6·90	·19	crude fibre 63·87	1·75
		100·00		100·00

In the next table is stated the detailed composition of lupines, both in a natural state and dried at 212° Fahr. :—

Detailed Composition of Yellow Lupines (cut down in a green state).

	In Natural State.	Dried at 212° F.
Water	89·20	..
Oil	·37	3·42
*Soluble albuminous compounds	1·37	12·68
Soluble mineral (saline) substances	·61	5·64
†Insoluble albuminous compounds	1·01	9·35
Sugar, gum, bitter extractive matter, and digestible fibre	3·96	36·68
Indigestible woody fibre (cellulose)	3·29	30·48
Insoluble mineral matters	·19	1·75
	100·00	100·00
*Containing nitrogen	·22	2·03
†Containing nitrogen	·16	1·48

The juice of the green plants has a somewhat bitter taste, which is due to a bitter principle, the nature of which I have not further examined.

Sheep and cattle soon get accustomed to lupine, and even like it much after some time; but pigs, it appears, refuse this kind of food.

With respect to the nutritive qualities of green lupines, I would observe that the plants grown by Mr. Kimber are not nearly so nutritious as clover, lucerne, sainfoin, green rye, and rape, and indeed most other crops grown as green food. The large proportion of woody fibre and, comparatively speaking, the small amount of sugar in these lupines, certainly do not speak in their favour. On the other hand they contain quite as large an amount of albuminous or flesh-forming matters as the better kinds of crops grown as green food; but the amount of albuminous matters in food, as has been stated repeatedly in former contributions of mine, cannot be regarded as a trustworthy indication of the feeding or fattening qualities of any kind of green food.

Green food, described by practical men as good, sweet, nutritious herbage, like good roots, I find, invariably contains a considerable proportion of sugar. The deficiency of this constituent in lupines, coupled with the large amount of woody fibre and water, justifies me in considering lupines decidedly inferior to clover and other artificial grasses usually grown in this country as food for cattle and sheep.

Nevertheless, lupines cut down green under peculiar circumstances, when grown, for instance, on very poor sandy soils, on which more valuable crops will not thrive, will no doubt be found a useful auxiliary food.

These observations, it should be remembered, apply more especially to the specimens examined by me, and not generally to lupines grown under other and probably more favourable circumstances. It is well known that the chemical and physical condition of the soil has a mighty influence on the nutritive qualities of the crops raised upon it. In like manner the kind and amount of manure applied to the land tend to modify the composition of the produce, and with it its nutritive properties. And, finally, it ought not to be forgotten that the past summer was unusually wet and cold, and consequently decidedly unfavourable to the proper ripening of the herbage and the abundant formation of sugar, whilst it contributed, no doubt, to an unusually large proportion of water in all green food.

We have yet to learn to what extent the composition of lupines is affected by our changeable climate, by the soil, time of cutting down, &c. &c., before a generally correct opinion can be expressed as regards their value as green food.

It is well to bear in mind especially that the amount of water in every description of vegetable produce varies immensely with the circumstances under which it is raised. Thus I find the percentage of water in swedes varying from 86 to 91 per cent.; in turnips, from 87 to 94 per cent.; in mangolds, from 85 to 90 per cent. A chemist analysing a particular swede and finding the amount of water in that root to be 91 per cent., and also analysing a turnip and finding only 88 per cent. of water in this turnip, and not knowing the fluctuation in the amount of water and dry matter to which both roots are liable, might thus incautiously derive from these analyses the conclusion that turnips are more nutritious than swedes. In the same manner a farmer who one year consumes unusually good turnips, and the next, poor swedes, containing it may be 91 per cent. of water, might arrive precisely at the same opinion as the analyst. But what is perfectly true in particular instances does not apply to the vast majority of cases; we must therefore beware of deducing general conclusions from isolated facts.

In green food more especially the amount of water, and also that of other constituents, varies considerably. Thus in the analyses of one and the same kind of clover, lucerne, and sainfoin, as recorded by Professor Way, Dr. Anderson, and myself, we meet with the following differences :—

	Percentage of Water in Fresh State.		Percentage of Flesh-forming Matters in Dry State.	
	Highest.	Lowest.	Highest.	Lowest.
Red Clover—Trifolium pratense	85·30 (Anderson.)	79·98 (Anderson.)	22·194 (Way.)	12·46 (Anderson.)
Cow-grass—Trifolium medium	81·76 (Anderson.)	74·10 (Way.)	20·968 (Way.)	10·19 (Anderson.)
White Clover—Trifolium repens	83·65 (Voelcker.)	79·71 (Way.)	27·31 (Voelcker.)	18·45 (Way.)
Lucerne—Medicago sativa	80·13 (Anderson.)	69·95 (Way.)	16·56 (Voelcker.)	12·56 (Way.)
Sainfoin—Onobrychis sativa ..	77·32 (Voelcker.)	76·64 (Way.)	18·17 (Way.)	15·50 (Voelcker.)

It is by rejecting unusual or abnormal results, and striking an average of numerous determinations of the same produce, that practically useful data are obtained. Proceeding in this way, the averages of different analyses often agree very closely. Thus the percentage of water in the various clovers on an average amounts to :—

According to Way	78·25
„ Voelcker	78·65

In the absence of any other analysis of lupines cut down in a green state, besides that given above, the expressed opinion can only apply to the particular crop analysed, and our judgment respecting the average nutritive qualities of lupines in comparison with other food must remain suspended until the data are produced on the strength of which a trustworthy opinion can be formed.

On the Soil suitable to the Cultivation of Lupines.

It has been already remarked that lupines succeed well on light, sandy, and even poor, blowing sandy soils. The agricultural capabilities of the soil on which the yellow lupines were grown in the experiment under discussion are described in detail in Mr. Kimber's letter. I can therefore proceed at once to state its chemical composition.

The analysis was made from two samples, taken at the depth of 6 and 12 inches respectively, and then well mixed.

The first sample contained a percentage of—

Water	1·12
Organic matter	2·07

The second, which was darker coloured,—

Water	·81
Organic matter	·81

The mixture gave the following results when submitted to a minute analysis :—

Composition of a Sandy Soil on which Lupines were grown successfully by Mr. Kimber, Tubney Warren, near Abingdon, Oxon.

Moisture	·96
*Organic matter	1·46
Oxides of iron and alumina	1·84
Phosphoric acid	·17
Carbonate of lime	·23
Sulphate of lime	·04
Magnesia	·24
Potash	·12
Chloride of sodium	traces
Insoluble siliceous matter (chiefly fine quartz-sand)	95·01
	100·07
*Containing nitrogen	·075
Equal to ammonia	·091

It will be seen that this soil contained no less than 95 per cent. of insoluble siliceous matter, chiefly in the form of fine quartz-sand. The proportion of all the other constituents is, therefore, necessarily very small indeed. Thus we find in it hardly more than traces of potash, little phosphoric acid, and barely any lime—a constituent which is seldom so deficient in any soil.

As the field had received a dressing of farmyard manure previous to the sowing of the seed, some of the phosphoric acid, lime, and potash probably are due to the manure. Analysed in its natural condition, it is likely to exhibit in a still more striking manner this general deficiency of all the more important and valuable soil-constituents. Notwithstanding, it produced a luxuriant crop of lupines, weighing in a green state about 21 tons per acre.

The small proportion of sulphate and carbonate of lime in this soil is striking, and it is certainly remarkable that the crop, nevertheless, succeeded well. Leguminous crops, to which lupines belong, are, generally speaking, much improved by a dressing of gypsum or lime. I cannot help thinking, therefore, that a good dose of one of these substances may increase the produce and materially improve the feeding qualities of this crop. It may be partially due to the almost total absence of sulphuric acid and lime in this soil that the analysis of the lupines has not furnished more favourable results. My reason for throwing out this suggestion is based on the fact that every description of agricultural produce is increased by applying lime in some shape or other to land which is peculiarly deficient in this substance, and on the no less important observation of good farmers that turnips grown on land very poor in lime possess a low feeding value.

Whilst recommending the use of gypsum or *lime* as a means of increasing the produce and improving its quality on land like that on which the experimental lupines were grown, I would mention, however, that chalky and marly soils, according to the experience of trustworthy men, do not appear to be well adapted to this crop. It is likewise stated that land in too high condition does not suit it, and that on wet or imperfectly-drained land lupines do not succeed.

A deep, porous, naturally dry or perfectly-drained soil is essentially requisite for growing the crop to perfection, and as chalky and marly soils often rest on impervious clays or wet peat, it is probably due to these latter, and not to the excess of lime, that lupines fail in chalky or marly soils.

From the preceding observations, the following general conclusions may be drawn :—

1. Green lupines are a useful crop, which may be grown in England with much advantage on poor sandy soils, on which clover, sainfoin, and other kinds of produce do not succeed well.
2. Yellow lupines are useful as a green food for sheep and cattle.
3. The nutritive value of lupines cut down green, in comparison with clover, lucerne, sainfoin, rye, and other green food, remains to be determined by future and numerous analyses, and, above all, by an extended experience of practical men.
4. On soils destitute of lime and sulphuric acid, the application of gypsum, lime, marl, and road-scrapings (provided the road-metal consists of limestone) is likely to increase the produce and enhance the feeding value of the lupines.

Royal Agricultural College, Cirencester, December, 1860.

To Dr. Augustus Voelcker.

I HAVE great pleasure in answering your inquiries respecting my experiment with lupines as a farm crop. Let me give you in the first place some idea of the nature of the soil on which they were grown.

My farm is situated about 7 miles south-west of Oxford, and 2 miles south of the Thames; geologically, in the neighbourhood of the Coral Rag. Ours is mostly sandy land, interspersed with stone-brash.

The soil of this farm is what is commonly called a light, blowing sand, of so fine a nature that high winds very much disturb the surface in dry weather, and sometimes cause considerable injury to young growing plants—to turnips more especially. The sand-beds mostly rest on a porous sandstone rock, and therefore require no draining; on the contrary, we often suffer from drought: one week of hot, dry weather in the summer is enough to check the growth of corn. This season has not tested the powers of lupines to withstand dry, hot weather on poor, light sands; but, considering their habit of growth, it is likely that they possess this power in a great degree. They have a tap-root more than a foot in length. This sandy land possesses a very low agricultural value. Much of it has been brought into cultivation within the last few years; and at the present time there are still acres to be seen growing nothing but furze and heaths. The value of this kind of land varies from 10*s.* to 30*s.* an acre. My farm is made up principally of the lowest class. The field in which the lupines were grown may be considered of medium value. It has averaged 20 bushels of wheat and 28 bushels of barley to an acre when farmed in the four-course rotation, which I do not consider well suited for so poor a soil, although it is often adopted here. A section of a stone-pit gives the following:—First 6 inches, rather dark cultivated soil; below this, 2 feet of a somewhat lighter soil; below this, 10 feet of yellow sand, resting on sandstone rock.

With regard to the crops generally grown here, I may say wheat and barley are the favourites. A fair crop of peas may be grown occasionally, but the land does not bear a repetition of this crop for a long time. Clovers may be grown once in eight or ten years. Sainfoin generally takes well, and yields good crops when top-dressed with road-scrapings and yard-manure. Carrots are well suited to the soil. Above all, turnips grow to perfection if the land is well prepared and well manured for them; superphosphate appears to be the most suitable manure. On these sands, after they have been in cultivation for some years, turnips grow well, and are not subject to the disease of anbury; but in some places, on newly cultivated land, they fail altogether. On land where turnips are attacked by anbury, the plants generally look healthy and well until the time of hoeing; the leaves then turn pale or yellow, and the roots seldom get bigger than a finger.

As you wish to know how the field was cultivated and cropped previous to the lupines being planted, I will give you an account of the last five years:—In 1856 it was in clover, unmanured. 1857, wheat, top-dressed with 1½ cwt. Peruvian guano per acre. In the autumn the stubble was pared and cleaned, and winter vetches drilled; these were top-dressed with 10 2-horse cart-loads of yard-manure to an acre. 1858, vetches, eaten on the land by sheep. After the sheep the land was cultivated with a broadshare, cleaned, ploughed with a shallow furrow, and turnips drilled with 3 cwt. superphosphate. The turnips having been eaten on the land by sheep having hay, the land was next ploughed as shallow as possible. 1859, the broadshare passed across the furrows, and barley drilled. 1860, 10 2-horse cart-loads of well-made pig-manure applied to the acre in the last week of March, and ploughed in with a furrow 4 inches deep; the lupines drilled on the 3rd of April in rows 13 inches apart; 1½ bushel of seed per acre.

Three weeks passed before the plants made their appearance aboveground, and then only a few came up. On the 1st of May they were so thin on the ground that I quite despaired of a crop; however, they continued to increase in numbers, and at the end of six weeks from the time of planting there were enough. I am informed by a seedsman that the yellow lupine is always a long time coming up; but I may mention that in this instance the land was very dry at the time of planting, and the weather was very cold and dry for some time afterwards.

In the first six weeks after the plants appeared they made very little progress; at the end of that time their growth became astonishingly rapid; and by the first week of August they were just beginning to bloom, and the piece had a most luxuriant appearance. By the middle of August the lupines were so thickly covered with flowers as to appear almost a mass of yellow, and they continued in this state until the time of weighing, Sept. 24th.

I cannot give you much information on the feeding properties of green lupines. Having had a wish to save as many as I could for seed, with a view of testing the feeding properties of the dry seed and the yield per acre, and also to obtain seed for next season, I did not consume much in a green state at the time they were in the best state for feeding.

I had some ewes penned on a portion of the crop for a few nights, giving them a fresh piece every night; and they made good work, eating all but the main stem, which at this time (first week in September) was rather hard. At this time there was a show of abundance of seed, but the season was too wet and cold to ripen it. When I had given up all hope of obtaining seed, I again put the sheep on the lupines (this was early in November), and they cleared off all the leaves and soft branches, leaving only the woody stems. Four yearling heifers in a bare pasture-field have been supplied with a quantity every morning during the last three weeks. They come to this as they would to hay or turnips, and clear up all but the main stem. These heifers have improved since they have had the lupines, which they received instead of hay, the pasture not being sufficient to keep them up in condition. Pigs refuse the lupines.

With regard to the cultivation of this crop, it appears to require no more care than is usually bestowed on peas or beans. Indeed, in this case not more than ordinary care was bestowed upon them. Probably deep cultivation would favour their growth. Thirteen inches is a good width for the drills when the crop is intended for green food; but when intended for the growth of seed, 20 inches is not too wide, and the plants should stand singly in the drills. Perhaps dibbling might be better than drilling.

Before giving you the results of the weighings of green lupines, I must mention that, as the experiment was intended to show the produce of seed as well as of green food, a part of the field was selected where the plants stood wider apart and the crop was not so large as on the greater portion of the field, but where the seed would most likely be brought to perfection. On the 24th September the produce of exactly 4 poles of ground was taken from this part (without the roots) when almost free from adhering moisture, and weighed:—

	Tons.	cwts.	lbs.
4 poles gave 903 lbs. = for 1 acre	16	2	56

The produce of 4 poles in another part of the field, where the crop was rather more bulky, was also taken and weighed. Here

	Tons.	cwts.	lbs.
4 poles gave 1210 lbs. = for 1 acre	21	12	16

I think the lupine crop is likely to prove valuable on light sandy soils, where there is a difficulty of growing large crops of the ordinary farm-plants. Of the great quantity of green food which it produces I can speak with certainty, and I can express a favourable opinion of its feeding value. If it will produce a crop of ripe seed of a nutritious nature in ordinary seasons, it will become still more valuable.

Next season I shall venture to plant about the middle of March.

JAMES W. KIMBER.

Tubney Warren, Abingdon, 27th Nov., 1860.

Report of an Unsuccessful Experiment in growing Yellow and Blue Lupines. By P. H. FRERE.

IT is with some feeling of disappointment that I put on record results which tend to the conclusion that the lupine is a plant not adapted to all the varieties of dry soil which are indiscriminately called sandy or heath lands. If, as I trust may be the case, it thrives well on fields whose yellow or reddish colour indicates the presence of sand in the most popular acceptation of the word, it does not seem adapted for those black, gritty, siliceous heaths overlying chalk-rubble and chalk which abound in Cambridgeshire around Newmarket.

On my appointment last spring, being anxious to investigate thoroughly for the Society the merits of a plant which seemed to claim attention as being appropriate to soils for which some change of crops was especially desirable, I set aside 9½ acres for the growth of the yellow and blue lupines. The result was a total and costly failure, and my present object is only so far to state in detail the method of my proceeding, that others may be able to judge whether the result turned upon mismanagement or the peculiarity of the last season, or whether my experience is a legitimate warning against a repetition of the attempt on soils really resembling mine.

First, as to the season: it was one which, in regard to all other crops, was singularly favourable for the burning land in question. The wheat grown close at hand was almost the only good piece on the farm; the adjacent barley was unusually good (between 10 and 11 sacks, worth 40*s.* and upwards, on land worth from 12*s.* to 15*s.* per acre); the layers had more than twice their usual quantity of feed; moreover, the lupines were already on the wane before the season had developed its extreme tendency to cold and wet. I cannot think, therefore, that the season affected the result: and all the more, because for the kindred leguminous crop of tares, when grown on such soils, the rain can never fall in excess.

Next as to management: the land appropriated to the experiment was the last portion of the green rape reserved for feeding the ewes and lambs, until in our bleak district the rye-grass layer was nearly ready to receive them. The flock was liberally supplied with extra keep, and the land was in good heart, as the adjacent barley-crop clearly shows.

The lupines were sown on the 5th of May: 2 bushels of seed per acre, in rows 9 inches apart. On the 12th of May a grass layer was sown over these 9½ acres, in common with the rest of the barley-shift. Shortly the yellow lupines appeared, a tolerable plant; the blue never came up so as to form a plant from the bad quality of the seed.

By the early part of June there were plants of yellow lupine 3 and 4 inches high, and their roots were more large, fleshy, and long than the stem. At this point they all stopped: those at the upper end of the field, where the chalk was near to the surface, being the first stunted; those lower down, where the black sand was deeper, soon following that example. From this point the grass layer and weeds gained the ascendancy. In the first week in July the lupines began to die away, and when the layer was fed off on the 23rd of July not a lupine was visible. If it be objected that the layer choked the lupines, I can only say that when tares have in like manner been sown with layer this was not the case; and moreover, the lupines started with a good lead, if they could have kept it; and their deep and strong roots, as well as their stems, ought to have maintained their ascendancy but for untoward circumstances.

If this crop is not suited to the place in our rotation which was assigned to it, I hardly know where it can be inserted advantageously; especially, if it cannot hold its own against a layer, it will be of little service in my eyes, because I am more and more convinced that on heath land, as far as possible, *all the corn should be put in a whole furrow;* and that in a hot season this mechanical advantage is of more importance than almost any supply of fertilisers. A chief desideratum, therefore, for these soils is a new plant, that will either form a network of small roots itself, or, at least, not prevent other plants from commencing their career under its shade.

I was disposed to attribute the failure chiefly to the chalk ; it appeared to me that when the tap-root struck on the chalk rock the plant was poisoned. Professor Voelcker does not confirm this view. He writes, " Allow me to suggest that the presence of lime in your soil is not likely to be the cause of the failure which you have experienced. I am not acquainted with a single cultivated crop that is injured in any way by the presence of lime in the soil, and I imagine that a leguminous crop would be the least likely of all to be hurt by lime." He considers that we must look deeper for the cause of sterility which is connected with these black soils, not only in reference to lupines but likewise to other crops, and has kindly promised that he will endeavour to trace out the baneful influence.

Cambridge.

London: Printed by W. Clowes and Sons, Stamford Street,
and Charing Cross.

ON THE

COMPOSITION AND VALUE
OF
NORWEGIAN APATITE,
SPANISH PHOSPHORITE, COPROLITES,
AND
OTHER PHOSPHATIC MATERIALS

USED IN ENGLAND FOR AGRICULTURAL PURPOSES.

BY DR. AUGUSTUS VOELCKER.

LONDON:
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CHEMICAL COMPOSITION AND COMMERCIAL VALUE OF PHOSPHATIC MANURES.

When superphosphate of lime was first introduced into agriculture, it was exclusively prepared from raw or boiled bones. It was then sold more frequently under the name of dissolved bones and of German compost than under that of superphosphate. Animal black or bone-charcoal, in the shape of refuse from sugar-refineries, and South-American bone-ash, were soon recognised as valuable materials for the production of artificial manures. In some respects these refuse matters were found even superior to bones for making superphosphate. They are now eagerly bought up by manure-merchants, and extensively employed in the manufacture of phosphatic and other artificial manures.

The timely discovery of fossil bones and phosphatic nodules in the Suffolk crag, and of chalk coprolites further provided an abundant source of phosphates in our own country, to meet the yearly increasing demand for those artificials which owe their efficacy principally to the valuable phosphate of lime which they contain. But raw and boiled bones, animal black, South-American bone-ash, Suffolk and Cambridgeshire coprolites, are not the only materials that are employed at the present time in the manufacture of superphosphate. Apatite from Norway, phosphorite from Estramadura, Sombrero phosphate or Crust guano, American phosphates of various kinds, and certain phosphatic guanos, are likewise imported into England in considerable quantities, and converted, by means of sulphuric acid, into valuable manures, to the mutual benefit of producer and consumer.

Manure manufactories are now spread over the length and breadth of the country, and in all these works the staple product, under whatsoever name it may be sent out, is in reality, in nine cases out of ten, superphosphate of lime. The consumption of this kind of manure, large as it is at present, is increasing every year, and is likely to increase for years to come. It must not be supposed that the large demand for phosphatic manures is the result of extraordinary exertions on the part of the manure-merchants, or is due to a prevailing, and it may be passing, faith in this class of fertilizers. It rests on the universal experience of farmers that no description of manure repays a judicious outlay so well as this, especially when applied to root-crops. Whilst other kinds of fertilizers have been tried on a large scale, and not been found to realize the expectations raised, superphosphate and similar phosphatic manures have maintained a firm hold in the good opinion of the agriculturist. Far be it from me to undervalue the great utility of Peruvian guano, nitrate of soda, and nitrogenous manures. These are excellent fertilizers for wheat and corn-crops in general; but considering the circumstance that a good root-crop lies at the very foundation of an improved system of agriculture, and that this crop is more signally benefited by phosphates than by any other fertilizing constituent, I believe the farmer is right in attaching the highest importance to phosphatic manures. At all events, he has found by experience that in most cases in which it is deemed desirable to make up a deficiency of yard-manure, it pays better to purchase superphosphate and similar manures for the root-crop than to buy nitrogenous manures for the white crops.

It is certainly remarkable that whilst the direct application to the land of nitrogenous constituents has been by some considered useful only in special cases, and by others superfluous or even undesirable, nobody has ever expressed any doubt as regards the economical benefits that generally attend the use of phosphoric acid; whilst nitrogenous manures in the case of some crops, such as peas and beans and clover, have been found even to be injurious, every kind of produce has been more or less benefited by the direct application of phosphates in an available condition. Whereas ammoniacal salts and other purely nitrogenous fertilizers, when applied alone to swedes, turnips, and probably other root-crops, have, generally speaking, failed to increase the produce,—the exclusive use of soluble phosphates has, in almost every instance, largely benefited these crops.

Again, we can increase the proportion of nitrogenous constituents in the soil by other means than by their direct application in the shape of manure. Thus, after a good crop of clover, I have found that the amount of nitrogenous matters in the soil is very much larger than it was before the clover. If, therefore, we can succeed in growing a good crop of clover, we at the same time enrich the land with nitrogenous matters, and provide for the succeeding white crop that kind of food for which it appears to be specially grateful. The fact that a good crop of wheat may be confidently anticipated after a good clover-crop is generally admitted; the power of the clover to accumulate nitrogenous matter in the soil, which explains this result, may not be as fully recognised. Moreover, whilst few soils contain more than traces of phosphoric acid, nearly every kind of agricultural produce contains this acid in very large and often preponderating proportions; its presence being further required to furnish the phosphorus which largely enters into the composition of albumen, gluten, legumine, and indeed all albuminous compounds. How large then is the demand for those constituents which even the best soils supply but in scanty proportions! We can thus understand why their direct supply in an available condition is of more vital importance to our cultivated crops than that of any other fertilizing substance.

Generally speaking, phosphatic manures produce a more marked effect upon root-crops than upon cereals. At one time it was supposed that root-crops removed more phosphoric acid from the soil than white crops, and on that account required to be more abundantly supplied with phosphates. But this explanation is as little correct as all others in which no account is taken of the respective periods of vegetation of green and white crops, and the different mode in which these crops take up the food at their command in the soil. The roots of swedes and turnips, unlike the deep penetrating roots of the wheat-plant, with their numerous fibriles, feed, comparatively speaking, upon a small portion of the cultivated soil, and their whole period of vegetation is very much shorter than that of our cereals, especially that of wheat. Whilst the wheat-plant is thus enabled to search for proper food in a considerable depth of soil, and by degrees accumulates in its organism the requisite amount of phosphoric acid which is distributed in small quantities in a large mass of soil, turnips, swedes, and mangolds, in consequence of the peculiarities of their growth, do not find at their disposal available phosphoric acid in sufficient quantity to supply that weight of bulbs which we now look for in average seasons. Hence it is that manures, rich in soluble phosphates, produce such a striking effect on root-crops, no matter what the character of the soil may be on which they are grown.

Although superphosphate and bone-dust do not generally benefit wheat to the same extent as turnips, these and other phosphatic manures are very efficacious when cereals are grown on light sandy soils or land naturally very poor in phosphoric acid. I do not purpose to institute at present a minute inquiry into the relative utility of the various organic and mineral constituents which constitute the food of plants, nor to extend the preceding observations. They are merely offered as suggestions which to some extent, at least, explain the fact that the sale of phosphatic manures has been steadily increasing from year to year, and has now assumed gigantic dimensions.

The supply of bones is totally inadequate to meet the present large demand for superphosphate and similar fertilizers. It is fortunate, therefore, that England possesses an abundant source of phosphates in the extensive Suffolk and Cambridgeshire coprolite deposits, and that the enterprising character of English-men renders available for the use of farmers the discoveries of phosphatic deposits in Norway, Spain, America, and other countries. The composition of most of the phosphatic materials which are used at the present time by manure-manufacturers in England has been carefully ascertained; but many of the analyses are scattered in scientific journals, and not readily accessible to the agriculturist or manufacturer. Several phosphatic materials again have only recently been imported into England, and of these no trustworthy analyses have been as yet published. Of others we possess careful analyses made from picked specimens, but no published account of the composition of the materials in the state in which they actually occur in commerce. I propose, therefore, to give an account of all the more important phosphatic materials now in use, and briefly to describe their general appearance and more characteristic physical properties, stating the localities where they are found, their composition as ascertained by me, and some particulars which may be of interest or practical importance either to the farmer or to the maker of artificial manures. The following is a list of the substances of which I shall treat:—

1. Norwegian apatite.
2. Spanish phosphorite.
3. Cambridgeshire coprolites.
4. Suffolk coprolites.
5. American phosphate (Maracaibo guano).
6. Sombrero, or Crust-guano.
7. Kooria Mooria guano.
8. Other phosphatic guanos.
9. South-American bone-ash.
10. Animal-black, or bone-charcoal.
11. Bones.

There are a few other phosphatic materials which now and then find their way into commerce, but to these I shall either not refer at all or only incidentally.

1. NORWEGIAN APATITE.

Apatite, a hard and often well-crystallised mineral, chiefly composed of phosphoric acid and lime, is found in this country in Devonshire, Cornwall, and Scotland, but not as yet in sufficient quantity to allow of its being collected for technical purposes. In America it is found imbedded in granite at Baltimore, in gneiss at Germantown, in mica-slate in West Greenland; in granite at Milford Mills, near Newhaven, Connecticut; at Topsham, in Maine, in granite, and in various other localities mentioned in detail in Dana's 'Mineralogie.' On the Continent it is found in several places in the Tyrol and Switzerland, also in Bohemia, Saxony, Bavaria, Sweden, and Norway. Most commonly it occurs in thin seams, imbedded in crystalline or volcanic rocks, but seldom in sufficient quantity to repay the cost of working.

Mineralogists distinguish several varieties of apatite. Some specimens are regular crystals, others crystalline, others foliated or conchoidal. The colour varies as much as its crystalline structure; but, generally speaking, apatite has a light green or a reddish colour. The apatite which at present is imported into England from Norway is found chiefly at Krageroe.

Two specimens of red-coloured apatite furnished, on analysis, the following results:—

	No. 1.	No. 2.
Hygroscopic water	·43	·43
Water of combination	·40	·40
*Phosphoric acid	41·88	41·74
Lime	53·45	54·12
†Chloride of calcium	1·61	1·61
Magnesia	..	·20
Phosphate of iron and alumina	·66	·45
Insoluble siliceous matter	1·24	·97
Alkalies	..	·30
	99·67	100·22
* Equal to tribasic phosphate of lime (bone-earth)	90·74	90·44
† Containing chlorine	1·03	1·03

These specimens had a bright red colour like ironstone, and yet they contained but very little oxide of iron. Two other samples of very light green-coloured, almost white, apatite from Krageroe, were found to contain:—

	No. 1.	No. 2.
Hygroscopic water	·19	·298
Water of combination	·23	·198
*Phosphoric acid	41·25	42·28
Lime	50·62	53·35
†Chloride of calcium	6·41	2·16
Oxide of iron	·29	·92
Alumina	·38	
Potash	·04	..
Soda	·13	..
Insoluble siliceous matter	·82	·99
	100·36	100·196
* Equal to tribasic phosphate of lime (bone-earth)	89·37	91·60
† Containing chlorine	4·09	1·38

It will be seen that these samples of Norwegian apatite contain a very high percentage of phosphate of lime, only a small amount of foreign impurities, and no carbonate of lime whatever. They are also perfectly free from fluorine, which is present in most other varieties of apatite. The amount of chloride of calcium, I find, varies from 2·16 to 6·41 per cent. in pieces chipped off the same block, showing that large blocks are not always uniform in their composition.

The preceding analyses were made some years ago. Quite recently I analysed a sample of ground Norwegian apatite, which yielded the following results:—

Moisture (driven off at 212° F.)	·24
Water of combination	·66
Lime	45·12
*Chloride of calcium	2·53
Magnesia	·74
Oxide of iron	1·29
Alumina	1·53
Potash	·36
Sulphuric acid	·29
†Phosphoric acid	35·69
Insoluble siliceous matter	11·62
	100·07
* Containing chlorine	1·62
† Equal to tribasic phosphate of lime (3 Ca O, P O_5 = bone-earth)	77·33

This sample, like all those from Krageroe in Norway which I have hitherto examined, does not contain a trace of fluorine. It is likewise free from carbonate of lime, but contains more siliceous matter, and also more oxide of iron and alumina than the cargoes imported from the same locality in former years. These impurities necessarily reduce the percentage of phosphate of lime, which, however, is still very considerable in the last-mentioned sample.

I have already noticed that the composition of the unground mineral is not quite uniform. In some pieces fragments of quartz, hornblende, and other foreign minerals, can be seen with the naked eye. In order, therefore, not to be misled by the analyses of picked specimens, it is necessary to reduce to a fine powder a considerable quantity of the mineral, say five or ten cwts., and to have an analysis made of such a mixed average sample.

2. Spanish Phosphorite (Estramadura Phosphate).

This mineral occurs in immense quantities at Lagrosa, near Tuxillo, in Estramadura. It is here associated with foliated apatite and quartz, and forms solid beds that alternate with limestone and quartz. This Spanish phosphorite has a fibrous structure, a light yellow colour, and a considerable degree of hardness. Reduced to powder, and placed upon a heated piece of sheet-iron, it becomes beautifully phosphorescent—hence its name.

In Estramadura this phosphorite has been employed as a building-stone. Professor Hausmann, of Göttingen, in his classical Handbook of Mineralogy, published in 1847, says with respect to the Spanish phosphorite, that building purposes are probably the only use to which this mineral can be applied.

We in England of course know how to turn phosphorite to a better purpose than that of building houses with it. The fact, however, that such a valuable mineral is, or, more correctly speaking, has been, used for building purposes not many years ago, shows plainly in what immense layers it is to be found at Lagrosa. It is to be regretted that the want of adequate means of transport and other difficulties have hitherto prevented this valuable deposit from being brought in large quantities to the English market.

Several large cargoes of Estramadura phosphate, it is true, found their way hither two years ago, but the importers lost money by the speculation, although the mineral was sold at a rate quite high enough in comparison with the then current price of bone-ash and other phosphates.

The following analyses were made from average samples, fairly representing the composition of the different cargoes :—

Composition of Spanish (Estramadura) Phosphorite.

	No. 1.	No. 2.
Moisture and water of combination	·68	1·42
Lime	42·68	41·47
*Phosphoric acid	36·36	33·55
Oxide of iron, alumina, magnesia, and fluorine .. .. { determined by difference }	8·81	5·19
Insoluble siliceous matter	11·47	18·37
	100·00	100·00
* Equal to tribasic phosphate of lime (bone-earth) ..	78·79	72·69

It will be seen that the Spanish phosphorite is not equal to the best samples of Norwegian apatite. It is, however, a valuable mineral, since it is rich in phosphate and free from carbonate of lime.

Like Norwegian apatite, the Estramadura phosphorite must be reduced by means of powerful machinery to a fine powder, and afterwards treated with sulphuric acid, before it can be economically employed for manuring purposes.

Fibrous phosphorite has also been found at Amberg, in Bavaria. This phosphorite resembles, in composition and structure, that of Estramadura, but is distinguished from it by containing some iodine.

Bavarian phosphorite has lately been raised in some quantities, and is used in Germany for the making of superphosphate, but as yet it has not found its way into England.

Another species of phosphorite, distinguished by the name of *osteolith*, was discovered some years ago near Hanau, in Germany. It occurs in thin seams in a volcanic rock, is soft and almost white, and very rich in phosphate of lime. Unfortunately the seams of this osteolith are not of sufficient thickness to repay the cost of excavation, consequently no practical application has been made of it as yet.

3. CAMBRIDGESHIRE COPROLITES.

The phosphatic nodules of the lower chalk are known in commerce under the name of Cambridgeshire coprolites. Their physical character and the localities where they are found are so well known that I need not dwell on these points.

The composition of different average samples, obtained by reducing to powder several tons, varies to some extent. In some more carbonate of lime and insoluble siliceous matter occur than in others, and consequently the amount of phosphate of lime in different samples fluctuates to a certain degree.

In commercial analyses it is usual to determine the amount of phosphate of lime or bone-earth by digesting the finely-powdered coprolites in hydrochloric acid, filtering off the solution from the insoluble siliceous matter, and precipitating the phosphates with ammonia. However careful the analyst may be to employ ammonia perfectly free from carbonic acid, and to avoid contact with the air, some carbonate of lime invariably falls down with the precipitated phosphates. It is necessary, therefore, to redissolve the latter in hydrochloric acid, and to throw them down a second time with ammonia. If this be neglected, the amount of phosphates in coprolites, and in all other phosphatic substances containing carbonate of lime, is determined too high.

By way of example, the following commercial analyses of powdered Cambridgeshire coprolites are given :—

General Composition of Cambridgeshire Coprolites.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Moisture and a little organic matter ..	3·11	4·02	3·49	4·45	4·01	3·44
Phosphates	62·32	61·04	59·67	61·06	61·40	61·96
Carbonate of lime, magnesia, alkalies, and fluorine (determined by difference)	28·42	27·67	30·65	28·37	28·37	29·36
Insoluble siliceous matter	6·15	7·27	6·19	6·12	6·22	5·24
	100·00	100·00	100·00	100·00	100·00	100·00

As both chalk-coprolites and Suffolk-coprolites contain much fluoride of calcium, by determining the amount of phosphates in the usual way by precipitation, fluoride of calcium is thrown down with the precipitate, in consequence of which the amount of phosphate of lime (bone-earth) is stated three to four per cent. higher than it is in reality. The true amount can only be correctly estimated by determining the percentage of phosphoric acid which they contain, and calculating from this acid the amount of bone-earth. In order to ascertain the true proportion of bone-earth in coprolites, and at the same time the exact quantity of other constituents which take up the sulphuric acid with which coprolite powder is mixed in the manufacture of superphosphate, I have made several detailed analyses of average samples of Cambridgeshire coprolites, and obtained the following results :—

Detailed Composition of Average Samples of Cambridgeshire Coprolites.

	No. 1.	No. 2.	No. 3.
Moisture and organic matter	4·63	4·01	3·52
Lime	43·21	45·39	46·60
Magnesia	1·12	·48	1·06
Oxide of iron	2·46	1·87	2·08
Alumina	1·36	2·57	1·41
*Phosphoric acid	25·29	26·75	27·01
†Carbonic acid	6·66	5·13	5·49
Sulphuric acid	·76	1·06	not determined
Chloride of sodium	·09	traces	traces
Potash	·32	·84	not determined
Soda	·50	·73	
Insoluble siliceous matter	8·64	6·22	6·04
Fluorine and loss	4·96	4·95	6·79
	100·00	100·00	100·00
* Equal to tribasic phosphate of lime (bone-earth)	54·89	57·12	58·52
† Equal to carbonate of lime	15·13	11·66	12·47
Amount of phosphates, determined in the usual way by precipitation	..	61·40	60·81

It will be seen that in the second sample the amount of phosphates obtained by precipitation is, in round numbers, four per cent. higher, and in the third sample two per cent. higher, than that resulting from the more accurate method of determining the percentage of phosphoric acid, and calculating from it the amount of bone-earth.

Powerful machinery is required for reducing coprolites to a fine powder. Coarse coprolite powder is not easily acted upon by acid, and has little or no effect upon vegetation. It is therefore advisable to reduce coprolites to a minute state of subdivision, and to digest them afterwards with a quantity of acid sufficient to saturate all the carbonate of lime and other constituents, and to render the insoluble phosphates completely soluble.

This precaution is not always observed by manufacturers, and hence superphosphate made from coprolites is often of an inferior quality. Properly dissolved, they are converted into a most efficacious turnip-manure, for soluble phosphate of lime made from coprolites is in every respect as good as soluble phosphate made from bone or any other source.

4. SUFFOLK COPROLITES (PSEUDO OR FALSE COPROLITES).

These phosphoric deposits occur in the more recent tertiary strata, as a layer varying from three to eighteen inches in thickness, between the coralline crag and London clay. The Suffolk crag is exceedingly rich in fossils, consisting partly of the fractured and rolled bones of cetaceous and other animals, with some fish-teeth, and chiefly of rolled water-worn pebbles, which were formerly supposed to be the fossilized excrements of saurian and other animals, for which reason they were called coprolites.

Professor Buckland, however, showed that they are not true fossil excrements, but in all probability calcareous pebbles which have undergone a peculiar metamorphosis, and become impregnated with phosphoric acid by long-continued contact with decaying animal and vegetable substances.

The name pseudo or false coprolites, which Professor Buckland proposed for them, has been generally accepted by the scientific world. In commercial phraseology, we have to understand by Suffolk-coprolites, or crag-coprolites, or pseudo-coprolites, the mixed fossil bones, fish-teeth, and phosphatic pebbles which occur in the Suffolk crag.

These phosphatic matters are distinguished from the grey-coloured chalk-coprolites by a brownish, ferruginous colour, and a smoother appearance. They are very hard, and yield on grinding a yellowish-red powder.

Analysed in the manner usually adopted in commercial analyses, the composition of several samples of ground Suffolk coprolites may be illustrated by the following tabulated results:—

General Composition of Suffolk Coprolites.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Moisture and a little organic matter	4·61	3·80	4·11	6·28	4·74
Phosphates	56·52	60·21	61·15	60·99	44·20
Carbonate of lime, magnesia, fluorine, &c. (determined by difference)	25·95	21·77	22·39	21·74	20·92
Insoluble siliceous matter ..	12·92	14·22	12·35	10·99	30·14
	100·00	100·00	100·00	100·00	100·00

In good samples of Suffolk coprolites the amount of insoluble siliceous matter varies from 10 to 14 per cent.; No. 5, therefore, appears to be a very inferior specimen.

Besides fluoride of calcium, they contain a good deal of oxide of iron and alumina, which partially, at least, are thrown down with the phosphates when the latter are determined by precipitation with ammonia, as is usual in commercial analyses. In this case the amount of phosphates will be stated in excess. The true value of these pseudo-coprolites, therefore, can only be correctly estimated if the phosphoric acid which they contain is accurately determined. This has been done in the subjoined analyses, which at the same time represent their detailed composition.

Detailed Composition of Suffolk Coprolites.

	No. 1.	No. 2.
Moisture and water of combination with a trace of organic matter	5·76	2·53
Lime	40·70	38·20
Magnesia	·34	1·34
*Phosphoric acid	28·32	24·24
Oxide of iron	4·87	4·81
Alumina	..	3·72
†Carbonic acid	5·08	5·37
Sulphuric acid	·87	1·40
Potash	·78	·56
Soda	·25	1·18
Chlorine	traces	·07
Fluorine and loss	3·02	4·31
Insoluble siliceous matter	10·01	12·27
	100·00	100·00
* Equal to tribasic phosphate of lime (bone-earth)	61·30	52·52
† Equal to carbonate of lime	11·64	12·20

No. 1, it will be seen, is a very superior sample; No. 2 represents a good average sample of Suffolk coprolites. In two other samples, in which the amount of insoluble matter and phosphoric acid alone was determined, I find:—

	No. 1.	No. 2.
Insoluble siliceous matter	12·56	11·05
Phosphoric acid	23·48	24·26
Corresponding to bone-earth	50·87	52·56

The remarks already made respecting the conversion of chalk coprolites into superphosphate apply, with equal force, to the pseudo-coprolites of the Suffolk crag.

A new process for converting phosphatic nodules into effective manures has quite recently been communicated by a Frenchman—a M. Roblique—in the 'Comptes Rendus.' This gentleman recommends us to mix pulverised phosphatic nodules with

50 per cent. of their weight of sea-salt, and to expose this mixture to a current of steam placed in a furnace or cylinder at a temperature a little below red heat.

If, as is sometimes the case, the nodules do not contain a sufficiency of silica, the deficiency must be made up previous to the operation.

M. Roblique remarks: "The reaction of silica on chloride of sodium (salt) in contact with the vapour of water is well known, resulting in the formation of silicate of soda and hydrochloric acid. In this special case the latter acts on the phosphate of lime, from which it takes two equivalents of lime, and gives rise to chloride of calcium and biphosphate of lime. All the phosphoric acid does not, however, combine with the lime; it sometimes forms a considerable quantity of phosphate of soda. The same process thus furnishes in the dry state, without excess of acid, both silicates and phosphates, which readily yield to plants not only silica and phosphoric acid, but also a considerable quantity of alkali."

I have not been able to learn if this plan has been tried on a large scale and been found practicable. If, by any cheap method not necessitating the use of sulphuric acid, coprolites could be brought into a state in which the phosphates they contain can be readily taken up by plants, a great saving would be effected. I question, however, very much whether this new plan can be successfully carried out on a large scale, but think it well worth a trial.

5. Maracaibo or Monk's Island Guano (American Phosphate).

This singular phosphatic mineral was originally introduced into commerce under the name of Maracaibo Guano. It is also known as Columbian Guano, also as Monk's Island Guano, and is sometimes simply described as American Phosphate.

It occurs in large lumps, in which are frequently pieces of quartz-rock imbedded. These lumps are hard, and have a compact interior of a chocolate-brown colour, and a grayish-white mammillated exterior, resembling an enamel. Between this enamel-looking portion and the compact interior is a lighter brown porous structure.

It is reduced under a millstone with some difficulty into a brownish-gray powder. Burned in an open platinum capsule, it turns beautifully white, showing that it contains organic matter, which imparts a chocolate-brown colour to the lumps in their natural state.

A fair average sample, prepared by reducing to powder portions taken from several blocks, was submitted to a careful analysis, which furnished the following results:—

Moisture	2·39
*Organic matter and water of combination	7·93
Lime	39·48
Magnesia	1·17
Phosphoric acid	41·34
Sulphuric acid	4·57
Soluble silica and sand	2·28
	99·16
* Containing nitrogen	·139
Equal to ammonia	·169

By dissolving this mineral in hydrochloric acid and precipitating the solution, filtered from the sand, with ammonia, 76·71 per cent. of phosphate of lime and magnesia (bone-earth) were obtained. The filtrate from the phosphate contained no lime whatever, but no less than 4·90 per cent. of phosphoric acid.

It is thus clear that Monk's Island Guano contains a phosphate which has a different constitution from that of ordinary tribasic or bone-phosphate of lime. On uniting the sulphuric acid with lime we obtain 7·77 per cent. of sulphate of lime, and, deducting the lime in the sulphate from the total quantity of lime found in the analysis, 36·28 per cent. of lime are left, which are united with phosphoric acid. The magnesia takes up 2·11 of phosphoric acid, and yields 3·28 of phosphate of magnesia (2 Ma, O, PO_5). There thus remains 39·23 of phosphoric acid to unite with 36·28 of lime.

From these data it appears that this singular and highly valuable phosphate consists chiefly of a mixture of pyro-phosphate and ordinary tribasic phosphate of lime. Since this substance contains a phosphate richer in phosphoric acid than ordinary or bone phosphate, and is free from carbonate of lime, it is rendered soluble with much less sulphuric acid than is required for dissolving bone-ash, apatite, and other phosphates. Monk's Island Guano, therefore, is a peculiarly valuable and excellent material for preparing artificial manures that are rich in soluble phosphate of lime.

6. SOMBRERO ROCK, OR CRUST GUANO.

This valuable phosphatic material occurs in one of the West Indian Islands, and of late years has been imported into England in some quantities. Sombrero Rock, as the name implies, is quarried in the islet of Sombrero. A large portion of this islet has been quarried away already, and sold both in America and in England as Crust or Sombrero Guano. This is not a very appropriate name, for this material is not a guano deposit, but in reality the rock itself, of which the islet of Sombrero consists almost entirely. Although fragments of bones are not often found imbedded in the rock which is imported into England, it cannot be doubted that the latter is a true bone-breccia. I have in my collection a specimen of Sombrero Rock, in which several pieces of bone are distinctly visible. These pieces of bone are perfectly white, and free from organic matter. The rock varies considerably in colour, texture, and other external characters. Whilst some is porous and friable, other specimens are of considerable density. Most samples have a light yellowish-green colour, which is, however, sometimes varied by a bright green or bright yellow, a violet, bluish, or pinkish hue. On the whole, this rock is reduced to powder with tolerable ease.

I have carefully and minutely examined some average samples taken from a bulk of several tons, which gave the following results :—

Composition of Sombrero Rock or Crust Guano.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Moisture	9·06	7·51	10·09	4·22	2·94	15·10	13·08
Water of combination and a little organic matter	4·38	6·19	4·90	6·57	5·94		
*Phosphoric acid ..	34·41	35·09	34·11	34·76	35·52	32·51	34·34
Lime	36·17	38·19	38·42	39·07	37·99	35·95	37·52
Magnesia	·[illegible]6	·44	·41	·52	·58	2·74	11·73
Alkalies and fluorine	1·86	1·87	1·61	1·85	1·92		
Oxide of iron	2·82	3·22	2·85	2·98	3·70	11·42	
Alumina	6·89	4·26	4·23	6·23	7·55		
Carbonic acid	1·55	1·36	1·68	1·75	·96	1·14	1·45
Sulphuric acid	·66	·44	·36	·36	·42	..	..
Chlorine	Not determined.	·39	·31	·28	·43	..	..
Insoluble siliceous matter	1·84	1·04	1·03	1·41	2·05	1·14	1·88
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Equal to tribasic phosphate of lime (bone-earth)	74·55	76·02	73·90	75·31	76·90	69·42	74·40

Sombrero Rock has been used in America for agricultural purposes, it is said, with considerable success, when simply reduced to powder. Such a practice cannot, however, be recommended; for this, like most mineral phosphates, requires to be treated with sulphuric acid in order to become really efficacious as a manure. It will be noticed that there is not much carbonate of lime, but a good deal of alumina, and in some samples also a good deal of oxide of iron. The proportion of phosphate of lime in this rock is as high as in good samples of South American bone-ash.

Phosphatic rocks similar in composition to the Sombrero Rock have lately been discovered in the Anguilla Isles, forming part of the Leeward Islands.*

7. Kooria Mooria Guano.

A considerable portion of the Kooria Mooria guano imported into England is bought up by manure manufacturers, and by means of sulphuric acid converted into useful turnip-manures.

Although this guano may be used by itself as a manure for turnips or Swedes, it is better to add to it some sulphuric acid (say one-third of its weight), with a view to changing a portion of the insoluble phosphates, in which it is rich, into the more efficacious form of a soluble phosphate.

Kooria Mooria guano varies considerably in composition, as the following analysis made in my laboratory will show :—

Composition of Kooria Mooria Guano.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Moisture	9·63	5·94	4·12	9·53	5·43	6·21	7·84
*Organic matter.. ..	5·68	8·49	3·49	5·19	11·45	5·01	3·23
Phosphates of lime and magnesia (bone-earth)	53·93	46·39	55·21	56·09	35·04	61·20	60·03
Sulphate of lime ..	4·37	11·73	14·79	2·82	13·88	8·39	2·68
Alkaline salts and magnesia (chiefly common salt) ..	6·48	5·12	1·97	6·09	5·33	5·68	8·68
Insoluble siliceous matter (sand) ..	19·91	22·33	20·42	20·28	28·87	13·51	17·54
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	·33	·30	·21	·26	·33	·28	·26
Equal to ammonia	·40	·36	·25	·31	·40	·34	·31

Kooria Mooria guano, it will be seen, contains but little organic matter, and hardly any ammonia. It is generally met with in commerce in a tolerably fine powder, offering its phosphates in that finely divided state which enables plants to assimilate them more readily than those found in coprolites or other like substances which have become completely fossilized.

8. Other Phosphatic Guanos.

There are several species of African and West Indian guanos which at present are occasionally used in the manufacture of

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* *Vide* Communication by Sir Roderick Murchison, in Journal, vol. xx. p. 31.

artificial manures. They are generally distinguished from the Peruvian by the almost entire absence of ammonia and soluble phosphates, by the small quantity of organic matter, and by the large proportion of insoluble phosphates which they contain. On the latter the commercial value of these guanos chiefly depends. They usually contain a considerable quantity of gypsum, and occasionally carbonate of lime besides. If a guano is to be used as a manure without any further preparation, the presence of carbonate of lime, though it does not add to, does not detract from its value; but if the guano is to be employed as the basis for superphosphate, or for drying artificial manures containing soluble phosphate, the less carbonate of lime it contains the better.

If guano containing carbonate of lime is mixed with sulphuric acid, all the carbonate must be saturated with acid before any soluble phosphate can be formed; and again, if such a guano be added as a drying material to a manure containing soluble phosphate, the carbonate of lime of the guano, taking up the acid which keeps the phosphate in a soluble state, renders the latter insoluble. In either case more acid is required for the production of a given amount of soluble phosphate than is wanted if phosphatic materials free from carbonate of lime are employed.

Saldanha Bay guano, South African, Pedro Keys, Swan Island, Baker Island, Birds' Island guanos are some of the inferior phosphatic guanos which may be used either by themselves, or better after having been treated with some sulphuric acid. As the composition of nearly every cargo of these guanos varies greatly, the analysis of particular samples is of no general interest. I therefore pass them over as well as the analyses of some other kinds of phosphatic guanos which occasionally find their way into the market.

9. BONE-ASH.

Bone-ash of good quality unquestionably is one of the most valuable materials for making superphosphate of lime. Indeed, it is far too good to be used for agricultural purposes in any other form. Most of the bone-ash of commerce comes from South America, and possesses, like other commercial articles, a variable composition, arising chiefly from the mechanical impurities, such as sand and earth, with which it is always more or less contaminated.

The following commercial analyses of different samples of South American bone-ash will give an idea of the extent of this variation :—

Composition of South American Bone-ash.
(Commercial Analysis.)

No.	Moisture.	Organic Matter.	Moisture and Organic Matter.	Phosphates of Lime and Magnesia (Bone-earth).	Carbonate of Lime, Fluoride of Calcium, and Alkaline Salts.	Insoluble Siliceous Matter (Sand).	Total.
1	7·60	2·29	..	67·58	9·36	13·17	100
2	2·05	3·52	..	74·08	12·59	7·76	100
3	10·76	3·76	..	55·36	7·45	22·67	100
4	14·50	2·56	..	65·89	9·44	7·61	100
5	12·52	1·20	..	66·33	7·17	12·78	100
6	..	..	16·37	64·44	9·13	10·06	100
7	..	..	14·38	67·99	10·45	7·18	100
8	..	..	7·75	68·97	7·62	15·66	100
9	..	..	10·49	60·63	9·99	18·89	100
10	..	..	9·04	66·71	7·34	16·91	100
11	..	..	10·53	66·33	7·25	15·89	100
12	..	..	8·76	75·76	8·57	6·91	100
13	..	..	13·98	66·59	8·42	11·01	100
14	..	..	8·08	61·61	9·40	20·91	100
15	..	..	7·73	72·65	9·45	10·17	100
16	..	..	9·68	64·70	7·63	17·99	100
17	..	..	6·87	75·05	12·02	6·06	100
18	..	..	8·07	65·26	12·26	14·41	100
19	..	..	12·97	63·17	11·62	12·24	100
20	..	..	9·59	70·45	10·72	9·24	100
21	..	..	14·58	67·74	8·66	9·02	100
22	..	..	11·91	73·48	10·43	4·18	100
23	..	..	3·29	82·48	10·33	3·90	100
24	..	..	5·63	77·15	10·36	6·86	100
25	..	..	9·61	64·27	9·95	16·17	100
26	..	..	17·31	59·67	8·29	14·73	100
27	..	..	5·44	75·81	10·47	8·28	100
28	..	..	8·26	70·50	10·32	10·92	100
29	..	..	14·45	59·13	8·89	17·53	100
30	..	..	8·60	69·09	7·13	15·18	100

The above were made in the manner usually adopted for commercial analyses. It will be seen that, generally speaking, samples poor in phosphate of lime are also poor in carbonate of lime, lime not united with phosphoric acid, and alkaline salts; and the samples rich in phosphate of lime likewise contain a higher percentage of the latter constituents. Thus, the sample which contained 66·33 of bone-earth, yielded 7·13 of carbonate of lime, &c.; and the sample containing 64·70 of bone-earth, yielded 7·63 of carbonate of lime, &c.; whilst that which gave 70·45 of bone-earth yielded 10·72 of the latter constituents; and another sample in which 75·05 per cent. of bone-earth were found yielded 12·02 of carbonate of lime, &c.

Considerable allowance of course must be made for the natural variations in the composition of the bones which produced the ash. It is well known that some bones contain more carbonate of lime and likewise more alkaline salts than others. We must not, therefore, expect to find always in the richest samples the highest percentage of carbonate of lime, &c., nor in those poor in bone-earth necessarily a correspondingly low percentage of the last-mentioned constituents. But, generally speaking, a higher percentage of carbonate of lime and alkaline salts will be found in good samples of bone-ash than in those that are inferior. This we may naturally expect, for as pure bones contain a certain amount of carbonate of lime, &c., the less sand a sample of bone-ash contains, and the more perfectly the bones are burned, the more phosphate of lime and likewise the more of all the other incombustible constituents it necessarily must contain. On the other hand, if bones are imperfectly burned and contaminated with much sand, they naturally must yield an ash which is not only poorer in phosphates but in all the ash-constituents of bones. At all events, bone-ash must contain more bone-earth and more carbonate of lime and other mineral matters than the bones which furnished the ashes.

In commercial analyses, however, the proportions of carbonate of lime, &c., are frequently stated to be far smaller than can be the case. This mistake arises from the faulty determination of the bone-earth. When determined in the usual way, the precipitated bone-earth invariably contains a good deal of carbonate of lime. The phosphates are therefore given higher than they are in reality, and, as it is usual to determine the rest of the lime which is not united with phosphoric acid and the alkaline salts together by difference, the latter constituents are consequently stated too low.

Thus an analysis lately brought under my notice gives the composition of a sample of bone-ash as follows:—

Charcoal	2·1
Sand	4·3
Water	3·8
Carbonate of lime	1·9
Phosphate of lime	87·9
	100·0

Another chemist, who analysed the same bone-ash, gives the following results:—

Moisture	3·00
Carbonaceous matter	3·00
Siliceous matter	3·90
Phosphate of lime	84·84
Carbonate of lime (4·48) &c.	5·26
	100·00

In both analyses the amount of phosphate of lime is given too high, and that of carbonate of lime and alkaline salts too low.

The first analysis, more especially, has evidently been done in a very careless manner, for bone-ash prepared from pure bones does not contain so high a percentage of phosphate of lime as this sample of the commercial article is reported to contain. The proportion of charcoal, moisture, and sand—three matters not properly belonging to pure bone-ash, amount to 10 per cent. in round numbers. Deducting these accidental constituents, and calculating the results for pure bone-ash, the latter would contain no less than 97·66 per cent. of bone-earth. It is hardly conceivable how such absurd results as those contained in the first analysis can be committed to paper by an analytical chemist.

If these were solitary instances I would take no further notice of analyses the incorrectness of which is proved by abundant internal evidence. But unfortunately this is not the case. Bone-ash is usually sold by importers at a price depending upon the percentage of phosphate of lime in it, and hence it is not the interest of dealers to have the determination of bone-earth made by a chemist who states the amount correctly, but rather to employ an analyst who, adopting an expeditious and incorrect method, makes the percentage of phosphates 3, 4, and even 6 per cent. higher than it is in reality. The importance of this subject has led me to examine minutely the composition of pure and of commercial bone-ash.

The mineral portion of pure bones or pure bone-ash has been repeatedly examined by various chemists. The more recent researches by Professor Heintz, of Berlin, deserve especial notice. According to Heintz, the phosphate of lime present in bone-ash is a combination of 3 equivalents of lime and 1 equivalent of phosphoric acid; its formula consequently is $3\,C\,O + P\,O_5$. Although some chemists still retain the older formula $8\,C\,O + 3\,P\,O_5$ assigned to bone-earth by Berzelius, most agree with Heintz in considering the chief constituent of bone-ash to be the tribasic phosphate of lime. In the analyses of human and other bones, the same gentleman obtained a certain proportion of lime, which was neither united with phosphoric acid, as tribasic phosphate, nor with carbonic acid. This excess of lime is calculated in Heintz's analyses as fluoride of calcium. Thus he states in one place that human bones contain 3·52 per cent. of fluoride of calcium; in another analysis he gives 3·82 per cent. of fluoride of calcium in bones dried at 212° Fahr. It should be mentioned, however, that no direct fluorine determination has been attempted, but that the result has been obtained by calculation. Every chemist is acquainted with the fact that bones contain small quantities of fluorine; but, at the same time, considerable difficulty is experienced occasionally in obtaining with recent bones a deep etching upon glass, even if large quantities of bone or of bone-ash are employed in testing for fluorine. It strikes me that such an etching would be readily produced if bones really did contain from 3·52 to 3·85 per cent. of fluoride of calcium, as calculated by Heintz. Moreover, such a proportion of fluoride of calcium would admit of at least an approximate determination. I have endeavoured to determine quantitatively the proportion of fluorine in recent bones and in bone-ash; but although I have carefully tried all known methods for determining small quantities of fluorine, I have utterly failed in all attempts, and am inclined to think that the proportion of fluoride of calcium in recent bones is very much smaller than Heintz imagines it to be. To verify this supposition, I added 1 per cent. of finely-powdered fluoride of calcium to pure phosphate of lime, and then was able to ascertain the amount of fluorine with tolerable precision. This is not the place to mention the details of my experiments, but the conclusion to which they seem to lead is that recent bones contain only a small amount of fluoride of calcium, and not $3\frac{1}{2}$ per cent. in round numbers as stated by Heintz. This much is certain, that the mineral portion of bones contains a certain quantity of lime, which is neither united with carbonic acid, nor with phosphoric acid as tribasic phosphate.

If it be highly improbable that this excess of lime exists in bone-ash entirely in the state of fluoride of calcium, the question naturally arises, In what combination does it occur? As lime and phosphoric acid unite together in so many different proportions, and as many of these compounds are basic in their character, it is highly probable that bone-ash contains a more basic phosphate of lime than has hitherto been supposed to exist.

It is a matter of considerable practical importance that the composition of the precipitate which is obtained on adding caustic ammonia to a dilute solution of bone-ash in hydrochloric acid should be known with certainty. This precipitate, consisting of phosphate of lime and a little phosphate of magnesia, is usually called bone-earth. It was considered by Berzelius to be a combination of 8 equivalents of lime and 3 equivalents of phosphoric acid; its formula accordingly is $8\,C\,O + 3\,P\,O_5$.

Other chemists assign to it the formula $3\,C\,O + P\,O_5$. Indeed, most scientific chemists of the present day have, for good reasons, given up the older formula, and consider bone-earth to be principally tribasic phosphate of lime,—that is a combination of 3 equivalents of lime and 1 equivalent of phosphoric acid.

In commercial analyses the amount of bone-earth is usually determined by precipitation; but since some chemists very properly prefer to ascertain the total amount of phosphoric acid in the article submitted to analysis, and to calculate subsequently the phosphoric acid as tribasic phosphate of lime, the ammonia precipitate, which is still erroneously assumed by many to be $8\,CO + 3\,PO_5$, is recalculated as tribasic phosphate of lime. This practice deserves to be strongly condemned, for it leads to wrong results, giving invariably the amount of tribasic phosphate much higher than it is in reality. Great discrepancies in the determinations of phosphate of lime in bone-ash, &c., by different analysts, are a source of constant annoyance and frequent disputes between seller and buyer. As long as the practice prevails of ascertaining the phosphates simply by precipitation, such discrepancies must remain matters of almost daily occurrence.

It is, of course, a much more expeditious plan to determine the phosphates by precipitation than to ascertain correctly the amount of phosphoric acid; but if we consider the difference that an error of 3 or 4 per cent. of phosphate of lime will make in the value of a ship's cargo, we shall admit that accuracy ought not to be sacrificed to expedition. There is, indeed, ground to fear that analyses are carried out in a too commercial—nay, often a too interested—spirit, such as is calculated to bring analytical chemistry into disrepute. It is therefore the duty of all desirous of carrying out analytical investigations in a manner consistent with truth to raise a strong opposition against the mode in which more especially commercial analyses of bone-ash and animal charcoal are frequently executed at present.

I have myself repeatedly analysed the ammonia precipitate from bone-ash, and arrived at the conclusion that, under the most favourable circumstances, it never contains less than 3 equivalents of lime for 1 equivalent of phosphoric acid. Generally, however, it contains an additional quantity of lime, or, more correctly speaking, carbonate of lime,—for I find it extremely difficult to prevent more or less carbonate of lime from falling down with the phosphates when precipitating the latter with ammonia. This is especially the case when the precipitation is effected in a hot solution. Notwithstanding the entire absence of carbonic acid in the ammonia used for precipitation, and the observance of every precaution to exclude the air from the precipitated phosphates, some additional lime beyond the proportion required to combine with phosphoric acid to form tribasic phosphates is invariably found in the precipitate obtained from a boiling-hot solution, even after the precipitate has been re-dissolved and thrown down again a second or third time. If, on the contrary, the precipitation is effected in the cold, and the phosphates are re-dissolved in acid after washing with ammonia-water, and thrown down again a second time with pure ammonia from a dilute cold solution, I find their composition agrees closely with tribasic phosphate of lime. Thus from a sample of bone-ash, which yielded an amount of phosphoric acid corresponding to 82·59 of tribasic phosphate of lime, I obtained 82·48 per cent. of phosphate by precipitation.

But unless these precautions are carefully observed and the phosphates are washed with strong ammonia-water, discordant results are obtained. At the best, the method of determining the amount of phosphate of lime by precipitation is liable to furnish results that cannot be relied upon. In proof of these statements the following instances may be cited:—

Two separate determinations in bone-ash gave 75·84 per cent. and 73·29 per cent. of bone-earth by the ordinary method of precipitation.

In another sample, I obtained, by throwing down the phosphates once, 79·03 per cent.

By re-dissolving the phosphates in acid and precipitating a second time, 76·21 per cent. were obtained.

On analysing the 79·03 per cent., I obtained 34·95 per cent. of phosphoric acid, corresponding to 75·72 of tribasic phosphate; whilst the precipitated phosphates in the second determination (76·21 per cent.) furnished 34·89 per cent. of phosphoric acid, corresponding to 75·59 per cent. of tribasic phosphate.

A sample of animal charcoal gave—

Phosphates precipitated once	77·46
Re-dissolved and precipitated a second time	73·63
Again re-dissolved and thrown down a third time ..	72·96

A direct determination of phosphoric acid in the same sample of animal charcoal furnished 33·34 per cent., which, calculated as tribasic phosphate of lime, gives 72·23.

These results thus show that the amount of bone-earth is stated too high if the phosphates are thrown down only once; that a tolerably near approach to truth is obtained if the phosphates are re-dissolved in acid and thrown down a second time; and, that lastly, perfectly accordant results are obtained if the phosphoric acid is determined, and from it the amount of tribasic phosphate is calculated.

Since bone-ash, animal charcoal, coprolites, &c., are chiefly purchased for the sake of the phosphoric acid which they contain, all possible care should be bestowed to obtain an accurate determination of that constituent which mainly regulates their commercial value.

In purchases of bone-ash, the dealer generally guarantees a certain amount of phosphate of lime or bone-earth; but since a question may arise as to the precise meaning of these terms, I would suggest, as far more satifactory both to the purchaser and the honest dealer, that the seller should guarantee the percentage of phosphoric acid; or, to render the change in present usages less abrupt, phosphoric acid, equal to say 74 or to 76 per cent. of tribasic phosphate of lime, as the case may be. If this suggestion were generally adopted, all squabbles respecting the composition of bone-earth would be set aside. By stating the amount of phosphoric acid which was actually found in the analysis, and the corresponding percentage of tribasic phosphate of lime, it would be seen at once that a reliable method, and not the uncertain process of precipitation, had been employed by the analyst.

The correct determination of phosphoric acid is attended with a good deal of trouble, and necessitates much care and experience on the part of the operator.

The method of analysing bone-ash which I have adopted in my laboratory yields most satisfactory results; and, as it may be useful to others, I will give a brief outline of it.

Moisture and organic matter are determined as usual. About twenty grains of finely-powdered bone-ash are carefully dissolved in hydrochloric, or better in nitric, acid; the solution is evaporated to dryness in a waterbath. By this means any pyrophosphate which may be present in the bone-ash is converted into the ordinary phosphate, and the soluble silica which always occurs in commercial bone-ash is rendered insoluble. The dry residue is taken up in the smallest possible quantity of nitric acid, and the sand filtered off; the solution passing through the filter is heated to the boiling-point, and precipitated with an excess of oxalate of potash or ammonia. The oxalate of lime held in solution by the liberated oxalic acid is thrown down with the first precipitate of oxalate of lime by neutralising the liquid with caustic potash or soda, by adding afterwards an excess of oxalate of potash or soda, and boiling. The oxalate of lime is removed by filtration, and the filtrate and washings evaporated to a small bulk, and finally the phosphoric acid precipitated with ammoniacal sulphate of magnesia. To prevent any oxide of iron or alumina, which occasionally are present in commercial bone-ash, from falling down with the phosphate of magnesia, it is desirable to add a little tartaric acid to the liquid before precipitating the phosphoric acid.

The precipitated phosphate of magnesia has to be set aside for at least twelve hours before it may be safely collected on a filter. As an excess of oxalate of potash has to be used for the determination of lime, and an excess of ammoniacal sulphate of magnesia for the determination of the phosphoric acid, oxalate of magnesia is formed, which, after standing for a time, separates and falls down with the phosphate of magnesia, unless a very large amount of ammoniacal salts is present. I find, indeed, that the phosphate of magnesia obtained in this kind of analysis is almost always contaminated with oxalate of magnesia, and therefore make it a general practice to redissolve the partially-washed precipitated phosphate of magnesia in ammonia, and to throw it down a second time. The magnesia precipitate must be washed with strong ammonia water.

The lime precipitate generally continues a variable and often altogether insignificant proportion of phosphate of iron and alumina. In ordinary analyses, it is hardly necessary to take any notice of the traces of phosphate of iron, which exist in good white samples of bone-ash. For very minute analyses, I dissolve the lime precipitate, after having been weighed, in hydrochloric acid, precipitate the solution with ammonia, collect precipitate on a small filter, wash and redissolve on filter, and precipitate a second time in the cold. The phosphate of iron and alumina, after washing, is free from lime. Its weight is determined, and deducted from the first weight of the lime precipitate. In order to obtain the phosphoric acid contained in the phosphate of iron and alumina, the precipitate is dissolved in hydrochloric acid, a little tartaric acid is added, then ammonia, and finally the phosphoric acid is determined as phosphate of magnesia. If necessary, a separate determination of carbonic acid and sulphuric acid is made in the bone-ash.

As regards accuracy, this plan of analysis leaves nothing to be desired. A proof of this is furnished in the subjoined analyses of the same sample of bone-ash; two of them were made by myself, and two by my first assistant, Mr. Sibson.

Though all ordinary care is taken in preparing a sample for analysis, it is next to impossible to obtain a perfectly homogeneous powder. The trifling discrepancies in the results of the four separate analyses are due, perhaps, in a higher degree to this circumstance than to the method of analysis.

Composition of a Sample of Bone-ash.

	1st Analysis.	2nd Analysis.	3rd Analysis.	4th Analysis.
Moisture	6·34	6·34	6·35	6·35
Organic matter (chiefly charcoal)	3·38	2·83	3 26	2·84
*Phosphoric acid	34·95	34·48	34·89	34·83
Lime	44·35	43·93	43·59	43·99
Magnesia	1·12	1·19	·71	·97
Insoluble siliceous matter (sand)	8·43	9·34	9·39	8·83
Carbonic acid and alkalies (determined by loss)	1·43	1·89	1·81	2·19
	100·00	100·00	100·00	100·00
* The phosphoric is equal to tribasic phosphate of lime (bone-earth)	75·72	74·71	75·59	75·46
Average percentage of bone-earth	..	..	75·32	..

The same bone-ash was likewise submitted by myself and by Mr. Sibson to an analysis, in which the ordinary precipitation method was adopted, and the following results were obtained:—

	Voelcker.	Sibson.
Water	6·34	6·35
Organic matter	3·38	3·09
Phosphates	79·03	76·70
Carbonate of lime	3·18	5·34
Alkaline salts	2·68	2·52
Insoluble siliceous matter	8·43	9·39
	103·04	103·39

In explanation of these results, I may observe that the excess in the analyses is principally due to the circumstance that all the lime which is not united with phosphoric acid is introduced here as carbonate of lime. The alkaline salts likewise help to increase the excess, for in reality the greater part of the alkalies occurs in bones as such, or in union with phosphoric acid, the total amount of which is mentioned in the analyses already. The direct weight of the thoroughly-heated residue, which is obtained on evaporation of the liquid from which the phosphates and the lime have been removed, therefore gives the alkalies too high.

In reality commercial bone-ash contains seldom more than 1¾ to 2 per cent. of carbonate of lime, and the lime which is not in union with phosphoric acid, nor with carbonic acid, must therefore be present in some other state of combination. Some of it, no doubt, is present as fluoride of calcium and some as silicate of lime; silicate of lime is not a normal constituent of bone, but it is produced when bones are reduced to ash in large heaps. The silica, which is usually attached to raw bones in the shape of fine sand, at a high temperature, decomposes some of the carbonate of lime which bones naturally contain, and gives rise to silicate of lime.

It might, perhaps, be supposed that bone-ash contained some caustic lime, arising from the high temperature at which the bones are sometimes burned. But this is not generally the case, as I have proved repeatedly by determining the amount of carbonic acid in the natural sample, as well as after having moistened and heated it with carbonate of ammonia. Had there been any caustic lime present in the bone-ash, the portion treated with carbonate of ammonia would have yielded a larger amount of carbonic acid than the sample analysed in its natural state, whereas both furnished almost identical results.

Again, commercial bone-ash contains a little sulphate of lime, but its quantity is quite insignificant.

In all the following analyses, phosphoric acid and lime have been carefully ascertained; in several the magnesia, sand, carbonic acid, and the small amount of sulphuric acid and oxide of iron and alumina which generally occur in bone-ash, have been determined:—

Detailed Analysis of South American Bone-ash.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Moisture	4·83	9·91	15·34	3·29	10·30
Organic matter	4·06	1·75	2·03		
*Phosphoric acid	35·38	33·89	32·52	38·12	29·56
*Lime	41·27	39·53	37·84	44·47	34·48
Lime not united with phosphoric acid	3·53	4·07	1·92	4·45	1·02
Insoluble siliceous matter (sand)	6·95	8·32	6·51	3·90	20·24
Magnesia	·97	·99	1·48	5·67	
Carbonic acid	..	·78	·84	..	·77
Sulphuric acid	..	..	·37		
Oxide of iron and alumina ..	..	..	·21		3·63
Alkalies	..	1·39	·84 (By difference)		
Alkalies, carbonic acid, and loss	3·01	..	..	..	..
	100·00	100·63	100·00	100·00	100·00
*Forming together bone-earth (tribasic phosphate of lime)	76·65	73·42	70·46	82·59	64·04

For analyses required for practical purposes, it is, indeed, unnecessary and often impossible to determine accurately all the constituents besides the phosphoric acid; but whether two or half-a-dozen constituents are determined, the analytical results should be correct, and be stated in such a manner that manufacturers and agriculturists who prefer making their own superphosphate, can make use of an analysis as the basis for calculating the amount of acid which will be required for rendering the bone-ash soluble. The method most commonly used for determining the phosphates, as well as the present mode of stating the results, are equally objectionable. I would, therefore, recommend for adoption the method and the mode of stating the results adopted in analysis No. 4. In this, it will be seen, phosphoric acid, lime, and sand are the only constituents that have been determined separately; moisture and organic matter are ascertained together, and all the rest by difference.

PURE BONE-ASH.

I have asserted that the amount of phosphate of lime found in commercial bone-ash is frequently overstated, and that the constitution of pure bones is well known, and affords a ready means for checking such errors. It has appeared to me more desirable to prove this assertion by the results of direct investigations of my own than to base it upon calculations derived from published analyses of bones.

With this view I prepared samples of ox and horse bones, selecting the cleanest and hardest. The bones, after being carefully scraped, were broken into small pieces, which were soaked in cold distilled water for a week, in order to remove any soluble salts. After that time they were reduced to powder; this was repeatedly washed with distilled water. The bones thus purified were next burned in a platinum capsule at a moderate heat, the ash was again washed repeatedly with distilled water, then moistened with carbonate of ammonia in order to convert any caustic lime which might have been produced during burning into carbonate. Direct experiments, however, showed that the heat employed was not sufficiently strong to drive off carbonic acid.

Although both the bones and their ash were washed with a great deal of water, it was found impossible completely to remove the alkalies. Even the hardest bones contain some potash and soda. By long washing, the amount of alkalies may be diminished, but hitherto I have not been able to obtain a bone-ash perfectly free from alkalies, though I have washed small quantities for longer than a fortnight on a filter.

Prepared in this way, the ash of horse and ox bones, in a perfectly dry state, was found to consist of:—

Composition of the Ash of—

	Horse-bones.	Ox-bones.
*Phosphoric acid	40·29	39·81
Lime	55·01	55·43
Magnesia	·84	·80
Potash	·25	·49
Soda	·03	·60
Carbonic acid	2·99	3·52
Sulphuric acid	traces	·04
Chlorine	traces	·06
	99·41	100·75
* Corresponding to tribasic phosphate of lime (bone-earth)	87·29	86·25

The ash of the ox-bones was not washed quite so long with water as that of the horse-bones, and contains for this reason rather more potash and soda. These results are here stated as they have been actually obtained in the analysis. In bone-ash, the phosphoric acid is united with magnesia and with lime, and the carbonic with lime. The traces of chlorine and sulphuric acid, in all probability, are present as sulphate of soda and chloride of sodium.

By uniting together the analytical results in the same manner in which the constituents occur in bone-ash, we obtain for the ash of—

	Horse-bones.		Ox-bones.	
Tribasic phosphate of lime, $3\,Ca\,O + P\,O_5$.				
Consisting of—				
Phosphoric acid	38·77		38·38	
Lime	45·24	84·01	44·77	83·15
Phosphate of Magnesia. $2\,Mg\,O, P\,O_5$.				
Consisting of—				
Magnesia	·84		·80	
Phosphoric acid	1·51	2·35	1·43	2·23
		86·36		85·38
Carbonate of Lime.				
Consisting of—				
Lime	3·80		4·48	
Carbonic acid	2·99	6·79	3·52	8·00
Lime, neither united with phosphoric acid nor with carbonic acid	..	5·97	..	6·18
Potash	..	·25	..	·49
Soda	..	·03	..	·51
Chloride of sodium	..	traces	..	·11
Sulphate of soda	..	traces	..	·07
	..	99·40	..	100·74

In perfectly pure bone-ash thus we find no more than 85½ to 86½ per cent. of phosphate of lime and magnesia (bone-earth). It will be noticed that pure bone-ash is much richer in carbonate of lime than the commercial articles, after deduction of sand and other accidental impurities. There is no silica in pure bone-ash, and it is the silica in the shape of fine sand which, driving out carbonic acid from the carbonate of lime, causes the difference in the proportion of carbonate of lime found in pure and the commercial bone-ash respectively.

After uniting the lime and magnesia with phosphoric acid, and the carbonic acid with lime, it will be seen a considerable quantity of lime remains over. I do not think it probable that all this lime is present in the shape of fluoride of calcium.

The state of combination in which it may exist, is of comparatively speaking little importance to the manufacturer of artificial manures. But the fact pointed out in my analyses, I believe for the first time, that there is in bone-ash, and of course also in bones themselves and in bone-black, a considerable excess of lime over and above the lime in the phosphate and the carbonate, will explain why a larger proportion of oil of vitriol must be used for producing a certain amount of soluble phosphate from bone-ash than appears to be necessary according to prevailing theory.

The theory of the formation of soluble phosphate from insoluble bone-earth has been perfectly well known some years; it is not affected by apparent discrepancies between so-called theoretical calculations and actual practice. In the case before us the simple fact is, that in all the analyses of bone-materials a considerable quantity of lime has been overlooked or been supposed to be united with phosphoric acid. As this excess of lime, which I have pointed out as existing in all bone-materials, takes up sulphuric acid when such material is employed for making soluble phosphate, more acid is required than has hitherto been supposed. It is a common complaint of manufacturers of superphosphate, that the materials which they use do not produce the quantity of soluble phosphate which they ought to yield. There is, however, nothing surprising in this complaint, for it originates in a proceeding that rests on calculations in which altogether erroneous data are employed. Instead of 77 per cent. of phosphate of lime, as supposed, the bone-ash employed in all probability only contains 73 per cent.; and instead of 2 or 3 per cent. of carbonate of lime, there is an additional quantity of lime, equal to 5 to 8 per cent. of carbonate of lime, to be saturated before any soluble phosphate can be produced.

10. ANIMAL CHARCOAL (BONE-BLACK).

The animal charcoal or bone-black which is used by sugar-boilers for decolourizing crude sugar is far too valuable a material to be used for agricultural purposes. When it has served for some considerable time as a decolourizing agent it loses its effect, and then is revivified by heating in cylinders. This revivifying process is repeated many times, until most of the carbon in the black is burned off; it is then sold to manure-manufacturers as a refuse material, under the name of animal charcoal. Like all refuse materials, its composition varies greatly. Some samples are very rich in phosphates, others poor. The amount of sand is usually very small; in some samples I have found a large proportion of carbonate of lime.

The subjoined analyses illustrate the differences found in samples of various qualities :—

Composition of Animal Charcoal (Bone-black).

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Moisture and organic matter	30·26	9·52	30·15	27·98	17·38	12·63	12·54
Phosphates of lime and magnesia	60·75	82·48	55·01	49·69	68·53	68·41	70·16
Carbonate of lime, magnesia, &c. (by difference)	5·96	6·19	8·81	13·90	9·42	14·27	12·77
Insoluble siliceous matter	3·03	1·81	6·03	8·43	4·67	4·69	4·53
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

11. BONES.

Bones are used for agricultural purposes in the following states :—

a. Bone-dust.
b. Boiled Bones.
c. Bone Shavings.

a. Bone-Dust.

Before crushing, raw or butchers' bones are now generally boiled out in an open cauldron, and by this means deprived, in a great measure, of their fat. As an article of commerce fat is the most valuable constituent of bones. As a manuring agent it has no value whatever, or perhaps, more strictly speaking, its presence is undesirable, inasmuch as it retards the decomposition and solution of the bones. Far from being injurious, the removal of fat from the bones decidedly improves their agricultural value.

The following is the average composition of a number of samples of bone-dust analysed by me :—

Moisture	12·06
*Organic matter	29·12
Phosphates of lime and magnesia (bone-earth) ..	49·54
Carbonate of lime (determined by difference) ..	6·99
Alkaline salts and magnesia (chiefly common salt)	1·91
Sand	·38
	100·00

* Containing nitrogen	3·69
Equal to ammonia	4·49

In the next table is given the composition of—

No. 1. Sound foreign bones.
„ 2. Decayed foreign bones.
„ 3. Decayed and sound foreign bones mixed.
„ 4. London bones.

	No. 1.	No. 2.	No. 3.	No. 4.
Moisture	12·02	12·15	12·13	12·31
*Organic matter	28·71	27·27	27·80	30·73
Phosphate of lime and magnesia (bone-earth)	49·28	52·99	52·70	49·72
Carbonate of lime (determined by difference)	4·37	4·35	4·17	4·25
Alkaline salts	4·55	2·59	2·84	2·78
Sand	1·07	·65	·36	·21
	100·00	100·00	100·00	100·00
* Containing nitrogen	3·44	3·31	3·43	3·73
Equal to ammonia	4·17	4·02	4·16	4·52

In decayed bones the proportion of organic matter is not quite so great as in sound bones, and the phosphates are rather higher. But the differences are not sufficiently striking to require any comment. In the preceding analyses, the lime which is left in solution after the phosphates have been removed has likewise been determined quantitatively. Calculated as carbonate of lime, it amounts in the four analyses to 8·60, 8·71, 7·50, 7·78, respectively.

b. Boiled Bones.

The bones from which glue-makers have extracted a certain portion of gelatine and nearly all the fat are known in commerce under the name of boiled bones. It must not be supposed, however, that boiled bones do not contain any organic matter, nor furnish on decomposition any ammonia. The following two analyses show the contrary :—

Composition of Two Samples of Boiled Bones.

Moisture	8·06	7·70
*Organic matters	25·45	25·27
Phosphates of lime and magnesia (bone-earth)	60·48	43·73
Carbonate of lime	3·25	9·77
Alkaline salts	·43	
Sand	2·33	13·53
	100·00	100·00
* Containing nitrogen	1·84	2·78
Equal to ammonia..	2·24	3·37

c. Bone Shavings.

Bone-shavings are produced in button-works, manufactories of knife-handles, &c., &c. Being the turnings of hard bones they contain rather more phosphate of lime and a little less organic matter or nitrogen than ordinary bone-dust.

Composition of Bone Shavings.

Moisture	13·12
*Organic matter	26·12
Phosphates of lime and magnesia	53·74
Carbonate of lime	5·39
Alkaline salts	·78
Sand	·85
	100·00
* Containing nitrogen	3·28
Equal to ammonia	3·98

Purchasers of this valuable refuse should be on their guard, for it is frequently mixed with vegetable ivory—a substance which has no appreciable value as a manure, and which resembles so closely bone shavings that the admixture cannot be recognised by simple inspection.

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REPORT

ON

FIELD EXPERIMENTS AND LABORATORY RESEARCHES

ON THE

CONSTITUENTS OF MANURES

ESSENTIAL TO CULTIVATED CROPS.

BY

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Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops. *By* Dr. AUGUSTUS VOELCKER, *Royal Agricultural College, Cirencester.*

THE field experiments on which I have to report were begun in 1855, and have been continued since from year to year. They were at first instituted chiefly for the purpose of ascertaining practically the comparative economic value of some of the artificial manures, such as guano, superphosphate of lime, bone-dust, &c., in reference to root-crops. In the course of my experiments, however, I was led to abandon, more or less, the primary object for which the experiments were at first undertaken, and to make them subservient to assist the solution of several disputed and important points in agricultural and physiological science.

Amongst other questions which arise in the mind of the agricultural chemist who has closely followed the progress of agricultural chemistry, the following are some of the more important:—

1. Can ammonia or nitrogenized matters be dispensed with in manures, or is it desirable that there should be a certain proportion of nitrogenized matter or ammonia in manures?

2. What is the effect of ammoniacal salts, of phosphates, of alkalies, and other fertilizing constituents applied separately upon vegetation?

3. Is the practical effect produced by ammonia, or by phosphates, &c., the same upon wheat or other grain crops as that produced upon turnips or clover?

4. Are there fertilizing constituents which benefit certain crops more than others?

5. Is it desirable or unphilosophical, and therefore leading to the ultimate exhaustion of the soil, to apply special fertilizing matters to the land, *i. e.* matters which contain but 1, 2, or at all events a limited number of chemical compounds? or is it necessary, in order to maintain the permanent fertility of the land, to restore to the soil in the shape of a compound and universal manure, all the constituents removed by the crops grown upon the land in previous years? These and other similar questions, affecting agricultural practice, have occupied me for several years past.

The results of my experiments detailed in the following Report, I trust will be found useful contributions towards the final settlement of the mooted questions.

Field Experiments made in 1855.

Although I believe that the minute chemical analysis of soils, generally speaking, affords but little or no indication as to the fertilizing matters which are best calculated to improve their productive powers, I am still of opinion that it is desirable and even indispensable to record in all field experiments, the principal physical characters, and the amount of at least the chief or preponderating constituents of the soil of the experimental field.

I would therefore observe that the experimental field was a naturally poor shallow soil with clayey subsoil of inconsiderable depth, and resting on the Great Oolite limestone rock.

Submitted to a general analysis, it yielded—

Organic matter and water of combination	6·339
Oxides of iron and alumina, with traces of phosphoric acid	9·311
Carbonate of lime	54·566
Magnesia Alkalies Sulphuric acid } determined by loss	·837
Insoluble siliceous matter (chiefly clay)	28·947
	100·000

The land was left unmanured in the preceding year, and was considered a poor turnip soil.

I purposely selected a poor field; for it strikes me on such a soil the manurial effect of different fertilizers is much better discerned than on land in a high state of fertility. The productive power of soils cannot be increased to an unlimited extent; and when by good cultivation it approaches its maximum state of fertility, the addition of the most effective fertilizing matters cannot produce any marked effect. I may, however, observe that care was bestowed upon the mechanical preparation of the land, which is not always done in field experiments.

The experimental field was divided into ten different plots of one-eighth of an acre each. These plots were arranged side by side in continuous rows of drills, care being taken to reject the headlands. The different manures were all applied to the land on the same day, and the Swedish turnip-seed sown by a ridge-drill on the 20th of June. Subsequently all the plots were treated in precisely the same way, and care was taken to render the experiments in every respect comparative.

One of the plots was left unmanured, the nine remaining were manured as follows:—

Plot 1 received 56 lbs. of Peruvian guano, or at the rate of 4 cwt. per acre.

Plot 2 received 84 lbs. of Suffolk coprolites, treated with one-third their weight of sulphuric acid and 28 lbs. of guano, or at the rate of 6 cwt. of dissolved coprolites and 2 cwt. of Peruvian guano per acre.

Plot 3 received 100 lbs. of bone-dust, or 7 cwt. 16 lbs. per acre.

Plot 4 received 93 lbs. of bone-dust dissolved in one-third its weight of sulphuric acid, or at the rate of 6 cwt. 72 lbs. per acre.

Plot 5 received 56 lbs. of economical manure, or at the rate of 4 cwt. per acre.

Plot 6 received 120 lbs. of nut-cake, or at the rate of 8 cwt. 64 lbs. per acre.

Plot 7 was manured with 140 lbs. of dissolved coprolites, or at the rate of 10 cwt. per acre.

Plot 8 was left unmanured.

Plot 9 received 180 lbs. of commercial night-soil manure, or at the rate of 12 cwt. 96 lbs. per acre.

Plot 10 was manured with a mixture of 1 bushel of soot, 30 lbs. of guano, and dissolved coprolites and dissolved bones.

The respective quantities of these fertilizing matters were all obtained at the same cost of 5*s.* per plot, or at the rate of £2 per acre.

All the different fertilizers were carefully analysed; but in order not to swell too much this Report I abstain from giving the details of the analyses. I may, however, observe that the guano contained 14·177 per cent. of nitrogen, and 25·06 of bone-earth, and nearly 3 per cent. of phosphoric acid in combination with alkalies. We have thus in Plot 1 a manure containing a large proportion of nitrogenized matters as well as phosphates and alkalies.

In Plot 2 only half the amount of guano was used, and phosphates more largely supplied in the shape of dissolved coprolites.

The coprolites, however, having been treated with only one-third their weight of acid, contained scarcely more than 6 per cent. of soluble phosphates; and it is to be feared that the remainder of the undissolved phosphates in the coprolites exercised little or no effect upon the turnip-crop.

In Plot 3 we have a manure which contains 44·22 of insoluble phosphate of lime, and 4·28 per cent. of nitrogen.

In Plot 4 bone-dust dissolved in one-third its weight of sulphuric acid, consequently a manure which contained both soluble and insoluble phosphates, was employed.

The economical manure, a manure highly recommended for the growth of root-crops, and used upon Plot 5, contained in 100 parts—

Water	36·525
Protosulphate of iron	23·756
Sulphate of lime	·860
Sulphate of magnesia	·204
Bisulphate of potash	4·677
Bisulphate of soda	10·928
Sulphate of soda	15·143
Sulphate of ammonia	2·648
Insoluble siliceous matter (sand)	5·850
	100·591

This manure thus contained no phosphoric acid whatever.

In Plot 6 nut-cake was used. This refuse manure contained 4·863 per cent. of nitrogen and 4·12 of phosphate of lime.

The dissolved coprolites used in Plot 7 were free from nitrogenized matter.

In the commercial night-soil manure was found 4·399 per cent. of phosphoric acid.

The whole produce of each experimental plot was weighed, and the weight of the trimmed roots calculated per acre.

The following Table exhibits the yield of the trimmed roots of each plot, calculated per acre, and the increase per acre over unmanured plot:—

	Per acre.			Increase per acre.		
	tons.	cwt.	lbs.	tons.	cwt.	lbs.
Plot 1 (guano) yielded	11	12	56	6	8	56
Plot 2 (guano and dissolved coprolites) yielded	12	16	16	7	12	16
Plot 3 (bone-dust) yielded	8	16	0	3	12	0
Plot 4 (bone-superphosphate) yielded	13	12	16	8	8	16
Plot 5 (economical manure) yielded	6	0	16	0	16	16
Plot 6 (nut-cake) yielded	10	0	0	4	16	0
Plot 7 (dissolved coprolites) yielded	11	12	0	6	8	0
Plot 8 (unmanured) yielded	5	4	0			
Plot 9 (commercial night-soil) yielded	9	4	0	4	0	0
Plot 10 (mixture of soot, guano, dissolved coprolites and bone-superphosphates) yielded	10	0	8	4	16	8

It will appear from these experiments—

1. That phosphatic manures greatly increased the yield of the root-crop.

2. That a purely mineral phosphate, when dissolved in acid and quite free from ammonia, gave as large a return as good Peruvian guano, which is rich in ammonia.

3. That the economical manure, which contained no phosphates, practically speaking, gave no increase in the crop.

4. That manures which are comparatively poor in phosphates produced less effect than manures rich in phosphates.

5. That the form in which the phosphates were employed very much affected the result.

Thus bone-dust treated with sulphuric acid, and consequently containing soluble phosphates, yielded an increase of 8 tons. 8 cwt. 16 lbs. over unmanured plot, whereas an equal money value of bone-dust undissolved yielded an increase of only 3 tons 12 cwt.

6. That guano proved to be a less economical manure for Swedes than superphosphate.

Experiments upon Swedes made in 1856.

The preceding experiments sufficiently show the great importance of phosphates presented in a soluble condition to the crop of Swedes. They appear likewise to indicate that nitrogenized or ammoniacal manures are not so essential as phosphates for the production of a good crop of roots; but they do not touch the question whether or not ammonia can be entirely dispensed with in the cultivation of turnips. This is an important question, for of all fertilizing matters ammonia is the most expensive.

My attention therefore was chiefly directed in the next series of experiments to study the influence which purely ammoniacal manures exert on the growth of Swedish turnips.

Reviewing the experiments made in 1855, it may appear that the nitrogenized matters and ammonia contained in the manures employed had some share in the production of the increase; for it will be remembered that the addition of a small quantity of guano to dissolved coprolites had a very beneficial effect. Again, the fact that bone-superphosphate, containing from 2 to 2½ per cent. of ammonia, gave a much larger return than the mineral superphosphate, might seem to indicate that ammonia in moderate proportion is a desirable fertilizing ingredient of a turnip manure.

A critical examination of these facts, however, I think neither proves nor discountenances the conclusion that ammonia has had a beneficial effect on the recorded experiments; for when comparing the effects of bone-superphosphate with dissolved coprolites, no account was taken of the proportion of soluble phosphate contained in each. I have since ascertained that the dissolved coprolites contained most of the phosphate in an insoluble state, not near enough acid having been employed for dissolving the coprolite powder. Indeed the coprolite manure contained but little soluble phosphate; and as insoluble phosphate, in the shape of coprolite powder, has little or no effect upon vegetation, whilst the insoluble phosphates in bone-dust, partially decomposed by acid, unquestionably are sufficiently available to produce an immediate effect on the turnip crop, the difference in the result may have been due to the larger amount of available phosphates, and not to the ammonia contained in the bone-phosphate. On the other hand, the addition of some guano to dissolved coprolites having produced a beneficial effect, it may be inferred that the ammonia in the guano helped to produce this effect; but since Peruvian guano contains both soluble phosphates and insoluble phosphate of lime in a highly finely-divided state, it may be maintained with equal force that the additional produce resulted from the additional quantity of available phosphates in guano. In short, the experiments in 1855 are not calculated to decide the question whether or not ammonia can be dispensed with as a manuring constituent in a turnip manure.

With a view of throwing some light on the action of ammonia on root-crops, I made in 1856 the following field experiments:—

A portion of a field was divided into twelve parts of one-twentieth of an acre each. The seed was sown on the 21st of June.

The soil on analysis yielded the subjoined results:—

Moisture when analysed	4·72	
Organic matter and water of combination	11·03	
Oxides of iron	9·98	
Alumina	6·06	
Carbonate of lime	12·10	
Sulphate of lime	·75	
Alkalies and magnesia (determined by loss)	1·43	
Silica (soluble in dilute caustic potash)	17·93	
Insoluble siliceous matter (chiefly clay)	36·00	
		100·00

The experimental field was well drained. The surface soil is thin, poor, and full of fragments of limestone, which render the land lighter. Separated from the stones, the soil may be regarded as a stiffish clay-marl, which in wet weather is very tenacious and heavy, and in warm weather dries into hard unmanageable lumps. The depth of the soil was inconsiderable.

The twelve experimental plots were treated in regard to manure as follows:—

		At the rate of per acre.
To Plot 1 was applied well-rotten farmyard manure		15 tons.
To Plot 2 was applied gypsum		6 cwt.
To Plot 3 was applied bone-ash dissolved in sulphuric acid		6 cwt.
To Plot 4 was applied sulphate of ammonia		6 cwt.
To Plot 5 was applied bone-ash dissolved in sulphuric acid	6 cwt.	
and sulphate of ammonia	6 cwt.—	12 cwt.
To Plot 6 was applied bone-ash dissolved in sulphuric acid		12 cwt.
To Plot 7 was applied sulphate of potash		6 cwt.
Plot 8 (unmanured).		
To Plot 9 was applied crystallized sulphate of soda		12 cwt.
To Plot 10 was applied bone-ash dissolved in acid	6 cwt.	
sulphate of potash	6 cwt.	
sulphate of ammonia	6 cwt.—	18 cwt.
To Plot 11 was applied bone-ash dissolved in acid		3 cwt.
Plot 12 (unmanured).		

The dissolved bone-ash on analysis yielded the following results:—

Water	32·80	
Organic matter	·13	
Biphosphate of lime (CaO, PO_5)	18·49	
Equal to bone-earth rendered soluble by acid	(28·80)	
Insoluble phosphates	6·43	
Hydrated sulphate of lime	38·39	
Alkaline salts	1·94	
Sand	1·82	
		100·00

This preparation thus contained a large per-centage of soluble phosphate as well as gypsum, which necessarily must be formed when bone-ash is dissolved in acid. It having been stated by a high authority that in Messrs. Lawes and Gilbert's turnip experiments the sulphate of lime contained in their superphosphate might have had quite as much influence upon the produce as the phosphate of lime, it appeared to me desirable to apply gypsum alone to one plot. Turnips contain a considerable quantity of sulphur; it is therefore not unlikely that in soils deficient in sulphate of lime, the artificial supply of sulphates may be found advantageous to the turnip crop. At the same time it appeared to me desirable to ascertain the effects of alkalies on turnips, and ammonia, potash, and soda applied in the shape of sulphates. We have thus in these experiments sulphuric acid in all the different states of combination in which it is likely to occur in arable land.

Two plots, it will be noticed, were left unmanured. This should always be done in field experiments; for otherwise it is impossible to ascertain whether or not an experimental field is uniform, and what are the unavoidable variations in the produce of two plots of the same field.

It will be noticed that in nearly all plots nothing but simple salts were used, in order not to complicate the interpretation of the results. It is useful, however, to ascertain how far the natural produce may be increased by a compound and approved fertilizer, such as farmyard manure, and in such an experiment ordinary manure should be as liberally supplied as in Plot 1.

The Swedes were taken up in the last week of November, topped and tailed, and the whole produce of each plot weighed.

Table, showing the produce of trimmed Swedes of Experimental Plots, calculated per acre, and increase over the unmanured part of field.

	tons	cwt.	lbs.		tons	cwt.	lbs.
Plot 1 (15 tons of farmyard manure) yielded	7	16	38		5	0	75
Plot 2 (6 cwt. of gypsum) yielded	2	1	45	Decrease.	0	11	30
Plot 3 (6 cwt. of dissolved bone-ash) yielded	8	3	38		5	7	40
Plot 4 (6 cwt. of sulphate of ammonia) yielded ..	2	12	51	Decrease.	0	3	24
Plot 5 (6 cwt. of sulphate of ammonia, and 6 cwt. of dissolved bone-ash) yielded	8	6	41		5	10	78
Plot 6 (12 cwt. of dissolved bone-ash) yielded ..	8	12	90		5	17	15
Plot 7 (6 cwt. of sulphate of potash) yielded	2	10	0	Decrease.	0	5	75
Plot 8 (unmanured) yielded	3	0	19				
Plot 9 (12 cwt. of crystallized sulphate of soda) yielded	3	6	9		0	10	46
Plot 10 (6 cwt. of dissolved bone-ash, 6 cwt. of sulphate of ammonia, 6 cwt. of sulphate of potash) yielded	6	17	6		4	2	43
Plot 11 (3 cwt. of dissolved bone-ash) yielded ..	7	19	51		5	4	88
Plot 12 (unmanured) yielded	2	11	19				

The natural produce of the experimental field was taken at 2 tons 15 cwt. 75 lbs., being the average of the two unmanured plots No. 8 and 12.

These results suggest the following remarks:—

1. The natural produce of this field was very small, as it scarcely amounted to 3 tons per acre; special fertilizing ingredients, such as phosphoric acid, ammonia, &c., therefore may be expected to have full play in a soil like the one of the experimental field.

2. Only those plots yielded an increase which contained phosphates; the other manuring constituents had no effect upon the turnip crop in these experiments.

3. Gypsum cannot replace phosphate of lime in manuring matters. In these experiments it had no effect whatever, which need not surprise if it be remembered that the soil contained naturally $\frac{3}{4}$ of a per cent. of sulphate of lime.

4. None of the other sulphates produced any effect upon the crop. Sulphates, especially sulphate of lime, are much more abundant in nature than phosphates. There are few soils which do not contain abundance of sulphate

of lime to supply our cultivated crops with abundance of sulphuric acid. This appears to me the chief reason why sulphates rarely show any effect upon turnips and other crops.

5. The bone-ash dissolved in acid did not contain any nitrogen, notwithstanding 3 cwt. produced as large an increase as 15 tons of well-rotten farmyard manure.

6. Sulphate of ammonia proved inefficacious when used by itself, or in conjunction with soluble phosphates.

It is possible, however, that the quantity of ammonia used in the experiments was too large. Similar experiments, which I have since undertaken and hope to continue for a number of years, induce me to believe that on the soils in our neighbourhood ammonia has no beneficial effect whatever upon Swedes. And yet it is quite possible that ammonia may prove beneficial on other soils, which, like sandy soils, do not possess in a high degree the power of absorbing ammonia from the atmosphere, nor to accumulate largely nitrogenized organic matters. But the cases in which ammonia or nitrogenized manures are really beneficial to turnips I think are quite exceptional; and I have little hesitation in saying that a great deal of ammonia, the most expensive fertilizing ingredient of guano, at the present time is wasted in most instances in which guano and other ammoniacal manures are exclusively employed in the cultivation of root-crops.

It is certainly a remarkable fact that many thousands of tons of turnips are now raised annually with nothing else but 3 cwt. or 4 cwt. of superphosphate, made exclusively of bone-ash and mineral phosphates.

At least 90 per cent. of all the artificial manures that are now offered for sale, whatever their name may be, are in reality superphosphates; and the great majority of superphosphates contains no appreciable amount of nitrogen. Even those artificial manures which, like nitro-phosphate, ammonio-phosphate, blood-manure, &c., convey the idea of manures rich in nitrogen or ammonia, when prepared for turnips, seldom contain any considerable amount of nitrogen. It is not likely that an intelligent class of men like the makers of artificial manures, would cut short the supply of nitrogenized matters or ammoniacal salts in turnip-manures, if they had not found out by experience that manures made from bone-ash and sulphuric acid alone, and consequently rich in soluble phosphates, have a more powerful influence upon the yield of root-crops than ammoniacal manures, which are comparatively poor in phosphates.

I would likewise specially notice, that even quite dilute solutions of ammoniacal salts retard the germination and early growth of turnips in a remarkable degree.

In the preceding experiments I was surprised to find, contrary to all expectation, that sulphate of ammonia impaired the development of leaves. Ammoniacal salts are generally considered as leaf-producing, fertilizing constituents; I therefore fully expected to see on Plot 4 a luxuriant development of tops on the expanse of the bulbs. But not only did sulphate of ammonia retard the germination of the seed for a short period, instead of pushing it on rapidly, but throughout the whole season the turnip-tops on Plot 4 looked quite as bad, if not worse, than the unmanured plot.

However, in Plot 5, in which sulphate of ammonia was used in conjunction with dissolved bone-ash, I observed, to some extent, the effects which are generally ascribed to ammoniacal manures. The leaves of the turnips in Plot 5 had a much darker appearance than in other plots not dressed with ammoniacal salts, and the plants on this plot, on the whole, looked the most luxuriant.

It would appear from this that ammoniacal salts are useless by themselves as leaf-producing substances, when applied to poor soils deficient in phosphates and other mineral matters necessary for the growth of leaves.

In conjunction with phosphates, sulphate of ammonia in the preceding experiment had a marked effect upon the turnip-tops, but none upon the bulbs.

Experiments on Turnips made in 1857.

My experiments in 1857 were principally made with a view of trying whether sulphate of ammonia, applied alone and in conjunction with phosphates, had the same or a similar effect on richer land than that experimented upon in 1856, and at the same time to determine the influence of nitrogenized matters on the turnip crop. To this end I selected a field which was somewhat deeper, more level, and altogether more fertile than the experimental field in 1856. It yielded on analysis the following results:—

Moisture	1·51	
Organic matter and water of combination	11·08	
Oxides of iron and alumina	14·25	
Carbonate of lime	10·82	
Sulphate of lime	·71	
Magnesia	·51	
Potash (soluble in acid solution)	·32	
Soda (soluble in acid solution)	·05	
Phosphoric acid	·10	
Insoluble siliceous matter (chiefly clay)	61·78	
		101·13

On comparing the composition of this soil with that of the experimental field in 1856, it will be found that the chemical characters of both soils are very much alike. The seed sown on the 10th of June was that of white Swedes. The different manures were mixed with three times their weight of fine sifted burnt clay, in order to secure a more uniform distribution of the manure over the land. Each experimental plot measured $\frac{1}{20}$ of an acre. Leaving unnoticed a number of field trials, I select only those experiments which have a more immediate scientific interest.

Plot 1 was manured at the rate per acre with 3 cwt. of superphosphate.

Plot 2 was manured at the rate per acre with 3 cwt. of fine bone-dust.

Plot 3 was manured at the rate per acre with 3 cwt. of superphosphate, made by dissolving fine bone-dust in 50 per cent. of sulphuric acid.

Plot 4 was manured at the rate per acre with 3 cwt. of bone-superphosphate (purchased).

Plot 5 (unmanured).

Plot 6 was manured at the rate per acre with 1½ cwt. of sulphate of ammonia.

Plot 7 was manured at the rate per acre with 1½ cwt. of sulphate of ammonia and 1½ cwt. of superphosphate, made by dissolving bone-ash in sulphuric acid.

Plot 8 was manured at the rate per acre with 1½ cwt. of bone-ash dissolved in sulphuric acid without ammonia.

Plot 9 was manured at the rate per acre with 4 cwt. of gypsum.

Plot 10 was manured at the rate per acre with 9 cwt. of burnt clay alone (the same quantity which was used with the manures in the other experiments).

Plot 11 was manured at the rate per acre with 3 cwt. of Peruvian guano.

On each plot a good plant was obtained, and the crop singled on the 16th of July, with the exception of the plots upon which sulphate of ammonia and guano were used. Although sulphate of ammonia was used in the small proportion of 1½ cwt. per acre, and previously mixed with three times its weight of burnt clay, it retarded the germination of the seed and the growth of the turnips in their first period of existence. Several other experiments, made on a small scale, and all my experiments upon turnips in 1858 and in 1859, confirm the fact first observed by me in 1855, that sulphate of ammonia, instead of rapidly pushing on the young plant, as generally supposed, retards its development in a very marked degree.

The produce of each plot was taken up on the 19th of November; after trimming and cleaning, the roots were weighed. The following Table gives the produce in Swedes, topped and tailed, and cleaned per acre, and increase per acre:—

Plot.	tons.	cwt.	qrs.	lbs.		Increase per acre. tons.	cwt.	qrs.	lbs.
1. 3 cwt. of superphosphate	10	17	0	16	...	4	5	1	20
2. 3 cwt. of bone-dust	8	11	0	26	...	1	19	2	2
3. 3 cwt. of superphosphate, made by dissolving bone-dust in 50 per cent. sulphuric acid	9	14	3	1	...	3	3	0	5
4. 3 cwt. of purchased bone-superphosphate........................	9	17	2	2	...	3	5	3	6
5. Unmanured	6	11	2	24			Decrease.		
6. 1½ cwt. of sulphate of ammonia ..	5	6	0	21	...	1	5	2	3
7. 1½ cwt. of sulphate of ammonia and 1½ dissolved bone-ash	9	3	0	26	...	2	Increase. 11	2	2
8. 1½ cwt. dissolved bone-ash	8	18	3	22	...	2	7	0	26
9. 4 cwt. of gypsum	6	13	3	17	...	0	2	0	21
10. 9 cwt. of burnt clay	6	16	3	1	...	0	5	0	5
11. 3 cwt. of Peruvian guano	8	18	1	25	..	2	6	3	1

Plot 1, it will be seen, yielded the largest increase; from first to last this plot had the lead as to appearance.

The superphosphate used in this experiment had the following composition:—

Moisture	10·80
Organic matter*	4·21
Biphosphate of lime	20·28
Equal to bone-earth made soluble by acid..	(31·63)
Insoluble phosphates	4·11
Hydrated sulphate of lime	46·63
Common salt	10·78
Sand..............................	3·19
	100·00

It will be seen that there is very little nitrogen in this superphosphate, and that in addition to much soluble phosphate it contains about 11 per cent. of common salt. Salt, I am inclined to think, increases the efficacy of phosphates upon turnips.

Plot 2. The bone-dust used upon this plot was as fine as sawdust, and yielded on analysis,—

Moisture	6·86
Organic matter†	13·14
Phosphates of lime and magnesia	68·17
Carbonate of lime	6·79
Alkaline salts	1·90
Sand..............................	3·42
	100·00

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* Containing nitrogen.......... ·34
Equal to ammonia .... ·41

† Containing nitrogen...... 1·83
Equal to ammonia ...... 2·22

Plot 3. A comparison of the produce of Plot 3 with Plot 2 will show the advantage of applying the phosphates to the land in a condition in which they are readily distributed in the soil by the rain that falls, and more easily dissolved in water than the phosphates in bone-dust.

These dissolved bones gave on analysis the following results:—

Water	24·33	
Organic matter and ammoniacal salts*	5·04	
Biphosphate of lime	17·00	
Equal to bone-earth rendered soluble by acid	(26·52)	
Insoluble phosphates	9·89	
Hydrated sulphate of lime	39·25	
Alkaline salts and magnesia	2·81	
Sand	1·68	
		100·00

Plot 5 (unmanured) gave 6 tons 11 cwt. 2 qrs. 24 lbs.

Plot 9 (gypsum) gave 6 tons 13 cwt. 3 qrs. 22 lbs.

Plot 10 (burnt clay) gave 6 tons 16 cwt. 3 qrs. 1 lb.

The produce of these three plots is so much alike, that the small difference may be safely ascribed to natural variations of the soil. The crop on these plots again shows that gypsum had no effect, and that the experimental field was uniform in its character.

Plot 6. The sulphate of ammonia used in this experiment contained in 100 parts,—

Sulphate of ammonia	98·28	
Fixed salts	·78	
Moisture	·94	
		100·00

We have here actually a decrease of 1 ton 5 cwt. 2 qrs. 3 lbs. of roots per acre. The plants on this plot, I may observe, came up much later, and looked decidedly worse than those on the unmanured plot, or any other part of the experimental field.

It will be remembered that in the preceding season sulphate of ammonia did not increase the yield in bulbs, and likewise prevented the development of luxuriant tops.

Plot 7. The addition of sulphate of ammonia to dissolved bone-ash, it will be seen by comparing the yield of this plot with that of Plot 8, gave but a slight increase, amounting to no more than 4 cwt. 1 qr. 6 lbs. per acre.

Plot 8. The dissolved bone-ash used in this experiment was the same as that used in experiments in the preceding year, and contained—

Biphosphate of lime	18·49
Equal to soluble bone-earth	(28·80)
Insoluble phosphates	6·43

It did not contain any nitrogenized constituents.

Plot 11. The Peruvian guano used upon this plot yielded on analysis,—

Moisture	18·50	
Organic matter and ammoniacal salts†	52·33	
Phosphate of lime and magnesia	21·66	
Alkaline salts‡	6·41	
Insoluble siliceous matter	1·10	
		100·00

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* Containing nitrogen 1·28
Equal to ammonia 1·55

† Containing nitrogen 14·16
Equal to ammonia 17·19

‡ Containing phosphoric acid 1·46

The roots on this plot were for a long time decidedly inferior to the superphosphate turnips. But towards the middle of September the plants took a start, and the guano turnips, so far as the tops were concerned, looked the best in the field. When the crop was taken up, the guano turnips were at least 3 inches higher in the tops, and promised, as far as appearance went, the heaviest crop; but the actual weight of the plots manured with dissolved bone-ash and superphosphate not containing any nitrogenized matters, showed that there was no advantage in using ammoniacal matters for producing good bulbs on the experimental field.

The whole tenor of the field trials in 1857 agrees well with the results of the trials in 1856. The experiments in 1859 afford a fresh proof that salts of ammonia applied alone to root-crops have no beneficial effect, but rather the reverse. They also show that phosphate of lime in a soluble state favours more the production of good bulbs than any other manuring constituent, and that nitrogenized matters are not required in a manure for Swedish turnips, grown on land similar to the experimental field, and under conditions similar to those which prevailed in 1856 and 1857.

In concluding this part of my Report, I may state that last year (1858) the results of my field experiments were entirely spoiled by the ravages which the fly and the black caterpillar committed.

This year (1859) I have an extensive series of field experiments upon Swedes. All the experimental plots look remarkably healthy, and I hope in a future year to repeat the result of this year's trials, which were made like those in 1856, 1857, and 1858, with a special view of determining the influence of nitrogenized substances and ammoniacal salts on root-crops.

Before proceeding with another series of field experiments, I may state that I have analysed at various times hundreds of turnips. It would be occupying too much space to give here tabulated abstracts of these analyses. Although I am still occupied with following up this examination of turnips grown under various conditions, and have not as yet arrived at any definite conclusions respecting the influence of different manuring matters on this crop, I may state a few general facts which my analyses have brought to light.

1. In the first place, I would observe that I do not find any striking differences in the composition of roots raised with different manures, provided they are pulled up in an equally mature condition.

2. Soluble phosphates appear to promote an early maturity of the roots, and ammoniacal salts, on the contrary, to retard the maturity of roots. However, on this point my experiments are not sufficiently numerous and conclusive to establish satisfactorily this matter.

3. Roots grown on poor soils and developed more gradually, contain less water and more sugar, and are consequently more nutritious than roots of a large size grown rapidly with much manure.

4. Contrary to a very prevalent opinion, I find that the best and most nutritious roots invariably contain less nitrogen than inferior less nutritious roots. Indeed I am of opinion that a high per-centage of nitrogen in turnips is a sure sign that the roots have not reached full maturity, and are less wholesome to cattle than well-ripened roots. In the latter I have found, in some instances, fully one-third less of nitrogen than in the same roots at an earlier stage of their growth.

The examination of roots, taken once every fortnight from the same field during several successive months, has shown that the per-centage of nitrogen in turnips steadily decreases in the measure in which they proceed towards maturity. In the measure in which the per-centage of nitrogen decreases, that of sugar increases. Thus in mangolds, which were as yet scarcely sweet to the taste, I have found as much as 2¾ per cent. of nitrogen in the dry roots, whilst in the best and fully ripe mangold wurzels only 1·30 per cent. of nitrogen was found.

The nutritive value of different roots, therefore, is not dependent on the relative proportion of nitrogen which they contain, but is regulated chiefly by the relative proportion of sugar which they yield.

Field Experiments upon Wheat made in 1859.

I have now to record the results of a series of experiments upon the wheat-crop.

The field upon which the experiments were made was perfectly level, and apparently of uniform depth and agricultural capability.

It was divided into seven plots of ¼ of an acre each.

Plot 1 was manured with Peruvian guano at the rate of 2½ cwt. per acre; cost £1 12*s.* 6*d.* per cwt.

Plot 2 was manured with nitrate of soda, 1¾ cwt.

Plot 3 was manured with nitrate of soda, 180 lbs., and common salt, 1½ cwt.; cost £1 12*s.* 6*d.*

Plot 4 was manured with wheat-manure specially prepared, and containing both mineral and ammoniacal constituents, at the rate of 4 cwt. per acre.

Plot 5 was manured with the same wheat-manure, at the rate of 6 cwt. per acre.

Plot 6 (unmanured).

Plot 7 was manured with chalk-marl, 1 ton.

The nitrate of soda used in the experiments contained 97 per cent. of pure nitrate, and the wheat-manure on analysis was found to contain in 100 parts,—

Composition of Wheat-manure, same as used in Experiments on Royal Agricultural College Farm, March 8, 1859.

Moisture	13·60
Sulphate of ammonia*	10·97
Soluble nitrogenized organic matter†	8·08
Insoluble†	14·72
Biphosphate of lime	3·54
Equal to bone-earth rendered soluble by acid	(5·52)
Insoluble phosphates (bone-earth)	9·45
Sulphate of magnesia	·61
Hydrated sulphate of lime	19·73
Chloride of sodium (common salt)	16·84
Insoluble siliceous matters	2·46
	100·00

The different fertilizers were applied in the shape of top-dressings on the 22nd of March, and the produce reaped in the first week of August and thrashed out on the 24th of August.

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* Containing nitrogen	2·32
Equal to ammonia	2·82
† Containing nitrogen	3·53
Equal to ammonia	4·28
Per-centage of anhydrous sulphuric acid (SO_3) in manure (total amount of sulphuric acid in all the sulphates)	15·93
Per-centage of chlorine	10·22
Per-centage of phosphoric acid	8·91

The following Table gives the yield in corn and straw of each experimental plot, the manures employed, and the produce calculated per acre.

Each plot measured $\frac{1}{4}$ of an acre.

	Manures employed and sown, March 22, 1859.	Produce thrashed out, August 24, 1859.
Plot 1.	Peruvian guano, $2\frac{1}{2}$ cwt.; cost £1 12*s.* 6*d.* (guano, £13 per ton).	Grain, 2406 lbs. or $40\frac{1}{10}$ bushels; weight per bushel, 60 to $60\frac{1}{2}$ lbs. Straw, 1 ton 3 cwt.
Plot 2.	Nitrate of soda, $1\frac{3}{4}$ cwt.; cost £1 12*s.* 6*d.* (nitrate of soda, £18 10*s.* per ton).	Grain, 2280 lbs. or 38 bushels; weight per bushel, 60 lbs. Straw, 1 ton 4 cwt. 8 lbs.
Plot 3.	Nitrate of soda, 180 lbs., and chloride of sodium, $1\frac{1}{2}$ cwt.; cost of manure per acre, £1 12*s.* 6*d.* (cost of salt, 30*s.* per ton; of nitrate, £18 10*s.* per ton).	Grain, 2436 lbs. or $40\frac{6}{10}$ bushels; weight per bushel, $60\frac{3}{4}$ lbs. Straw, 1 ton 4 cwt. 48 lbs.
Plot 4.	Wheat-manure, 4 cwt. per acre; cost £1 12*s.* 6*d.* (price of wheat-manure, £8 per ton).	Grain, 2370 lbs. or $39\frac{1}{2}$ bushels; weight per bushel, 60 lbs. Straw, 1 ton 3 cwt. 92 lbs.
Plot 5.	Wheat-manure, 6 cwt. per acre; cost £2 8*s.* (price of wheat-manure, £8 per ton).	Grain, 2652 lbs. or 44 bushels 12 lbs.; weight per bushel, 60 lbs. Straw, 1 ton 7 cwt. 8 lbs.
Plot 6.	Unmanured.	Grain, 1620 lbs. or 27 bushels; weight per bushel, 60 lbs. Straw, 17 cwt. 80 lbs.
Plot 7.	Chalk-marl, 1 ton.	Grain, 1618 lbs. or 27 bushels less 2 lbs.; weight per bushel, $60\frac{1}{2}$ lbs. Straw, 16 cwt. 80 lbs.

A comparison of the different quantities of corn and straw reaped on each experimental plot will show,—

1. That the plot manured with chalk-marl furnished as nearly as possible the same amount of corn and straw as the unmanured plot.

The produce in the one amounted to 1620 lbs. of corn, and in the other to 1618 lbs.; or each gave within 2 lbs. 27 bushels of corn.

In some parts of England chalk-marl is used with considerable benefit for the wheat-crop; but as the soil on the experimental field is full of limestone rubble, it could not be expected that a marl which owes its fertilizing properties almost entirely to the carbonate of lime and to a little phosphate of lime which it contains, should produce any marked effect upon the wheat-crop.

Indeed I did not expect any increase by the application of this marl, and merely used it to ascertain the extent of variation in the produce of two separate plots. The result plainly shows that the experimental field was very uniform in its character and productiveness.

2. The application of only $1\frac{1}{3}$ cwt. of nitrate of soda raised the produce in corn to 38 bushels, and that of straw to 1 ton 4 cwt. 8 lbs.

We have thus here an increase of 11 bushels of corn and $6\frac{1}{4}$ cwt. of straw.

3. By mixing nitrate of soda with common salt, the produce in corn was raised to 40 bushels, thus showing the advantage of a mixture of nitrate of soda with common salt.

4. Almost the same produce as by nitrate of soda and salt was obtained by the application of guano, and by the small quantity of wheat-manure.

By the latter $39\frac{1}{2}$ bushels of corn, and by guano $40\frac{1}{10}$ bushels were obtained, or by the top-dressing with wheat-manure an increase of 12½ bushels; and by that of guano an increase of 13 bushels of corn was obtained at an expense of £1 12*s*. 6*d*.

5. The larger supply of a mixed mineral and ammoniacal fertilizer gave an increase of 17 bushels of corn and 9 cwt. of straw over the yield of the undressed plot.

It will thus appear—

1. That nitrates applied by themselves materially increase the yield of both straw and corn.

2. That the admixture of salt to nitrate of soda is beneficial.

3. That ammonia and nitrogenized matters, which proved ineffective or even injurious in relation to turnips grown on a similar soil on which the wheat was grown, had a most marked and decidedly beneficial effect upon the wheat-crop.

In conclusion, I would observe that I purpose to record the effect of the top-dressings used in the preceding experiments upon the succeeding crops.

EXPERIMENTS UPON SWEDES.

BY

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EXPERIMENTS UPON SWEDES.

AGRICULTURAL experiments are of little or no practical utility unless they are continued from year to year for a long period, and tried on a variety of soils in good and in bad seasons in a manner which allows us, if not to eliminate, yet clearly to recognise the disturbing influences of climate, season, condition of soils, and other circumstances which often affect the produce in a higher degree than the manures on which we experiment. A single field-experiment is as likely to lead us in a wrong as in a right direction. Few persons have the inclination or are in a position to persevere in such a laborious, expensive, and in many respects unthankful course of investigation. But little trustworthy experience and no knowledge is gained from the great majority of published experiments with artificial manures which meet our eye from time to time in the agricultural newspapers, from the want of this continuity of action. For this reason I have continued field-experiments upon swedes, similar to those published in this Journal in 1855 and 1858, and have now the pleasure of presenting to the Royal Agricultural Society a third report on field-experiments upon swedes. I regret to say that in 1858, and again in 1860, my experiments were failures; and only in 1859 did I succeed in getting an even plant and results on which reliance can be placed, and from which I trust some useful information may be gathered.

Although I completely failed in securing an even crop in 1858, it still appears to me advisable that I should describe briefly the kind of experiments which I then made, and give the weight of the produce; for sometimes useful lessons may be learned from failure as well as from success.

In previous trials, extending over five seasons, I found that, on the soils on our farm:—

1. Ammoniacal salts, such as sulphate of ammonia, used alone, had a decidedly injurious effect upon the turnip-crops, even when used in small quantities.

2. Ammoniacal manures applied to swedes at first checked the growth of the plant, and had ultimately no beneficial effect on the crop, either alone or in conjunction with phosphates.

3. Guano proved a less economical manure than superphosphate of lime.

4. The addition of salt to superphosphate seemed to benefit the crop.

5. In dry seasons the best artificial manures are often of little

or no more service to the produce than inferior and all but worthless manures.

With a view of verifying these general conclusions, and obtaining at the same time information on some other points on which I shall have to speak presently, I made the following experiments.

Part of a 40-acre field, marked Nos. 6 and 10 in the map of the farm attached to the Royal Agricultural College, was divided into 20 plots, of 8 poles each:—

No.
1 was manured with farmyard-manure, at the rate of 20 tons per acre.
2 ,, 20 tons of farmyard manure and 2 cwts. of superphosphate per acre.
3 ,, 3 cwts. of superphosphate.
4 ,, 1 cwt. of superphosphate.
5 ,, 6 cwts. of superphosphate per acre.
6 ,, 3 cwts. of gypsum.
7 ,, 2 cwts. of superphosphate and 1 cwt. of guano per acre.
8 ,, 3 cwts. of Peruvian guano per acre.
9 ,, 1 cwt. of sulphate of ammonia per acre.
10 was left unmanured.
11 was manured with 3 cwts. of bone-dust per acre.
12 ,, 2 cwts. of sulphate of ammonia per acre.
13 ,, 3 cwts. of dissolved bones per acre.
14 ,, 1 cwt. of nitrate of soda.
15 ,, 2 cwts. of superphosphate, 1 cwt. of salt, 40 lbs. of nitrate of soda, and 40 lbs. of sulphate of ammonia per acre.
16 ,, 3 cwts. of common salt per acre.
17 ,, 3 cwts. of superphosphate per acre.
18 ,, 3 cwts. of superphosphate and 1 cwt. of sulphate of ammonia per acre.
19 ,, 3 cwts. of sulphate of potash per acre.
20 ,, 3 cwts. of superphosphate and 1 cwt. of nitrate of soda per acre.

The artificial manures were all finely powdered, and before sowing mixed with red ashes (couch-ashes and burnt soil) at the rate of 10 cwts. per acre. The manures mixed with the ashes were sown on the 19th of May, and the seed (Liverpool or Skirving's swede) on the 21st of May. The plants came well up, but were eaten by the fly, and the field had to be resown on the 7th of June. Each experimental plot measured one-twentieth of an acre, and comprehended 4 rows of drills of equal length. The distance from drill to drill was 26 inches. The plants were singled out 12 inches apart. Unfortunately the experimental swedes, as well as the roots adjoining, after having passed the ordeal of the fly, were afterwards attacked by a black caterpillar, the 'black-jack,' as it is called here. Every exertion was made to prevent the ravages of this pest, but without effect. I then tried to make good the bare places by transplanting young swedes, and succeeded tolerably well; but as I had to repeat the transplanting of the roots several times when the season was far advanced, many of the transplanted roots came to nothing, and after all I obtained an unequal crop.

Passing over the composition of the different manures, and the analysis of the soil, I will now record at once the result of the weighings of each plot:—

TABLE *showing Produce in Swedes, topped and tailed and cleaned, of each Experimental Plot and per Acre.*

Plot.	Manure.	Per $\frac{1}{20}$ Acre.			Per Acre.			
		cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.
1	20 tons of farmyard-mauure per acre ..	10	1	21	10	8	3	0
2	20 tons of farmyard-manure aud 2 cwts. of superphosphate	10	1	2	10	8	2	9
3	3 cwts. of superphosphate	11	1	12	11	7	0	16
4	1 cwt. of superphosphate	9	1	0	9	5	0	0
5	6 cwts. of superphosphate	11	0	13	11	2	1	8
6	3 cwts. of gypsum	10	3	16	10	17	3	12
7	2 cwts. of superphosphate and 1 cwt. of guano	12	0	8	12	1	1	20
8	3 cwts. of Peruvian guano	13	2	9	13	11	2	12
9	1 cwt. of sulphate of ammonia	13	2	10	13	11	3	4
10	No manure	11	1	13	11	7	1	8
11	3 cwts. of bone-dust	10	2	15	10	12	2	20
12	2 cwts. of sulphate of ammonia	10	1	22	10	8	3	20
13	3 cwts. of dissolved bones	11	0	0	11	0	0	0
14	1 cwt. of nitrate of soda	12	3	20	12	18	2	8
15	2 cwts. of superphosphate and 1 cwt. of salt	12	1	13	12	7	1	8
16	3 cwts. of common salt	11	3	24	11	19	1	4
17	3 cwts. of superphosphate	10	2	18	10	13	0	24
18	3 cwts. of superphosphate and 1 cwt. of sulphate of ammonia	10	3	17	10	18	0	4
19	3 cwts. of sulphate of potash	9	3	26	9	19	2	16
20	3 cwts. of superphosphate and 1 cwt. of nitrate of soda	10	0	0	10	0	0	0

I give this table in order to show how strangely sometimes experiments turn out, and how necessary it is to observe carefully all circumstances which may affect the final produce. If no notice had been taken of the cause which operated so injuriously on the experimental roots, the strangest deductions might have been arrived at. Thus, it might appear that 1 cwt. of sulphate of ammonia per acre was the best turnip-manure; that 1 cwt. of superphosphate per acre, on the other hand, was injurious to swedes, inasmuch as in the preceding experiments it diminished the produce; that 3 cwts. of gypsum per acre were as good as 3 cwts. of bone-dust for turnips, and that both are equal in fertilizing power to 20 tons of farmyard-manure. These and other absurd conclusions might all be derived from experiments in which the produce has been accurately weighed. Similar contradictions and anomalies strike the attention of the experienced and critical reader of the many reports of like experiments printed in our newspapers. In many instances we cannot but admit that these have been conducted in a conscientious and careful manner; yet the results are such, that if due allowance be not made for circumstances which may easily be overlooked, conclusions may readily be drawn from them which may mislead the inexperienced or confirm the particular fancy of the prejudiced. Thus, let a manure be ever so worthless, yet, if it be tried under varied conditions, it will for some reason or other prove in some few cases superior to fertilizers of recognized merits. If we suppose that these accidental successes are recorded, and all the preponderating number of failures or questionable successes ignored, we see at once how it comes to pass that artificial manures, like the British Economical manure and many others that possess little or no fertilizing value, are nevertheless strongly recommended, and that men of undoubted character are found to testify in good faith that such rubbish is superior to guano, bone-dust, and other well-known fertilizers. Testimonials of manures, even when given by the best and most experienced men, have little value; and, as they are much more apt to lead astray than to do good, it would be well if leading agriculturists would abstain altogether from giving them.

Nothing is more difficult than to establish by experiment a general truth in agriculture. We not only require to modify agricultural experiments in a great variety of ways, but, after we have continued them for a number of years and carefully recorded the results, it is necessary to exercise the greatest caution in interpreting the results, and to look almost with suspicion on everything which at first sight appears plausible or even conclusive.

The preceding experiments, beyond the lesson which they afford of diffidence in accepting points which are said to have been proved by practical experiment, teach us absolutely nothing.

FIELD EXPERIMENTS ON SWEDES MADE IN 1859.

The field selected for the experimental trials in 1859 was in tolerably good condition. It bore clover in 1857, and wheat in 1858. The soil is moderately deep, and well-drained. A portion of the soil, taken from a large sample from different parts of the field, was submitted to analysis, and the following results obtained:—

Composition of Soil from Experimental Field No. 7 of the Royal Agricultural College Farm, Cirencester.

Moisture (when analysed)	3·960
Organic matter and water of combination	9·616
Oxides of iron and alumina	19·660
Carbonate of lime	3·805
Sulphate of lime	·345
Phosphoric acid	·075
Magnesia	·783
Potash	1·239
Soda	·090
Insoluble siliceous matter (chiefly clay)	60·525
	100·098

The soil contains hardly any sand that can be separated by the mechanical process of washing and decantation. It contains, like most of the soils on our farm, an appreciable quantity of sulphate of lime, and also of phosphoric acid. It is not so rich in carbonate of lime as many other of our fields, and is rich enough in clay to be called a good agricultural clay.

This field was quite level, and in a good state of mechanical subdivision.

An acre of this land was divided into 20 parts. The different artificial manures, after having been mixed with couch-ashes and burnt soil, were sown on the 6th of June; the land was ridged up and the seed (Skirving's swedes) drilled on the 7th of June. Each experimental plot contained 4 rows of equal length. The distance between the drills was 22 inches; the plants were singled out 12 inches apart. One part of the field was manured in autumn; the greater part in spring; the portion selected for experiments being then left unmanured.

The following list exhibits the arrangement of the experimental field, the kinds of manure employed, and their quantities, calculated per acre:—

Experiments upon Skirving's Swedes in Field No. 7, Royal Agricultural College Farm, Cirencester, 1859.

Plot		Per Acre.
1	was manured with	15 tons of rotten dung.
2	,,	15 tons of rotten dung and 2 cwts. of superphosphate.
3	,,	3 cwts. of superphosphate.
4	,,	1 cwt. of superphosphate.
5	,,	6 cwts. of superphosphate.
6	,,	3 cwts. of gypsum.
7	,,	2 cwts. of superphosphate and 1 cwt. of guano.
8	,,	3 cwts. of guano.
9	,,	1 cwt. of sulphate of ammonia.
10	was left unmanured.	
11	was manured with	3 cwts. of fine bone-dust.
12	,,	2 cwts. of sulphate of ammonia.
13	,,	3 cwts. of turnip-manure.
14	,,	1 cwt. of nitrate of soda.
15	,,	6 cwts. of turnip-manure.
16	,,	3 cwts. of salt.
17	,,	3 cwts. of bone-ash treated with sulphuric acid.
18	,,	3 cwts. of dissolved bone-ash and 1 cwt. of sulphate of ammonia.
19	,,	3 cwts. of sulphate of potash.
20	,,	3 cwts. of dissolved bone-ash and 1 cwt. of nitrate of soda.

The rest of the field received about 15 tons of farmyard-manure and 3 cwts. of superphosphate mixed with ashes at the time when the seed was drilled. The seed was of the same kind as that used in the experiments. Four rows of turnips, occupying exactly one-twentieth of an acre, were reserved on two sides of the experimental plots, and the produce from these two additional plots was weighed when the produce of the 20 experimental plots was ascertained.

On each plot of the experimental field a remarkably even and good plant was obtained. The season being mild, the roots continued to grow throughout November; they were, therefore, left in the field until the 8th of December, when the crop was taken up. The roots were topped and tailed and cleaned, and the whole produce of each plot then carefully weighed, with the following results:—

TABLE *showing Produce per Acre of Swedes, topped and tailed and cleaned, and Increase per Acre over the Unmanured portion, in Field* 7, *Royal Agricultural College Farm, Cirencester,* 1859.

Plot.	Manure.	Produce per Acre.				Increase per Acre.			
		tons.	cwts.	qrs.	lbs.	tons.	cwts.	qrs.	lbs.
1	15 tons of farmyard-manure	18	10	2	24	3	16	1	20
2	15 tons of farmyard-manure and 2 cwts. of superphosphate	17	6	3	4	2	12	2	0
3	3 cwts. of superphosphate	17	11	2	10	2	17	1	6
4	1 cwt. of superphosphate	17	6	3	4	2	12	2	0
5	6 cwts. of superphosphate	21	2	3	12	6	8	2	8
6	3 cwts. of gypsum	16	14	1	4	2	0	0	0
7	2 cwts. of superphosphate and 1 cwt. of Peruvian guano	18	11	1	20	3	17	0	16
8	3 cwts. of Peruvian guano	18	17	2	20	4	3	1	16
9	1 cwt. of sulphate of ammonia	15	17	3	12	1	3	2	8
10	No manure	14	14	1	4		..	..	
11	3 cwts. of fine bone-dust	18	9	2	16	3	15	1	12
12	2 cwts. of sulphate of ammonia	16	17	3	12	2	3	2	8
13	3 cwts. of turnip-manure	20	1	1	20	5	7	0	16
14	1 cwt. of nitrate of soda	18	9	1	4	3	15	0	0
15	6 cwts. of turnip-manure	20	7	0	16	5	12	3	12
16	3 cwts. of common salt	15	16	1	0	1	1	3	24
17	3 cwts. of dissolved bone-ash	20	15	2	24	6	1	1	20
18	3 cwts. of dissolved bone-ash and 1 cwt. of sulphate of ammonia	20	6	3	24	5	12	2	20
19	3 cwts. of sulphate of potash	17	0	2	4	2	6	1	0
20	3 cwts. of dissolved bone-ash and 1 cwt. of nitrate of soda	21	0	2	4	6	6	1	0

The two plots adjoining the experimental field yielded:—

1	Manured with farmyard and superphosphate	17	6	1	20	2	12	0	16
2	Manured with farmyard and superphosphate	17	18	0	24	3	3	3	20

In looking over the list of the different manures employed in these experiments, it will be noticed in the first place that certain simple salts which commonly enter into the composition of artificial manures have been used separately. It is not likely that we shall ever understand the action of complicated manures if we do not carefully study the separate effect of their component parts on vegetation. For this reason one plot was manured with sulphate of ammonia, another with sulphate of lime (gypsum), a third with sulphate of potash, a fourth with chloride of sodium, and, finally, one with nitrate of soda.

In the next place we have in Plot 17 phosphates chiefly in a soluble condition, and free from organic matter or anything else but sulphate of lime, which is necessarily produced when bone-ash is treated with sulphuric acid. In another plot (No. 18) we have the same materials in conjunction with sulphate of ammonia; and in No. 20 we have them united with nitrate of soda.

Then with respect to the form in which the nitrogen is applied in these experiments, I would observe that we find it in farmyard-manure, partly as ready-formed ammonia, partly in the shape of semi-decomposed nitrogenized organic matter. In sulphate of ammonia it exists, of course, as a salt of ammonia. In nitrate of soda we apply nitrogen in the shape of nitric acid. In guano nitrogen exists, partly only in the form of ammoniacal salts, the greater portion of nitrogen being present as uric acid and other organic compounds which readily yield ammonia on decomposition. And, lastly, we have in the turnip-manure all these different forms in which nitrogen can be applied to the land combined together with phosphates.

The results of these experiments, though unsatisfactory in some respects, are nevertheless interesting and suggestive in others, and worthy of some comments:—

Plot 1. *Manured with* 15 *tons of Farmyard-manure per Acre.*

	tons.	cwts.	qrs.	lbs.
Produce	18	10	2	24
Increase	3	16	1	20

Plot 2. *Manured with* 15 *tons of Farmyard-manure and* 2 *cwts. of Superphosphate per Acre.*

	tons.	cwts.	qrs.	lbs.
Produce	17	6	3	4
Increase	2	12	2	0

In comparing the weight of roots from these two plots, it would appear that the additional quantity of superphosphate has had rather an injurious than a beneficial effect. This, however, would be against common experience. It is probable that there were more plants on No. 1 than on No. 2. Let us suppose that there were 100 plants more on Plot No. 1, and that each root on an average weighed 2 lbs.; on calculating the increase per acre we should obtain nearly 1 ton more on the first plot than on the second. I regret not having counted the number of roots.

If the land is in a poor, unmanured condition, the difference in the weight of roots taken from 2 acres of land—one acre containing 2000 or 3000 plants less than the other—may be hardly appreciable, provided the roots have not been drilled too far apart and not singled out too wide apart; for on the acre on which a less number of roots is grown, each root has more room, and, as the land is in a poor condition, the plants are less stinted in food than on the second acre. We obtain thus larger but fewer roots on one acre, and smaller but more roots on the other; and the difference in the produce of both acres may be imperceptible, and even in favour of the acre on which the smaller number of roots were grown. But supposing the land is in a high state of fertility, and each plant can find abundance of ready-prepared food, the result must be quite different. If singled out too wide apart, the roots will be found not much larger than on similar land planted moderately close; and in the latter case the weight per acre will be larger than on the former.

Here, as in so many other instances, it is impossible to lay down exact rules how far apart the drills should be, and how wide the plants should be singled out. On some land 26 inches by 15 inches is not too wide; on other land 22 inches is a good width between the drills, and 12 inches a fair distance between the plants. If the soil is shallow and poor, the drills should be at least 26 inches apart, and the plant singled out rather wide; for the roots in that case will extend their feeding-fibres on the surface, and require a larger space than they do in a deep, well-pulverised, loamy soil.* On the whole, I am inclined to think that in many cases we do not get so heavy a crop of roots when we plant too far apart, as when we plant closer. Farmers do not like to see their neighbours grow bigger roots than they themselves can grow; but I question much whether the objectionable custom of giving silver prize-cups to large-sized roots has not done a great deal towards diminishing the quality as well as the quantity of the produce in bulbs per acre. I am inclined to think an acre of roots of moderate size, and grown tolerably near together, is worth more money than an acre of

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* The proposed time and mode of consuming the crop will have nearly as much to do with determining these distances as the soil. Late white turnips, intended to serve as spring food for ewes and lambs, may well be sown with 5 drills, occupying the same space as 3 rows of Swedes intended to be partly drawn and stored. Plants not fully developed, and young, resist atmospheric influences far better than those that are ripe and large. It is by no means clear to me that on the poorer soil the smaller root is not more eligible, apart from the question of total weight per acre.

The difference between the power of full grown white mustard, and that which is but a few inches high, in resisting frost is remarkable. For many of man's uses the ideal and fully developed plant is not the most serviceable.—P. H. F.

large-sized roots planted far apart. Some time ago I had a calculation made of the number of roots which can be grown per acre when drilled at different distances and singled at different breadths, and as these calculations may be useful to others, and convince them, as they have done myself, that we should manure the root-crop well in the first instance, and then plant tolerably closely, I have incorporated them in the following table:—

TABLE, *showing the Number of Roots per Acre, drilled at different intervals and singled at different distances, also the Area occupied by each Plant, in square inches.*

Singled apart, in Inches.		Width of Drills.	Number of Plants per Acre.	Area occupied by each Plant. Sq. inches.		Sq. feet.
9	by	26	26,806	234	=	$1\frac{5}{8}$
9	,,	22	31,680	198	=	$1\frac{3}{8}$
12	,,	26	20,104	312	=	$2\frac{1}{6}$
12	,,	22	23,760	264	=	$1\frac{5}{6}$
15	,,	26	16,083	390	=	$2\frac{5}{7}$
15	,,	22	19,008	330	=	$2\frac{7}{24}$
18	,,	26	13,403	468	=	$3\frac{1}{4}$
18	,,	22	15,840	396	=	$2\frac{3}{4}$

But to return to the plots. I have reason for believing that there must have been more roots on Plot No. 1 than on Plot No. 2; for I find the land on one side of the experimental plots yielded 17 tons 6 cwts. 1 qr. 20 lbs. per acre, and on the other side it gave 17 tons 18 cwts. 24 lbs. per acre. The whole field, as mentioned already, was manured with about 15 tons of yard-manure and 3 cwts. of superphosphate. This produce agrees well with the weight of the roots on the second plot, manured with dung and superphosphate. Still we have a difference of nearly 12 cwts. of roots in the two plots adjoining the experimental lots, and ought, therefore, to remember that the natural variations of the land and other purely accidental circumstances may readily give a difference in the produce of different portions of land which have been treated in every respect alike. Indeed, if the difference in the produce does not amount to more than 1 ton, or even 1¼ ton, I fear we cannot do much with the results. It certainly would be rash to lay stress on such differences, and to use them as arguments in proving or denying the efficacy of certain manuring matters:—

Plot 3. *Manured with* 3 *cwts. of Superphosphate.*

	tons.	cwts.	qrs.	lbs.
Produce	17	11	2	10
Increase	2	17	1	6

Plot 4. *Manured with* 1 *cwt. of Superphosphate.*

	tons.	cwts.	qrs.	lbs.
Produce	17	6	3	4
Increase	2	12	2	0

Plot 5. *Manured with* 6 *cwts. of Superphosphate.*

	tons.	cwts.	qrs.	lbs.
Produce	21	2	3	12
Increase	6	8	2	8

The superphosphate used in these experiments had the following composition:—

Moisture	10·80
*Organic matter	4·21
Bi-phosphate of lime	20·28
Equal to bone-earth rendered soluble	(31·63)
Insoluble phosphates	4·11
Hydrated sulphate of lime (gypsum)	46·63
Alkaline salts (common salt)	10·78
Insoluble siliceous matter	3·19
	100·00

* Containing nitrogen	·34
Equal to ammonia	·41

It will be observed that in this experiment 1 cwt. of this superphosphate gave nearly as much increase as 3 cwts. of the same manure. It would, however, be rash to generalise from this one instance; nothing less than a dozen experiments in different parts of the field would have warranted the conclusion that on this soil 1 cwt. of superphosphate will give as good a crop of roots as 3 cwts.; for the fact that the soil is not particularly rich in phosphoric acid renders such a supposition unlikely. Moreover, we have a direct evidence in the Experiment No. 5 that the roots were grateful for an abundant supply of phosphates. 6 cwts. of the same superphosphate here yielded the heaviest increase of all the 20 experimental plots. The superphosphate ued in this experiment was chiefly made from bone-ash, and contained but very little nitrogen. We have thus here another proof that a good crop of roots can be obtained on clay land with superphosphate alone, containing but little nitrogenized or other organic matters.

Plot 6. *Manured with* 3 *cwts. of Gypsum.*

	tons.	cwts.	qrs.	lbs.
Produce	16	14	1	4
Increase	2	0	0	0

The gypsum employed in this experiment was ordinarily good, finely-powdered gypsum, which did not effervesce with an acid, thus proving that it did not contain any carbonate of lime.

It seems that in this instance gypsum has had unusual effect on the produce. Probably the ashes with which the gypsum was mixed had a share in the increase.

Plot 7. *Manured with* 2 *cwts. of Superphosphate and* 1 *cwt. of Peruvian Guano.*

	tons.	cwts.	qrs.	lbs.
Produce	18	11	1	20
Increase	3	17	0	16

The increase produced by a mixture of 2 cwts. of superphosphate and 1 cwt. of Peruvian guano, it will be seen, is greater than the increase produced by 3 cwts. of the same superphosphate.

In many instances I find that a mixture of two parts of good superphosphate and one part of Peruvian guano gives a better crop than either superphosphate or guano applied alone.

Plot 8. *Manured with* 3 *cwts. of Peruvian Guano.*

	tons.	cwts.	qrs.	lbs.
Produce	18	17	2	20
Increase	4	3	1	16

In this case Peruvian guano produced rather a better result than the mixture of superphosphate and guano used in the preceding experiment. However, the difference does not amount to more than 6 cwts., which is too insignificant to decide the question whether in the case before us Peruvian guano alone had really a better effect upon the crop than the mixture of superphosphate and guano. In former years I have found, however, that Peruvian guano produced not nearly so great an increase as superphosphate alone, or a mixture of superphosphate and guano. There are, no doubt, soils for which guano is the most profitable manure even for root-crops; but this is rather the exception than the rule.

If there is a deficiency of available nitrogenized matters in a soil, a moderate amount of ammoniacal matters appears decidedly to benefit the turnip-crop.

On the soil of the experimental field nitrogenized matters appear to have had a beneficial effect even when applied by themselves, which was not the case in the experiments which I tried on other soils in past years.

The composition of the Peruvian guano used in this and the preceding experiment shows that it was a genuine sample of superior quality, as 100 parts on analysis yielded—

Moisture	16·12
*Organic matter and ammoniacal salts	52·31
Phosphates of lime and magnesia	22·55
Alkaline salts	7·94
Insoluble siliceous matter	1·08
	100·00
* Containing Nitrogen	14·64
Equal to ammonia	17·77

Plot 9. *Manured with* 1 *cwt. of Sulphate of Ammonia.*

	tons.	cwts.	qrs.	lbs.
Produce	15	17	3	12
Increase	1	3	2	8

Plot 12. *Manured with* 2 *cwts. of Sulphate of Ammonia.*

	tons.	cwts.	qrs.	lbs.
Produce	16	17	3	12
Increase	2	3	2	8

The sulphate of ammonia used in these experiments was found to consist, in 100 parts, of—

Pure sulphate of ammonia	98·28
Fixed salts	·78
Moisture	·94
	100·00

The increase on Plot 9, obtained with 1 cwt. of sulphate of ammonia, is inconsiderable, and might be ascribed to natural variations in the soil, or to the ashes with which the sulphate was mixed. But the larger increase, produced by double the quantity used on Plot 12, together with the fact that Peruvian guano produced a much better result than in former experiments, shows that sulphate of ammonia has had a beneficial effect on the swedes in this instance. The effect, however, was not great when compared with that produced by phosphatic manures.

Plot 11. *Manured with* 3 *cwts. of fine Bone-dust.*

	tons.	cwts.	qrs.	lbs.
Produce	18	9	2	16
Increase	3	15	1	12

Bone-dust, as might have been anticipated, gave a considerable increase. The bone-dust used in this experiment was very fine, it having been specially reduced to a coarse meal. On analysis it was found to consist of—

Moisture	10·58
*Organic matter	30·61
Phosphates	51·67
Carbonate of lime and magnesia	6·03
Alkaline salts	0·58
Sand	0·53
	100·00
* Containing nitrogen	3·71
Equal to ammonia	4·50

Plot 13. *Manured with* 3 *cwts. of Turnip-manure.*

	tons.	cwts.	qrs.	lbs.
Produce	20	1	1	20
Increase	5	7	0	16

Plot 15. *Manured with* 6 *cwts. of Turnip-manure.*

	tons.	cwts.	qrs.	lbs.
Produce	20	7	0	16
Increase	5	12	3	12

The turnip-manure used in these experiments on analysis gave the following results:—

Moisture	15·16
*Sulphate of ammonia	8·64
†{Soluble nitrogenized organic matters ..	9·25
Insoluble nitrogenized organic matters ..	11·13
Bi-phosphate of lime	4·99
Equal to bone-earth rendered soluble ..	(7·79)
Insoluble phosphates (bone-earth)	16·48
Hydrated sulphate of lime	19·26
Alkaline salts	12·55
Insoluble siliceous matter	2·54
	100·00

* Containing nitrogen .. .. 1·83
† Containing nitrogen .. .. 3·91

This is a very superior manure, which it will be seen produced a very large increase on Plot 13, though only 3 cwts. were applied to the acre. It is somewhat remarkable that double the quantity of this manure did not produce a much more considerable increase.

Plot 14. *Manured with* 1 *cwt. of Nitrate of Soda.*

	tons.	cwts.	qrs.	lbs.
Produce	18	9	1	4
Increase	3	15	0	0

I am not aware of any accurate experiments in which nitrate of soda has been used by itself for turnips. The effect which so small a quantity as 1 cwt. of nitrate of soda produced on the crop was decidedly beneficial, for it will be noticed that as large a produce was obtained with 1 cwt. of nitrate of soda as with 3 cwts. of fine bone-dust. This result is certainly encouraging, and suggests a series of trials with nitrate of soda upon root-crops. The nitrate should be used in such trials by itself, as well as in conjunction with superphosphate or bones. The nitrate of soda used in this experiment was a good sample. It contained in 100 parts—

Moisture	1·87
Pure nitrate of soda	95·68
Chloride of sodium	·79
Sulphate of soda	1·17
Sand	·49
	100·00

Plot 16. *Manured with* 3 *cwts. of Common Salt.*

	tons.	cwts.	qrs.	lbs.
Produce	15	16	1	0
Increase	1	1	3	24

Common salt, it seems, has had little or no effect in this experiment; but it does not follow that it may not be beneficially applied to swedes in conjunction with other fertilizing substances. On analysis the salt yielded the following results:—

Moisture	7·66
Organic matter	·09
Sulphate of lime	3·44
Chloride of magnesium	·11
Chloride of sodium	88·70
	100·00

Plot 17. *Manured with* 3 *cwts. of Dissolved Bone-ash.*

	tons.	cwts.	qrs.	lbs.
Produce	20	15	2	24
Increase	6	1	1	20

In preparing the manure used in this experiment, 100 lbs. of good commercial bone-ash were mixed with 70 lbs. of sulphuric acid; and after some time this mixture was dried up with 50 lbs. of sulphate of lime. By these means an excellent superphosphate was obtained, as will be seen by the following analysis. The manure, being made of bone-ash, did not contain any ammoniacal salts nor appreciable quantities of nitrogen:—

Composition of Dissolved Bone-ash.

Moisture	5·65
Organic matter	3·51
Bi-phosphate of lime	19·64
Equal to bone-earth rendered soluble ..	(30·65)
Insoluble phosphates	·86
Hydrated sulphate of lime	64·96
Alkaline salts	1·83
Sand	3·55
	100·00

The result of this plot affords another proof that a good crop of swedes may be obtained with a superphosphate in which all the phosphates are rendered soluble, and which contains no nitrogenized matters. Some persons think that a good superphosphate should invariably contain insoluble as well as soluble phosphates, for they imagine that the latter are washed away too rapidly, and that therefore the superphosphate should contain insoluble phosphates, to sustain, as they say, the after-growth of the plant. It is a mistake to think that soluble phosphate is very readily washed away into the subsoil, and that it therefore merely pushes on the young plant, and is no longer available when the roots begin to swell. The fact is, no soluble phosphate—*i. e.* bi-phosphate—of lime, as such, can enter into the delicate structure of the root-fibres; it must first become insoluble before it can benefit the young turnip-plant, and this it does readily when it is washed by a shower of rain into the soil, or applied at once in a state of solution with the liquid-manure drill. At any rate we have here presented to us an instance in which a superphosphate containing no nitrogen, and, practically speaking, no insoluble phosphates, produced an increase of 6 tons of cleaned swedes, topped and tailed, or almost as large an increase as any of the fertilizers tried in these experiments.

Plot 18. *Manured with* 3 *cwts. of Dissolved Bone-ash and* 1 *cwt. of Sulphate of Ammonia.*

	tons.	cwts.	qrs.	lbs.
Produce	20	6	3	24
Increase	5	12	2	20

In this experiment the addition of sulphate of ammonia to dissolved bone-ash appears to have done no good whatever. I do not think, however, that the small difference in weight between Plots 17 and 18 warrants the conclusion that its influence was prejudicial.

Plot 19. *Manured with* 3 *cwts. of Sulphate of Potash.*

	tons.	cwts.	qrs.	lbs.
Produce	17	0	2	4
Increase	2	6	1	0

The sulphate of potash used in this experiment was a good commercial sulphate. It produced about the same increase as 2 cwts. of sulphate of ammonia; and, in comparison to the effect which phosphatic manures produced, must be considered as a manuring constituent which did not seem to be required on the soils on which the experiments were tried.

Plot 20. *Manured with* 3 *cwts. of Dissolved Bone-ash and* 1 *cwt. of Nitrate of Soda.*

	tons.	cwts.	qrs.	lbs.
Produce	21	0	2	4
Increase	6	6	0	1

In comparison with the produce from No. 17, we have here in round numbers 14 cwts. more roots. This larger increase falls quite within the limits of variation which we must naturally expect in two different parts of the same field. It cannot be, therefore, regarded as a proof that nitrate of soda increased the efficacy of the dissolved bone-ash.

Rejecting some anomalous results, as those obtained from

Plots 1 and 2, I think we may safely draw the following conclusions from the preceding experiments:—

1. They indicate in the most decided manner the great superiority of phosphatic matters as manuring constituents for root-crops.

2. It would indeed appear that a sufficient quantity of soluble phosphates renders other fertilizing matters superfluous on soils that have a constitution similar to that of the experimental field.

3. Although ammoniacal salts have had some slight effect when applied alone, they did not appear to exercise any specific action on the turnip-crop.

4. The experiments leave it undecided whether it is desirable to add ammoniacal salts or nitrates to superphosphate. At the same time they appear to favour the view that on clay soils nitrogenized matters do not increase the efficacy of soluble phosphate in a turnip-manure, and to confirm my previous observations extending over a number of years.

5. In this series of experiments nitrate of soda had a decidedly beneficial effect on the turnips.

In 1860 precisely the same fertilizing matters were used on another field of our farm, and the experiments made in every respect in the same manner as in 1859. An unfavourable season, the turnip-fly, and other casualties, unfortunately spoiled my experiments. I am glad, therefore, that in place of experiments made by myself, I am in a position to communicate a series of experiments which I induced the late Mr. Campbell, of Craigie House, Ayr, to institute in 1860. Mr. J. Russell, steward to the late Mr. Campbell, kindly favoured me with the following tabular statement, showing the quantity and kind of manure employed per acre, its cost, and the produce in clean roots, topped and tailed. (See p. 86.)

The experimental piece of ground, I am informed, appears to be of equal quality. The soil is considered a rich, light, sandy loam. Each plot was composed of 3 drills, and occupied 2 poles imperial measure. Distance from drill to drill 28 inches. The seed, Skirving's Improved Purple-top Swede, was sown on the 18th of May, and the roots taken up on the 22nd of November. The roots grown on the central drill of each plot were carefully freed from dirt, topped and tailed, and weighed. The roots on Plots 1, 2, 3, 11, I am informed, were soon left behind. On Plots 1 and 11, as will be seen, no manure was applied; and on Plots 2 and 3 sulphate of ammonia only. The produce on one of the two unmanured portions of the land amounted to 1 ton more than on the other.

Experiments upon Swedes made at Craigie House, Ayr.

Plot.	Manures applied per Imperial Acre.	Cost of Manure per Acre.			Produce per Imperial Acre.			
		£.	s.	d.	tons.	cwt.	qrs.	lbs.
1	No manure		..		17	0	0	0
2	1½ cwt. of sulphate of ammonia	1	4	0	18	17	0	16
3	3 cwts. of sulphate of ammonia	2	8	0	20	17	2	0
4	2 cwts. of sulphate of ammonia and 3 cwts. of superphosphate, made from bone-ash and sulphuric acid (dissolved bone-ash)	3	2	0	26	3	1	12
5	5 cwts. of dissolved bone-ash, the same as that used in No. 4	1	15	0	26	15	1	12
6	5 cwts. of dissolved bone-dust	1	17	6	24	17	0	14
7	7 cwts. of dissolved bone-ash, the same as in No. 4	2	9	0	24	19	1	4
8	3 cwts. of dissolved bone-ash, the same sample used in No. 4	1	1	0	24	0	0	0
9	10 cwts. of dissolved bone-ash	3	10	0	24	10	2	24
10	6 cwts. of phospho-Peruvian guano	3	12	0	30	6	1	2
11	No manure		..		16	0	0	0
12	6 cwts. of Peruvian guano	3	18	0	31	10	0	20
13	11 cwts. of dissolved bone-dust	4	2	6	30	8	2	8
14	30 tons of Dublin street-manure, including cartage	3	0	0	24	8	2	8
15	5 cwts. of Ritchie's dissolved bones	1	17	6	26	6	1	20
16	10 cwts. of Ritchie's dissolved bones ..	3	15	0	27	8	2	8

A careful reader will not fail to notice some strange discrepancies in the preceding experimental results. Thus it will strike him as peculiar that 3 cwts. of dissolved bone-ash yielded 24 tons of roots, whilst 7 cwts. of the same manure gave only about 1 ton more, and 10 cwts. only 10½ cwts. more per acre. 5 cwts of dissolved bone-ash, on the other hand, gave 26 tons 15 cwts. 1 qr. 12 lbs. 5 cwts. thus appear to have produced a heavier crop than 10 cwts. of the same manure.

I do not pretend to explain these discrepancies, but have no doubt the experiments were carefully made, and can only say that, for some reason or the other which often escapes our notice, some strangely anomalous results are sometimes obtained in field-experiments. The chief practical lessons which may be derived from these experiments appear to me to be—

1. That sulphate of ammonia had little effect upon turnips, even when applied to a light, sandy loam.

2. That the addition of sulphate of ammonia to superphosphate seemed to have had no decidedly beneficial effect on the crop.

3. That 5 cwts. of good superphosphate appear to be a suffi-

cient dressing for roots on rich, light land, and consequently that it is a waste of money to apply such dressings as 8 or 10 cwts.

4. That cheap manures, costing, it may be, only 1*s*. per ton, in reality are generally more expensive turnip-manures than fertilizers which, like Peruvian guano, cost 13*l*. a ton, or superphosphate, costing from 6*l*. to 8*l*. a ton.

Royal Agricultural College, Cirencester,
June 16*th*, 1861.

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ON THE

COMPOSITION OF CHEESE,

AND ON

PRACTICAL MISTAKES IN CHEESE-MAKING.

By DR. AUGUSTUS VOELCKER.

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COMPOSITION OF CHEESE.

In the opinion of many persons English cheese is not what it used to be in the good old time, when it was far more common than now-a-days for farmers' wives personally to preside over the dairy and conduct the making of cheese through its various stages. Some people assert positively that the English cheese of the present day is inferior in quality to that which was made centuries ago. It is of course impossible to give satisfactory proofs of this supposed inferiority; but at the same time it must be admitted that the prevailing custom of leaving the chief dairy operations almost entirely in the hands of servants furnishes strong presumptive evidence in favour of those who maintain these views. As a rule, we have found the best cheese on farms where the mistress of the house was herself dairymaid-in-chief, especially if industrious habits and scrupulous cleanliness were associated with superior intelligence. Indeed I have had recently frequent occasion to notice the intimate connection which appears to exist on the one hand between good cheese and cleanliness, order, general intelligence, and desire to excel, and on the other hand between bad cheese, slovenliness, ignorance, and practical conceit. In the best-managed dairies, however, cheese-making is practised entirely as an empiric art, which is admitted by our best practical authorities to be capable of great improvement, the importance of which is obvious when we consider the large amount of capital directly or indirectly embarked in dairy-farming. Mr. Humberstone, member for Chester, has the merit of having first directed the attention of our Society to the importance of scientific investigation into the principles of cheese-making; and the Council, on the recommendation of the Chemical Committee, made a special grant to enable me to visit the principal dairy districts of England, to carry out certain practical experiments, and obtain what practical assistance I required. The more direct laboratory experiments, which, like the whole investigation, are still in active progress, have been selected by the Chemical Committee as one of the regular subjects for investigation for the current year. During the last ten months I and two of my assistants have been almost exclusively occupied with the analytical work demanded by a thorough investigation into the principles of cheese-making. At the same time I have spent between four and five weeks at different times in visiting the dairies of Gloucestershire, Wilts, Somersetshire, Warwick, Stafford, and part of Cheshire; and I purpose paying another visit to Cheshire and Derbyshire in the ensuing summer vacation. This Paper will embody some of the practical conclusions to which I have arrived, partly from my visits, and partly from my investigations.

The first point to be observed is, that cheese is often spoiled (to use an Irishism) before it is made—that is, before it is separated from the milk: in other words, the milk is spoiled. Then the cheese is spoiled during the making, and also in the keeping. Again I have learned that richer cheese may be made on some land, even when a portion of cream has been taken from the milk, than on other land where the whole milk is used. 3rd. I concur with our best and most intelligent cheese-makers in the opinion, that good saleable, though perhaps not very fine-flavoured, cheese can be made on any description of land, provided proper care and attention are paid to the management of the milk at the beginning, to the treatment of the cheese in the tub, and to its after ripening. 4th. From all I could learn practically, and from what I have seen with my own eyes, I have come to the conclusion that bones improve the quality of the pasture and the richness of the milk, but also that more care is required to make cheese from boned-pasture than on poor land. 5th. The flavour of the different kinds of cheese, such as Cheddar, Stilton, Cheshire, and others, is much more dependent on the method in ordinary use in these different counties than on the quality of the pasture, although the latter exercises a considerable influence. The inferiority of the Boothy cheese, made from dry food, to that produced when the cows are at grass, is well known. Nevertheless, admitting that food does much affect the flavour of cheese, I still am of opinion that the various practical manipulations exercise a yet higher influence in this respect. 6th. Each system of cheese-making, whether that of Gloucestershire or Somersetshire, appears to have its peculiar excellences, but also its peculiar defects. 7th. Matters altogether indifferent are frequently insisted upon as essential to success, whilst others of the greatest importance are either neglected altogether or much under-valued: unless therefore a person thoroughly understands the grounds of his selection and preference, it is better to adopt one empiric method than to attempt to combine the different plans. 8th. I found good makers of cheese who had never heard a word about chemistry. 9th. Although much mystery is thrown around this art, all that is mysterious about it is purely accidental: the process in itself is very simple, and accords well with scientific principles so far as these have been ascertained; but skilful management is perhaps rather the exception than the rule. 10th. Even good practice may be considerably improved, or, more correctly speaking, simplified, by the application of scientific principles to cheese-making. 11th. With respect to the recent mechanical improvements which have been introduced in the dairy districts, Keevil's and Coquet's apparatus, and others which have been described at some length in a former volume of our Journal, save indeed a great deal of labour and time, but otherwise effect nothing which may not be done by skilful hands. 12th. Milk, as I have ascertained by numerous analyses, varies much in its composition, for which reason great differences must also be expected in cheese. 13th. Considerable loss both in quality and quantity of cheese was found to arise from careless management. 14th. In studying the action of rennet on milk I find that misapprehension, if not altogether wrong statements, prevail in what has hitherto been said and written respecting its action. I shall have presently to advance proofs in confirmation of this assertion. 15th. I would observe, that generally the scientific principles involved in the manufacture of cheese are either misstated by scientific writers on the subject, or but imperfectly recognised by practical men.

These are some of the principal conclusions at which I have arrived in the course of my investigation. As it is not my intention to write a complete essay on cheese-making, I shall at present only endeavour to point out—1st, some of the chief errors made in the process, stating my reasons for speaking of them as such; and 2ndly, to suggest some remedies and safeguards. But, in order to make my subsequent remarks a little more intelligible, I must briefly allude to the composition of milk, which, as is well known, is not a uniform white liquid, but a fluid owing its opaque character to a number of little cream globules. Seen under a miscroscope of no very great power, milk appears as a colourless fluid in which there are floating innumerable little white globules or small bags containing fatty matter. The butter is encased in these microscopic bags or cells, which themselves are composed of very much the same material as the curd of milk. These, being lighter than water, rise on standing, and are removed as cream. If it were possible to separate the cream completely by standing, the milk would be almost colourless; but inasmuch as a certain number of milk-globules always remain suspended in milk, even after long standing, skimmed-milk is always more or less opaque. We must find, therefore, in the cheese made from skimmed-milk a certain amount of butter, though much less than in whole-milk cheeses. On the removal of the cream the milk becomes bluer and more transparent; and hence the transparent and peculiarly blue appearance of some of the London milk is indicative of its poorness. On allowing milk to become acid, which it does readily in warm weather, one of its constituents, which, from its sweet taste, is called sugar-of-milk, is converted, at least in part, into lactic acid. This change is effected by simple transposition of the elementary particles of milk-sugar, without anything being added or detracted from them. This lactic acid again separates the next constituent, the casein or curd of milk, which may also be separated by rennet. On the removal of the casein, either artificially by rennet or naturally by the lactic acid, we obtain whey; and, provided this whey is perfectly clear and free from all butter and curd (which is not generally the case) in our dairies, we may, by evaporating the clear liquid, obtain milk-sugar and a certain quantity of matter which is incombustible, and constitutes the ash of milk. These then are the principal constituents of milk—curd or casein, butter, milk-sugar, and mineral matters or ash. Now, in the preparation of cheese we separate the curd or casein, and, if we want to make good cheese, also the butter and a small quantity of mineral matter contained in the milk. In the whey remains the milk-sugar and most of the mineral matter. A glance at the subjoined diagram, which gives the composition of different kinds of milk lately analysed by me, will show the enormous difference that exists in the relative amounts of the various constituents of milk.

Composition of New Milk.

	No. **1.** Milk analysed Oct. 21, 1860.	No. **2.** Milk analysed Nov. 29, 1860.	No. **3.** Milk analysed Sept. 18, 1860.	No. **4.** Milk analysed Aug. 7, 1860.	No. **5.** Milk analysed Sept. 6, 1860. (Morning's milk.)	No. **6.** Milk analysed Sept. 6, 1860. (Evening's milk.)
Water	83·90	85·20	86·65	87·40	89·95	90·70
Butter	7·62	4·96	3·99	3·43	1·99	1·79
Casein	3·31	3·66	3·47	3·12	2·94	2·81
Milk-sugar	4·46	5·05	5·11	5·12	4·48	4·04
Mineral matter (ash)	·71	1·13	·78	·93	·64	·66
	100·00	100·00	100·00	100·00	100·00	100·00
Percentage of dry matters	16·10	14·80	13·35	12·60	10·05	9·30

I have selected these analyses from a considerable number of milk-analyses lately made in my laboratory. They illustrate strikingly the great differences that exist in the quality of new-milk. It might readily be imagined that milk such as that which I examined on the 6th of September, containing 90½ per cent. of water, had either been diluted with water, or at least produced by cows fed on mangold-tops, distillery-wash, or similar food. Such, however, was not the case. The cows which yielded this poor milk were out in pasture, and every precaution was taken to get a fair average of the milkings from some 8 or 10 cows. The milk was received by me almost directly after it had left the udder, and I can thus vouch for its being genuine, and its watery condition natural. The pasture, however, was poor and overstocked, so that the daily growth of grass furnished hardly enough food to meet the daily waste to which the animal frame is subject, and was thus not calculated to meet an extra demand of materials for the formation of butter and curd. The milk consequently became not merely deficient in quantity, but also poor in quality. It is well then to bear in mind that an insufficient quantity of food in the case before us caused the supply of milk to be small and unusually poor. This analysis illustrates and confirms a principle generally recognised by good dairy-farmers, that it is bad policy to keep more cows than can be liberally supplied with food. The evening's milk on the 6th of September, it will be noticed, contained about ¾ per cent. more water and somewhat less casein and butter than the morning's milk of the same cows on the same day. From this and other instances some may be disposed to infer that the morning's milk is generally richer than the evening milk—a view which I myself was disposed to adopt until a larger range of experiments proved to me its inaccuracy. In truth, the comparatively greater richness of the morning or the evening milk depends on a variety of circumstances so complicated as to require a lengthened discussion, which I must postpone to a future paper.

The remarkably small quantity of butter in the milk of the 6th of September appears very striking when contrasted with the proportion of butter found in good milk, and still more so when compared with the unusually large quantity contained in the rich milk analysed on the 21st of October. This milk, like that of the 6th of September, was produced by cows out in grass, without any additional food rich in fat, such as linseed or rape-cake, and yet it contained nearly four times as much butter as that of the cows kept on an insufficient quantity of poor grass. The beneficial influence of abundance of good pasture on the butter-yielding qualities of milk, and the contrary effect of a stinted supply of grass, are seen in bold relief in the first and the sixth analyses.

Whilst the proportion of butter in different samples of milk varies exceedingly the relative amounts of curd or casein, of milk-sugar and of ash, though liable to certain fluctuations, do not greatly differ in good, indifferent, or even very poor milk. It would thus appear that the quantity and quality of food, and other varying circumstances which affect the composition of milk, exert their influence principally on the proportion of butter. And as this is certainly the most valuable constituent of cheese, and 1 lb. of butter suffices for about 2 lbs. of saleable cheese, we can readily understand that in one dairy a considerable quantity of cream may be taken off the milk, and yet a better quality and a greater quantity of cheese can be made than in another dairy, from the same quantity of milk, from which no cream has been removed.

The second analysis exhibits nearly 5 per cent. of butter, a proportion which is decidedly above the average. This analysis has been selected as an example illustrating the increasing richness of milk in the fall of the year. Practical cheese-makers are well acquainted with the fact, that in autumn, when green food becomes scarcer, the quantity of milk diminishes considerably, but that the weight of cheese which can then be made from a given quantity of milk is much greater than in spring or summer. An inspection of the second and fourth analyses affords a ready explanation of this fact.

Both these milks came from the same dairy. In August the milk scarcely contained 3½ per cent. of butter, and, in round numbers, 3 per cent. of casein; in November it yielded 5 per cent. of butter and ½ per cent. more casein than in August. Rightly to appreciate this increase, it should be regarded, not so much as an addition of 2½ parts in 100 parts of fluid, as of 2½ parts to 12½ solid matter, the total percentage found in August, or an increase of 20 per cent. on the solid matter. And if we consider that most of the milk-sugar and of the mineral matters pass into the whey in the cheese-manufacturing process, the difference in the cheese-producing qualities of the August and November milk appears still greater.

In one of the milks we have 3½ per cent. of butter and 3 of casein, or 5½ per cent. of solid cheese-producing materials in every 100 parts of milk; in the other there are 5 per cent. of butter and 3½ of casein, or 8½ of solid cheese-producing matters. Thus the real proportion in the two milks is as 5½ to 8½—that is to say, the latter yields 55 per cent. more dry cheese-forming materials than the former; and as we find in good cheese about one-third of its weight of water, the 55 per cent. of dry matter with this complement of water will amount to 83 per cent. In other words, 1 gallon of the November milk will nearly produce double the quantity of saleable cheese which can be made from the August milk.

The third analysis represents the composition of good, rich milk, and the fourth the average composition of milk neither rich nor poor.

In rich milk the proportion which the butter bears to the casein is always much greater than in milk of average quality. In the latter there is about as much butter as casein, and in decidedly poor milk the proportion of casein is larger than that of butter.

The preceding analyses have brought to light unexpectedly large differences in the amount of butter which is contained in different samples of milk. With proper care and skill in cheese-making nearly the whole of the butter becomes incorporated with the curd; and as the market price of cheese depends in a great measure, though not entirely, upon the proportion of butter which it contains, it is evident that the original quality of the milk must have a decided and direct influence on the quality as well as on the quantity of cheese which can be made from it. Although precisely the same process may be adopted, and equal care and attention may be bestowed on the manufacture, it nevertheless happens that not only more but also a better quality is made in one dairy than in another from the same number of gallons of milk.

The food upon which dairy-stock is kept unquestionably exercises a great influence on the milk. It is, therefore, reasonable to expect certain pastures to be naturally better adapted for the production of rich cheese than others. Thus good old pasture not only produces richer milk than grass from irrigated meadows, but likewise a better quality of cheese, all other circumstances being equal in both cases. There is thus some reason in the almost universally received opinion that on some land good cheese can invariably be made, whilst on other land no amount of skill or care can bring about a like result. But at the same time I believe it is quite a mistake to think that good cheese can only be made in certain localities, and that the character of the pasture accounts entirely for the great differences found in the quality of this article. Good saleable, and even high-priced, cheese, I believe with Mr. Harding, can be made in any locality, whatever the character of the pasture may be, where an industrious and skilful hand, and an observant and intelligent head, presides over the operation; and, on the other hand, the best and richest milk, the produce of peculiarly favourable pastures, may be spoiled by a slovenly and ignorant dairymaid. But inasmuch as the nature of the herbage, as is well known, affects the richness, and especially the flavour, of the milk, and the herbage is sweeter in one locality than in another, and at one time of the year than at another, it is not likely that the very finest-flavoured cheese should be made indiscriminately on all land and all the year round. Still, after every allowance has been made for these natural peculiarities, it is nevertheless true that the various processes which are adopted in different counties determine in a great measure the prevailing character of the produce, whilst the want or bestowal of care and attention in making cheese, whether it be on the Cheshire, Cheddar, or any other plan, materially influences the quality of the produce.

Before I proceed to point out some of the practical errors which are often made in the manufacture of cheese, let us examine the composition and chief peculiarities of some of the principal kinds made in England.

English cheese is produced either from milk to which an extra quantity of cream has been added, or secondly from the whole-milk, or thirdly from milk from which more or less cream has been taken before the addition of the rennet. Accordingly we obtain—

1. Cream-cheeses.
2. Whole-milk cheeses.
3. Skim-milk cheeses.

The first class is made in limited quantities only, and constitutes a luxury which is found chiefly in the houses of the wealthy.

The second class is produced in larger quantities; and the third furnishes our chief supply of this important article of food for the working-classes of this country.

To the first class belong Stilton, Cream-Cheddar, and the choicest quality of Cotherstone cheese, or Yorkshire Stilton. These, according to their quality, fetch more or less a fancy price in the market, as they are made in perfection only by few persons, and in limited quantity.

To the second class belong the best Cheshire, some Cheddar, good Double Gloucester, most of the cheese made in the Vale of Berkeley, as well as whole-milk cheese produced in Wiltshire and other counties of England.

In the third class we meet with ordinary Cheshire, Gloucester, Wiltshire, Warwickshire, Shropshire, Leicestershire, and other cheeses made in districts where its manufacture is combined with that of butter.

This division into three classes is to a great extent an arbitrary one, adopted more for the sake of convenience than on account of any definite line of demarcation. In reality the richer admixture often only compensates for the inferiority of the natural product. Thus the best Cheshire and Cheddar cheese is frequently as good and rich in butter as Stilton. Again, it is well known that in some dairies a richer cheese can be made from the mixed new morning's-milk and skimmed evening's-milk than in others from the whole-milk. The classification, therefore, does not so much refer to the quality and value of the cheese as to the description of milk which is used.

STILTON AND COTHERSTONE CHEESE.

The following Table embodies the results obtained in the analyses of two samples of Stilton and Cotherstone cheese :—

	Stilton.		Cotherstone, or Yorkshire Stilton.	
	No. 1.	No. 2.	No. 1.	No. 2.
Water	32·18	20·27	38·28	38·23
Butter (pure fatty matters)	37·36	43·98	30·89	29·12
*Casein	24·31	33·55	23·93	24·38
Milk-sugar and extractive matters ..	2·22		3·70	2·76
†Mineral matters (ash)	3·93	2·20	3·20	5·51
	100·00	100·00	100·00	100·00
* Containing nitrogen	3·89	..	3·83	3·90
† Containing common salt	·89	·29	·79	2·55

The two Stilton cheeses are very rich in butter, especially the second, which contains 44 per cent. of pure fatty matters; and as we have in common butter from 15 to 18 per cent. of water, besides casein and other impurities, the pure fat in the second Stilton represents more than 50 per cent. of butter. The first analysis expresses the composition of a rather new Stilton. It was sold at 1*s.* per lb. last October. The second analysis is that of an old Stilton, selling at 14*d.* per lb. There is about 12 per cent. less water in it than in new Stilton; more butter and less salt. Notwithstanding the smaller amount of salt, it had a more saline taste and much better flavour than the newer cheese. This saline taste is generally ascribed to the salt, and complaints are sometimes made by persons fond of mild-tasting cheese, that old cheese, in other respects rich and good, has been injured by too much salt. This is a mistake, of which the proof is found in the analyses of these two Stilton cheeses. The first was quite mild in flavour in comparison with the other, and yet it contained three times as much salt as the more saline-tasting older cheese. The fact is, the saline taste is developed during the ripening of cheese; newly-made cheese, though strongly salted, is always mild in taste. During the ripening of the cheese a portion of the casein or curd suffers decomposition, and is partially changed into ammonia; the latter, however, does not escape, but combines with several fatty acids formed in the course of time from the butter. Peculiar ammoniacal salts are thus produced, and these, like most other salts of ammonia, have a pungent saline taste. The longer cheese is kept, within reasonable limits, the riper it gets; and as it ripens the proportion of ammoniacal salts, with their pungent saline taste, increases. It can be readily shown that old cheese contains a good deal of ammonia in the shape of ammoniacal salts. All that is necessary is to pound a piece with some quick-lime, when, on the addition of a little water, a strong smell of spirits of hartshorn will be developed. In well-kept, sound old cheese the ammonia is not free, but exists in the form of salts, in which the base is ammonia in combination with butyric, caprinic, caprylic, and other acids, generated under favourable circumstances by the fats of which butter consists. Ripe cheese, even if very old, but sound, instead of containing free ammonia, always exhibits a decidedly acid reaction when tested with blue litmus-paper. Rotten cheese, on the other hand, is generally alkaline in its reaction, and contains free ammonia.

I have made a quantitative determination of the amount of ammonia in old Stilton cheese, and found it to amount to 1·81 per cent.

The first Cotherstone or Yorkshire Stilton was made near Barnard Castle, in the Vale of the Tees, and sold at 1*s.* per lb. It is highly esteemed in Durham and Yorkshire; but, to my taste, the cheese which I analysed is not to be compared with good, genuine Stilton, nor is it equal in flavour to Cheshire or Cheddar.

Cotherstone cheese, it will be noticed, contains a very much larger proportion of water than even new Stilton. This imparts to it a smooth and apparently rich texture, but the proportion of butter is not really as great as it appears to be, nor, in point of fact, equal to that found in an average Cheddar. It has usually a very strong taste, which would be decidedly objected to by Cheshire or Gloucestershire factors. In its preparation a good deal of whey appears to be left in the curd in mechanical combination, and to be the principal cause of the strong taste and smell which are its characteristics, and in which, more than any other English cheese, it resembles the foreign Rochefort.

CHESHIRE AND CHEDDAR CHEESE.

In making best Cheshire and good Cheddar cheese the whole-milk is used, and cheese generally made but once a day.

The following Table shows the composition of two kinds of Cheshire and a number of Cheddar cheeses:—

	CHESHIRE CHEESE.		CHEDDAR CHEESE.					
	No. 1. Old.	No. 2. New.	No. 1. Old.	No. 2. 5 Months old.	No. 3. 6 Months old.	No. 4.	No. 5.	No. 6.
Water	32·59	36·96	30·32	36·17	31·17	33·92	37·85	38·43
Butter	32·51	29·34	35·53	31·83	33·68	33·15	28·91	23·28
*Casein	26·06	24·08	28·18	24·93	26·31	28·12	25·00	32·37
Milk - sugar, lactic acid, and extractive matters ..	4·53	5·17	1·66	3·21	4·91	·96	4·91	2·10
†Mineral matters (ash)	4·31	4·45	4·31	3·86	3·93	3·85	3·33	3·82
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	4·17	3·84	4·51	3·99	4·21	4·50	4·00	5·18
† Containing common salt	1·59	1·91	1·55	1·18	1·15	1·23	·52	·65

The first analysis illustrates the composition of good ripe, and the second that of good new, Cheshire cheese.

Since a good deal of water evaporates in keeping, the proportion of dry casein, of mineral matters, and especially of butter (pure fat), must become larger with age.

The rich appearance of old cheese, however, is by no means attributable entirely to a very large proportion of butter; nor is the poor condition of new or badly-made cheese referable solely to a deficiency of butter. One of the chief tests of the skill of the dairymaid is the production of a rich tasting and looking, fine-flavoured, mellow cheese from milk not particularly rich in cream. That this can be done is abundantly proved by the practice of good makers. One of the finest Cheddars which I have ever examined is that mentioned as No. 4 in the above table. This was made by Mr. Harding, Marksbury, Somersetshire, and analysed by me when about six months old. Like all good cheeses, it of course contains a large amount of butter; though, as I found by experiment, not nearly so large an amount as its appearance, rich taste, and fine mature condition seemed to imply. Though only six months old, it had a much more mature appearance than the Cheddar cheese No. 1, which was at least eleven months old when analysed; and, thanks to Mr. Harding's skill and experience, had a much fatter and more mellow appearance and richer taste than a specimen which actually contained 2½ per cent. more butter.

Thus we see that the proportion of butter does not entirely determine the value of cheese, since a high-priced Cheddar or Cheshire cheese does not necessarily contain more butter than another which fetches 8*s.* to 10*s.* less per cwt. in the market.

In the opinion of good judges the Cheddar cheese No. 1, notwithstanding the larger amount of butter, and the smaller amount of water, which it contained, was worth less than No. 4 by 1*d.* per lb.—no inconsiderable difference in the returns of a dairy to remunerate careful and skilful management. The peculiar mellow appearance of good cheese, though due to some extent to the butter which it contains, depends in a higher degree upon a gradual transformation which the casein or the curd undergoes in ripening. The curd is hard and insoluble in water, but by degrees it becomes softer and more soluble, or, speaking more correctly, gives rise to products of decomposition which are soluble in water.

Now if this ripening process is badly conducted, or the original character of the curd is such that it adapts itself but slowly to this transformation, the cheese when sold will be, comparatively speaking, tough, and appear less rich in butter than it really is; whilst in a well-made and properly-kept cheese, this series of changes will be rapidly and thoroughly effected. Proper ripening thus imparts to cheese a rich appearance, and unites with the butter in giving it that most desirable property of melting in the mouth. On examining some cheeses deficient in this melting property, and accordingly pronounced by practical judges defective in butter, I nevertheless found in them a very high percentage of that substance—clear proof that the mellow and rich taste of cheese is not entirely, nor indeed chiefly, due to the fatty matters which it contains.

Good Cheshire and Cheddar, on an average, contain about the same quantity of butter; but of course inferior cheeses defective in this respect are to be found in both localities. The analysis No. 6 shows the composition of such an inferior Cheddar.

DOUBLE AND SINGLE GLOUCESTER CHEESE.

Gloucester, especially double Gloucester, is generally sold as a whole-milk cheese. It is, however, seldom made of the whole-milk. In most dairies more or less of the cream of the milk is made into butter; but unless the whole evening's milk is skimmed and added to the whole new morning's milk—in which case the cheese made is "half-coward"—the produce, whether single or double, is said to be whole-milk cheese. The distinction of single and double Gloucester is one merely of size and thickness, and has nothing to do with the quality.

The following Table embodies the results of some analyses of double and single Gloucester cheese:—

Double Gloucester.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Water	32·44	32·80	38·83	38·14	40·88	33·41
Butter	30·17	27·22	26·77	24·16	22·81	32·69
*Casein	31·75	34·76	26·25	26·56	31·88	27·75
Milk-sugar, lactic acid, and extractive matters	1·22		3·18	6·40		2·23
†Mineral matters (ash)	4·42	5·22	4·97	4·74	4·43	3·92
	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	5·12	..	4·20	4·25	..	4·44
† Containing common salt	1·41	1·27	2·04	1·28	1·45	1·01

Single Gloucester.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Water	28·10	31·96	37·20	31·81	32·42	37·91	36·50
Butter	33·68	31·37	27·30	29·26	27·42	22·70	28·75
*Casein	30·31	29·37	24·50	26·12	34·46	31·25	25·75
Milk-sugar, lactic acid, and extractive matters ..	3·72	2·85	7·44	8·63		3·30	4·68
†Mineral matters (ash)	4·19	4·45	3·56	4·18	5·70	4·84	4·32
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	4·85	4·70	3·92	4·18	..	5·00	4·12
† Containing common salt	1·12	1·35	·85	1·50	1·46	1·23	1·38

The differences in the proportion of water and butter here are very large, though probably not greater than will be found in other descriptions of cheese on examining a considerable number of specimens. It is worthy of notice that the poorer the cheese in butter the more water it usually contains. Thus the first sample of double Gloucester, which contained 32½ per cent. of water, yielded 30 per cent. of butter (pure fat), whilst the third sample, containing nearly 39 per cent. of water, yielded 27 per cent., and the fifth sample, with nearly 41 per cent. of water, scarcely 23 per cent. of butter.

These analyses show that the distinction made between double and single Gloucester has no reference to quality. Indeed the first analysis in the table of the single Gloucester shows that thin cheeses are made which are as rich in butter as any of the best Cheddar and Cheshire cheeses. No. 1 and No. 6 in the list of double Gloucester, and Nos. 1, 2, and 4 in the table of single Gloucester, alike establish this equality. Nevertheless, the price which is paid for thin, *i.e.* single Gloucester of excellent quality, was only 70*s.* per cwt., whilst Cheddar, not richer in butter and containing nearly as much water, sold at 90*s.* per cwt. The latter, of course, was well-made and nicely flavoured cheese, and nearly four months old, whilst the single Gloucester was only two months old. Still, making every allowance for loss in weight on keeping for two months longer, the difference in the price at which both were sold, amounting to exactly 1*l.*, leaves a handsome balance in favour of a system which I have no doubt will come more and more into favour.

We have here again presented to us striking examples showing that the difference in the quality and price of the cheese is not dependent merely on the richness or poverty of the milk, but that the process of manufacture exerts a decided and direct influence on its value. Different plans now followed have unquestionably various degrees of merit, but in our present state of knowledge it would be premature to lay down any absolute rule.

LEICESTERSHIRE, WARWICKSHIRE, AND WILTSHIRE CHEESE.

Some excellent cheese is made in Leicestershire and Warwickshire, but the generality of the produce of these two counties does not rank equally high with Cheshire, Cheddar, or even Gloucester cheese.

Some parts of Wilts are celebrated for their rich pastures, and for an excellent delicate-flavoured kind of cheese. In other parts of the county a good deal of butter is made, and here, as in all districts where much butter is made and dairy-farms are small, the cheese produced is of an inferior character.

Whole-milk cheese, I believe, is not generally made in Wiltshire, although in North Wilts a good deal is sold as such in the market.

Wiltshire and Gloucester cheese is commonly coloured with annatto, whilst that made in Leicestershire and Warwickshire is mostly uncoloured.

The following Table shows the composition of some specimens from the three counties to which I have just referred:—

Composition of Leicestershire, Warwickshire, and Wiltshire Cheese.

	LEICESTER.		WARWICKSHIRE.			WILTSHIRE.		
	No. 1.	No. 2.	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.
Water	35·21	32·89	31·97	33·61	33·53	34·44	39·22	40·07
Butter	27·28	29·28	29·08	30·04	30·89	28·71	19·26	25·55
*Casein	27·93	29·06	27·43	29·70	28·19	29·00	34·22	26·81
Milk-sugar, lactic acid, and extractive matters ..	5·54	4·42	7·16	1·95	2·84	3·60	2·28	2·24
†Mineral matters (ash)	4·04	4·35	4·36	5·60	4·55	4·25	5·02	5·33
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	4·47	4·65	4·39	4·74	4·51	4·64	5·38	4·29
† Containing common salt	1·03	1·21	·72	2·78	1·12	1·03	·60	1·41

The first analysis was made of an uncoloured Leicestershire cheese, sold retail at 9*d.* per lb. The second was a much better specimen from the same county. The latter, it will be seen, is drier and richer than the former.

The difference in the composition of the three Warwickshire cheeses is not great. In all three the proportions of water, butter, and casein, do not vary more than 2½ per cent. The greatest difference is observable in the amount of salt used. In the second specimen we have nearly 3 per cent. of salt, a proportion far above the average, and the cheese was to a certain extent spoiled by this excess. I would direct special attention to this, which I know from experience is not a solitary instance. For no description of cheese should more than 2 lb. of salt per cwt. of cheese be used, and 1½ lb. per cwt. will, I believe, in most cases be sufficient. This was by no means a good cheese; it had a strong taste, and was sold as common Warwickshire cheese. This and the third were uncoloured, and the flavour of the latter, as well as its texture and shape, was very good indeed.

The first analysis was made of a coloured cheese which was sold as best Warwickshire; apparently it was an old and very much richer cheese than No. 2, but on analysis it was found actually to contain 1 per cent. less butter than the common cheese of the same name, thus giving another instance of the fact that good materials are often spoiled by unskilful management.

Of the three Wiltshire cheeses No. 1 was decidedly the best flavoured, and, as will be seen, also the richest. No. 2 and No. 3

contained too much water, showing that the whey had not been carefully pressed out, and when this has been the case the cheese is very apt to heave and to acquire a strong taste. No. 2 is very poor in butter, and, although not sold as skimmed-milk cheese, for all I know may have been made of skimmed milk.

SKIM-MILK CHEESE.

Milk varies so much in quality that in one dairy a better and richer cheese can be made from milk which has been skimmed than in another where only the evening milk is skimmed and added to the whole new morning's milk.

The following analyses clearly bring out this important practical fact, but they also show that, as a rule, skimmed milk does not produce a good cheese:—

Composition of Skim-milk Cheese.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Water	27·68	39·43	38·39	43·87	45·39
Butter	30·80	27·08	23·21	15·89	9·97
*Casein	35·12	30·37	28·37	28·93	33·12
Milk-sugar, lactic acid, and extractive matters	1·46	·22	6·80	6·47	6·39
†Mineral matters (ash)	4·94	2·90	3·23	4·84	5·13
	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	5·62	4·86	4·54	4·63	5·34
† Containing common salt ..	1·27	·23	·33	1·66	1·51

With the exception of No. 4, which was bought in a shop at Cirencester as skim-milk cheese at 7*d.* per lb., the other cheeses, the composition of which is here given, were either made under my direction or according to a plan with which I was made acquainted.

No. 1 it will be noticed, though made from skim-milk, is as rich in butter as good Cheshire cheese. It was rather more than six months old before it was analysed, when its quality was pronounced by several good judges to be excellent; superior, indeed, to most of the Gloucester cheese which I have ever tasted.

No. 2 and No. 3, though not equal to No. 1, after keeping for six months turned out very good cheeses indeed.

No. 4 it will be seen contained only 16 per cent. of butter, in round numbers, and nearly 44 per cent. of water. If such cheese can be sold at 7*d.* per lb. and butter at 1*s.* to 1*s.* 4*d.* per lb., I can well understand that it must pay a farmer to make nothing but skim-milk cheese and to convert all the cream into butter.

No. 5 was made of milk skimmed at least three times, and sold on the farm where it was made to the labourers at 3*d.* per lb. Such cheese cannot be kept for any great length of time, for it soon gets so hard and horn-like that a pickaxe must be used to break it into pieces.

AMERICAN CHEESE.

Of late years a good deal of cheese has been imported into England from America, some of which is by no means bad: indeed one or two specimens which came under my notice were excellent in quality. The majority, however, are inferior, and are sold at a low price, being generally badly made and deficient in flavour.

The following Table gives the composition of American cheeses:—

Composition of American Cheese.

	No. 1.	No. 2.	No. 3.	No. 4.
Water	27·29	33·04	31·01	38·24
Butter	35·41	33·38	30·90	26·05
*Casein	25·87	27·37	26·25	26·81
Milk-sugar, lactic acid, and extractive matters	6·21	2·82	7·43	3·64
Mineral matters (ash)	5·22	3·39	4·41	5·26
	100·00	100·00	100·00	100·00
* Containing nitrogen	4·14	4·38	4·20	4·29
† Containing common salt	1·97	·47	1·59	1·94

No. 1 was as nice a cheese as could be desired; in flavour it much resembled good Cheddar, and was found to contain even a higher proportion of butter and rather less water than good Cheddar.

The second cheese, though rich in butter, was retailed at 7*d.* per lb., and the third at only 6*d.* per lb. Both were deficient in flavour and badly made.

The fourth cheese was the worst of the four, and had to be sold at 5*d.* per lb. It was full of holes, badly made, and had a very strong smell. It was evident that the whey was not carefully pressed out in the making.

The examination of these and other American cheeses leads me to the conclusion, judging from our imports, that good materials are even more thoroughly spoiled on the other side of the Atlantic than in England.

Let me next direct attention to some of the principal mistakes which are not unfrequently committed in the manufacture of cheese. I have said in the beginning of this paper—1st, that cheese is sometimes spoiled even before it is separated from the milk; 2ndly, that it is yet more frequently spoiled in the act of making; and, lastly, that it is sometimes deteriorated by bad keeping after it has been made.

I.—PRACTICAL MISTAKES MADE IN THE MANUFACTURE OF CHEESE BEFORE THE CURD IS SEPARATED.

The inferior character, and especially the bad flavour, of cheese owes its origin in many cases to a want of proper care in handling the milk from which it has been made. Milk sometimes gets spoiled by dirty fingers before it passes into the pail. If the vessels in which the milk is kept in the dairy have been carelessly washed, and the milk-pails and cheese-tub have not been well scrubbed, but merely been washed out, and if especially the dairy-utensils have not been scalded with boiling-hot water, it is vain to expect that cheese of the finest quality can be made, let the milk be ever so rich in cream. The neglect of these simple but important precautions soon manifests itself in a dairy by a peculiar ferment which taints the whole milk, and afterwards affects the flavour and consequently the quality of the cheese. Cleanliness, indeed, may be said to be the first qualification of a good dairywoman.

The nature of every ferment is to produce in other matters with which it comes into contact certain chemical changes depending on its own character. Thus a little yeast produces in fermentable liquids large quantities of alcohol and carbonic acid; acid ferments containing acetic or lactic acid have a tendency to generate vinegar or lactic acid in other liquids. A small piece of putrefying meat in contact with a large mass of sound flesh soon spreads putrefaction over the whole mass; and other ferments act in a similar manner. Such ferments generally produce in other matters with which they are brought into contact changes similar to those which they themselves undergo. The disagreeable smell of dirty or badly cleaned milk-pails and cheese-tubs is due to a peculiar ferment, which is rapidly formed, especially in warm weather, when milk is left in contact with air and with the porous wood of the cheese-tub and milk-pails. In the rapid process of vinegar manufacture a weak alcoholic liquid is allowed to trickle through a barrel perforated all over with holes to admit the air, and filled with wood-shavings. If the temperature of the room in which the vinegar-casks are put up is sufficiently high, the alcohol, in trickling over these shavings when in contact with abundance of air, undergoes a complete transformation, and collects rapidly at the bottom of the cask as vinegar. But such a change does not take place if the alcoholic liquid is left for ever so long in a clean cask filled with such a liquid. Contact with air, subdivision of the liquid into drops, and the presence of the porous wood-shavings, are necessary for the transformation. These casks do not at first produce vinegar as rapidly as after they have been in use for some time and become thoroughly soaked with vinegar-ferment. And this is another peculiarity of all ferments, that, under favourable circumstances, they reproduce themselves from other materials in immense quantities. Thus fresh and active yeast is generated in great abundance in fermenting malt-liquor, whilst the original yeast employed in brewing is more or less decomposed and becomes what is called inactive yeast. These chemical facts, well-known to the manufacturers of vinegar and to the intelligent brewer, have a direct bearing on cheese-making.

At the very beginning of her operations a good dairywoman unconsciously carries on a steady and constant battle with these remarkable ferments, and it is very interesting to the chemist to see her proceed in the most rational and philosophical manner.

No milk is admitted into the cheese-tub before it has been carefully strained through a cloth, lest a little bit of a dead leaf or any similar matter, accidentally blown into the milk in its passage from the milking-place to the dairy, should spoil the flavour of the cheese. No sooner has the cheese left the tub than she begins to pour scalding water into it, to scrub it, and to make it as clean and sweet as possible. In good dairies no utensil is allowed to remain for a moment dirty, but hot water and clean brushes are always close at hand to scrub the pails and make them almost as white as snow. The dairywoman probably knows nothing about the nature of the ferment, which is rapidly formed when a little milk is left at the bottom and adhering to the sides of the wooden milk-pails; she is unconscious that here, as in the vinegar process, the conditions most favourable to chemical change are present, and that the sugar of the milk, in contact with plenty of air and porous wood, is rapidly changed into lactic acid, whilst at the same time a peculiar milk-ferment is produced; all this may be a perfect mystery to her, but, nevertheless, guided by experience, she thoroughly avoids everything that favours the production of ferment, or taint, as she calls it, by leaving no vessel uncleaned, by scalding all that have been in use with boiling water, and if ever so little milk be accidentally spilt on the floor of the dairy, taking care that it is at once removed, and the spot where it fell washed with clean water.

It is, indeed, surprising how small a quantity of ferment taints a large quantity of milk. The most scrupulous cleanliness therefore is brought into constant play by a good dairywoman, who never minds any amount of trouble in scalding and scrubbing her vessels, and takes pride, as soon as possible after her cheeses are safely lodged in the presses, in having the dairy look as clean and tidy as the most fastidious can wish. It is a pleasure to see one of these hardworking women at work, especially as such a sight is not often witnessed, slovenly dairymaids being unfortunately in a majority. This being the case, we should encourage the use of tin pails and tin or brass cheese-tubs. Wooden pails, &c., are very good in the hands of a tidy dairymaid, but not otherwise. There is much less labour in thoroughly cleaning a tin or brass vessel than a wooden one, and boiling-hot water is not then required. Wood being a porous material inevitably absorbs more or less of the milk; tin or brass does not. The milk thus absorbed cannot be removed by simple washing. Inasmuch as all ferments are destroyed by water at the temperature of 212°, it is important to ascertain that the water is perfectly boiling; and yet it is strange that few women comparatively speaking, though they may have spent many years in the kitchen, know to a certainty when the kettle is really boiling. This remark applies to some educated as well as uneducated females. They often mistake the singing noise of the tea-kettle accompanied by a certain amount of vapour for a sign that water is in a state of ebullition; so that if you would drink good tea you must be careful to whom you trust to make it.

In some dairies of Cheshire it is customary to paint the wooden cheese-tubs in the interior. I confess I do not like this at all; lead-paint is not a very desirable thing to be used in connection with cheese; and I am glad to find that the best dairy-farmers are decidedly adverse to this proceeding.

Milk sometimes gets tainted by the close proximity of pigstyes or waterclosets, or by underground drains. Not very long ago I visited a dairy in Wiltshire, where every possible care was taken by the dairymaid to produce good cheese; but I noticed a peculiarly disagreeable smell in the dairy, and on making inquiries I found that there was a cesspool close at hand, which certainly tainted the milk, and rendered the making of good cheese an impossibility. In the third place, I would notice that if dairies are not well situated,—if they have, for instance, a south aspect, so that a proper low temperature in summer cannot be maintained,—the milk is apt to turn sour and to make sour cheese. It is important, therefore, that dairies should be built with a northern aspect.

These are some of the circumstances that spoil the cheese even before it is separated from the milk. The remedies are obvious. It is only with respect to the latter point,—that of milk getting sour, that I would offer a few observations. If the situation of a dairy is bad, and a new dairy cannot be erected, we should employ all possible means to prevent the milk from getting warm. We should keep it in shallow tins or leads, or, better still, as I have seen in some parts of Somersetshire, in shallow tin vessels with a double bottom, through which cold water may be run during the warm part of the season. By this means we can keep the milk at a considerably lower temperature than we should otherwise be able to do. Having seen nitre and salt used with great advantage to prevent cream turning sour, I would further suggest that they might probably be found serviceable in the same manner for the keeping of milk if used in moderate quantities. Some people, however, maintain that milk requires to become sour to a certain extent before it can be properly made into cheese. A great deal has been said and written with respect to the great utility to the dairyman of an instrument by means of which the amount of acid in sour milk might be accurately and readily determined. A careful study of the action of rennet on milk, however, has led me to the conclusion that the more carefully milk is prevented from getting sour, and, consequently, the less opportunity there is for the use of an acidometer, the more likely the cheese is to turn out good. Indeed, the acidometer appears to me a useless instrument,—a scientific toy which can never be turned to any practical account. If by accident the milk has become sour, the fact soon manifests itself sufficiently to the taste. An experienced dairymaid will even form a tolerably good opinion of the relative proportions of acid in the milk on different days and arrange her proceedings accordingly. Moreover, the knowledge of the precise amount of acid in the milk does not help us much. When milk has turned sour, the best thing to do is to hasten on the process of cheese-making as much as possible.

II.—PRACTICAL FAULTS COMMITTED DURING THE MAKING OF CHEESE.

1. Under the second head I would observe, first, that sufficient care is not bestowed upon noticing the temperature at which the milk is "set," or "run," as it is called in Gloucestershire. Thermometers, indeed, are seldom in use. Even where they are hung up in the dairy, they are more frequently regarded as curious but useless ornaments than trustworthy guides, and therefore are seldom put into requisition. In fact, most dairymaids are guided entirely by their own feelings; and as these are

as variable as those of other mortals, the temperature of the milk when it is "set" (that is, when the rennet is added) is often either too high or too low. They mostly profess to know the temperature of the milk to a nicety, and feel almost insulted if you tell them that much less reliance can be placed on the indications of ever so experienced a hand than upon an instrument which contracts and expands according to a fixed law, uninfluenced by the many disturbing causes to which a living body is necessarily subject.

It is really amusing to see the animosity with which some people look upon the thermometer. It is true there are not many dairies in which it may not be found; but if we took pains to ascertain in how many of these it is in constant use, I believe that the proportion would not exceed 5 per cent. This is a great pity, for a tolerably good one can be now bought or replaced at a trifling cost.

I have spoken frankly but unfavourably of the acidometer. With equal frankness I express my regret that the use of the thermometer is not more general, as I believe it is indispensable for obtaining a uniformly good product.

If the temperature of the milk, when the rennet is added, is too low, the curd remains too soft, and much difficulty is experienced in separating the whey. If, on the other hand, the temperature is too high, the separation is easily effected, but the curd becomes hard and dry. The amount of water, which is left in the curd when it is ready to go into the cheese-presses, to some extent indicates whether a proper temperature has been employed. When this has been too low, the curd will contain more than 50 per cent. of moisture; when too high, sometimes less than 36 per cent. How variable is this proportion of water (chiefly due to the whey left in the curd) will appear from the following determinations made in the same dairy on four following days:—

Amount of water in Curd when ready to go into the vat.

Percentage of water in	1st Cheese	41·53
,, ,,	2nd Cheese	41·49
,, ,,	3rd Cheese	38·20
,, ,,	4th Cheese	35·80

In this dairy the thermometer was not in daily use, and the heat employed in making the fourth cheese was evidently too high, for in good Cheddar when ready for sale the amount of moisture is hardly less than in this curd when put into the vat. The cheese from these four specimens of curd was made according to the Cheddar system. Five other specimens gave the following proportions of water:—

Percentage of water in Curd when ready to go into the vat.

1st specimen, percentage of water	59·67
2nd ,, ,, ,, ...	56·93
3rd ,, ,, ,, ...	53·40
4th ,, ,, ,, ...	52·80
5th ,, ,, ,, ...	50·01

These were produced according to the custom of Gloucestershire and Wiltshire, at a temperature varying from 72° to 75°; but, not having taken the observations myself, I am unable to speak more precisely. This much, however, is quite certain, that the lower temperature at which the cheese is usually made in Gloucestershire and Wiltshire, when compared with the Cheddar system, fully accounts for the large proportion of water that is found in curd made after the Gloucester or Wiltshire fashion. The cheese made from these five curds was best at the dairy in which I found the lowest proportion of water in the curd. The differences here noticed, however, are due not only to the higher or lower temperature employed, but also to the trouble and the time bestowed in breaking up the curd. Other circumstances being equal, the more thoroughly curd is broken up, and the longer time is occupied in this process, the more whey will pass out, and the better the cheese is likely to become. I consider 50 per cent. of moisture rather under the average, and 53 to 54 per cent. a proper quantity of water to be contained in the curd when it is vatted to form a thin or moderately thick cheese. In making thick cheese, it should not have more than 45 per cent. of moisture. 57 or 59½ per cent., the proportions of water in the first and second specimens of curd, are too high even for a thin cheese.

Curd being a very peculiar and delicate substance, which is greatly affected by the temperature to which it is exposed, I directed some special experiments to the investigation of its properties. First, I coagulated new milk at 60° Fahrenheit, and found that at such a low temperature it took three hours to complete the process, though the rennet was added in a very large excess. The curd remained tender, and the whey could not be properly separated. Milk at 65° F., on addition of rennet, curdled in two hours; but the curd, as before, remained tender, even after long standing. At 70° to 72° F. it only took from one-half to three-quarters of an hour, and the curd now separated in a more compact condition. The process was more expeditious, and the curd in better condition, when the temperature ranged from 80° to 84°. At 90° the rennet curdled the milk in twenty minutes, and at 100° F. an excess of rennet coagulated the milk in about a quarter of an hour, separating the curd in a somewhat close condition. By heating the curd in the whey to 130° F., I find it gets so soft that it runs like toasted cheese, and becomes quite hard on cooling. The limits of temperature between which curd can be improved or deteriorated in texture are therefore not very wide. The exact temperature to be adopted depends upon the description of cheese that is wanted—a lower range, *e. g.* 72° to 75°, being desirable when a thin cheese is made; whilst for thick cheese, such as Cheddar, it should vary from 80° to 84°, 80° being best adapted to warm weather, and a little increase in the heat desirable in the cold season. After a portion of the whey has been separated, it is advisable to scald the curd and to raise the temperature of the whole contents of the cheese-tub to 95° or 100°, but certainly not higher. I have seen much injury done to cheese by using too high a temperature in the making.

Secondly, apart from this influence of temperature, cheeses are often deteriorated by the frequently imperfect separation of the whey from the curd; by hurrying on too much the operation of breaking; and by too great an anxiety to get the curd vatted. The whey requires time to drain off properly, and hence the Somersetshire plan is a good one—to expose the curd for some time to the air, after it has been sufficiently broken and been gathered again and cut in slices of moderate size. A great deal of whey runs off, and the curd, moreover, is cooled, and runs less risk of heating too much after it leaves the presses.

When the whey has been ill-separated from the curd, no amount of pressure will squeeze out the excess of whey, which then causes the cheese to heave and blister, and imparts to it a somewhat sweet and at the same time strong taste. This taste is always found in an ill-shaped cheese, which bulges out at the sides, the interior of which will be found to be full of cavities, and far from uniform in texture. Many cheeses imported from America are evidently spoiled in this way, for they are often full of holes, have a strong smell, and contain too much moisture —sure indications that the whey was not properly separated. The sweet taste is given to the cheese by part of the sugar of milk, of which a good deal is found in whey; another portion of this, on entering into fermentation, forms, amongst other products, carbonic-acid gas, which, in its endeavour to escape, heaves up the semi-solid curd, and causes it to blister, producing the numerous apertures of considerable size which are found in badly-made cheese. If the cheese is coloured with annatto, the excess of whey at the same time causes a partial separation of the colouring matter, so that more colour collects in some parts than in others, and the cheese assumes that unequal condition in which it is called tallowy. A uniform colour and perfect shape are therefore to a certain extent indications of a superior quality; whilst mottled, mis-shaped cheese, almost invariably proves tallowy, and in flavour sweet when young, and very strong when older. The danger of leaving too much whey in the curd is especially great in warm weather, for it is then that the fermentation of the sugar of milk proceeds most rapidly.

There are three precautions to be taken against an undue proportion of whey in the curd:—

1. Plenty of time should be allowed for the whey to drain off properly.
2. Before the rennet is added, the milk should be heated to a temperature of 72° to 75° for thin, or of 80° to 84° for thick cheese.
3. The best preventive is the practice of *slip-scalding*, as it is called. The operation, which is highly recommended by Mr. Harding, one of our best Cheddar cheese-makers, and extensively practised in Somersetshire, consists of heating a portion of the whey, and adding it or hot water to the curd, whilst it is still covered with some of the whey, until the temperature of the whole be raised to from 95° to 100°. This has the effect of making the curd run together into a much smaller compass, and enables the dairymaid to draw off the whey more perfectly and with very much less trouble than by the common method. If well done, no injury, but every advantage, results from this practice. The curd, when slip-scalded, settles down very readily, and its closer condition implies that it does not contain so much whey as it did before scalding. Hence no skewers are required to drain off the whey from cheese that has been slip-scalded, and a great deal of subsequent labour and anxiety is avoided by this simple process. Slip-scalding, however, ought to be carefully performed, and the hot whey or water be poured slowly upon the curd by one person, whilst another stirs up the contents of the cheese-tub, so as to ensure a uniform temperature throughout. The necessity for these precautions will be best understood from the following explanation:—When curd, broken up and cut into slices, is suddenly and incautiously scalded with boiling water, the outer layer of the slices first melts and then becomes hard, enveloping the interior, which remains quite soft and full of whey. This hard covering acts like a waterproof wrapper, and prevents the escape of the whey, however strongly the curd may be pressed afterwards; hence the importance of a gradual and careful admixture of the hot whey. Better still is it to employ one of Coquet's jacketed tin or brass cheese-tubs, into the hollow

bottom of which steam may be let in, and the curd and whey be raised by degrees to the desired temperature. This utensil is to be strongly recommended to all who adopt the Cheddar mode of cheesemaking in their dairies.

Cheese is also spoiled by breaking up the curd too rapidly and carelessly. This delicate substance requires to be handled by nimble and experienced fingers, and to have a great amount of patient labour bestowed upon it. Dairymaids, as a class, break up the curd in far too great a hurry. In consequence of their careless treatment some portions of the curd are broken into fragments so small that they pass into the whey when this is drawn off, whilst others are not sufficiently broken up and remain soft. The result is, that the curd is not uniform in texture, and that less cheese and of inferior quality is produced than when the curd is first cut very gently into large slices and then broken up by degrees either by hand or machinery into small fragments.

The whey which separates from curd that has been gently broken up is as bright as Rhenish wine, provided the milk has been curdled at the proper temperature by a sufficient quantity of good rennet. On the other hand, if the curd has been broken up carelessly in too great a hurry, the whey is more or less milky, and separates on standing a large quantity of fine curd of the choicest character, for this fine curd is very rich in butter. Thus the best part of the curd, instead of becoming incorporated with the cheese, finds its way into the whey leads. Be the curd, however, broken up ever so gently, and the whey drawn off ever so carefully, the latter always throws up, on standing, some cream, which it is worth while to make into butter. But the quantity of whey-butter made in good dairies is very insignificant in comparison with that produced where less attention is paid to the breaking of the curd. I know it to be a fact, that in some dairies four times as much whey-butter is made as in others. Where much whey-butter is made, the cheese is seldom of first-rate quality. Believing that this is a matter of some importance, I have visited many dairies, and repeatedly watched dairymaids breaking the curd, and noticed the gentle and patient manner in which a clever woman goes to work, and the hurried and dashing proceedings of a slovenly girl. On these occasions I have taken samples of the whey, and submitted them afterwards to analysis. The results, as recorded in the following tables, show how much the whey of different dairies varies in chemical composition as well as in physical character:—

Composition of Whey.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Water	92·95	92·65	92·60	92·75	92·950
Butter (pure fatty matters)	·65	·68	·55	·39	·490
*Nitrogenous substances (casein and albumen)	1·20	·81	·96	·87	1·425
†Milk-sugar and lactic acid	4·55	5·28	5·08	5·13	4·491
Mineral matters (ash)	·65	·58	·81	·86	·644
	100·00	100·00	100·00	100·00	100·000
* Containing nitrogen	·19	·13	·15	·14	·228
† Containing free lactic acid	·48	·41	·36	·41	·120

	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
Water	92·95	93·150	92·95	93·30	93·25
Butter (pure fatty matters)	·29	·546	·24	·31	·26
*Nitrogenous substances (casein and albumen)	1·01	1·056	·81	1·01	·91
†Milk-sugar and lactic acid	5·08	4·662	5·27	4·68	4·70
Mineral matters (ash)	·67	·586	·73	·70	·88
	100·00	100·000	100·00	100·00	100·00
* Containing nitrogen	·16	·169	·131	·16	·148
† Containing free lactic acid	·54	None.	·39	·41	·41

	No. 11.	No. 12.	No. 13.	No. 14.	No. 15.
Water	92·85	93·35	92·70	93·15	93·10
Butter (pure fatty matters)	·29	·25	·31	·14	·14
*Nitrogenous substances (casein and albumen)	·93	·91	·96	·91	·76
†Milk-sugar and lactic acid)	5·03	5·00	5·31	5·06	5·31
Mineral matters (ash)	·90	·49	·72	·74	·69
	100·00	100·00	100·00	100·00	100·00
* Containing nitrogen	·151	·148	·15	·148	·123
† Containing free lactic acid	·60	·43	·40	·48	·46

When it is remembered that milk of good quality contains from 3½ to 4 per cent. of butter, it will be readily seen that where samples of whey contain more than ½ per cent. of butter, the cheese is deprived of a very considerable portion of its most valuable constituent, and that its quality must therefore depend in a great measure on the care with which the curd is broken up and the manner in which the whey is drawn off. In some samples the amount of butter is so trifling, that it is not considered worth the trouble to gather the cream and to make whey-butter. In the dairies in which this happy state of things exists excellent cheese is made. When the whey first separates from the curd it is always more or less turbid, but by degrees it becomes clearer; and if sufficient time is allowed, and it is then tapped off without disturbing the curd, it runs off almost as clear as water. By this means nearly the whole of the butter may be retained in the cheese. In order to place this beyond a doubt, I examined the whey which Mr. Keevil, the inventor of the excellent cheesemaking apparatus which bears his name, allowed me to take on the occasion of a visit which I recently paid to his dairy-farm at Laycock, near Chippenham. One sample of whey was taken at the stage in which it was usually tapped off in Mr. Keevil's dairy; the second when the whey had become a little brighter, about ten minutes after the first; and the third about twenty minutes after the first. It then was as clear as water. These three samples when analysed gave the following results:—

Composition of Whey taken at 3 different periods.

	No. **16.** 1st Sample.	No. **17.** 2nd Sample, taken 10 minutes after 1st Sample.	No. **18.** 3rd Sample, taken 20 minutes after 1st Sample.
Water	92·90	93·25	93·55
Butter (pure fat)	·18	·18	·03
*Albuminous compounds	·94	·94	·94
Milk-sugar and lactic acid	5·30	5·03	4·82
Mineral matters (ash)	·68	·60	·66
	100·00	100·00	100·00
* Containing nitrogen	·15	·15	·15

The two first samples are almost identical in composition; they both contain very little butter, but, small as that quantity is, it can be further reduced to a mere trace by letting the whey stand a little longer. In practice it may for other reasons not be desirable to let the whey stand at rest quite so long as the third sample stood; and a dairymaid may congratulate herself when she succeeds in breaking up the curd so carefully that the whey contains as little butter as that made under Mr. Keevil's personal direction and excellent management.

It may perhaps be supposed that the successful manner in which the butter is retained in the cheese in Mr. Keevil's dairy is entirely due to the use of his patent apparatus, and that by its introduction any dairymaid may be enabled to make good cheese. But this supposition is not correct. Keevil's apparatus, useful and good as it is in many respects, is no safeguard against carelessness. Cheese is spoiled with, as well as without it.

It does not supersede patience and skill, but its merit consists in saving a great deal of hard labour and time. Beyond this, I may say, without disparagement to his ingenious contrivances for breaking the curd, straining off the whey, and other appliances, that it effects nothing which may not be done by hand. But this saving of time and hard labour is a great merit in an apparatus which can be bought at no great cost. Where from 30 to 40 milking-cows are kept, it may be safely recommended; in smaller dairies there may not be sufficient use for it. Having made frequent trial of Keevil's apparatus, I am anxious that its true merits should be known, but no unreasonable expectations be entertained. It has been said that it makes more and better cheese than can be made by hand. My own opinion is, that it makes neither more or less, neither better or worse cheese than a skilful dairymaid will make by hand, and that a careless one is as likely to spoil her cheese when using this apparatus as when making it according to her own fashion.

Some of the very best and some of the very worst of cheeses which I have examined were made in dairies where Keevil's apparatus is in daily use. The superior character of the one cheese is as little a proof of the merits of Keevil's apparatus as is the bad quality of the other an evidence against it.

Again, I may point to the composition of the whey analyses marked No. 2, No. 3, No. 8, and No. 14, in the preceding large table, and to the three whey analyses to which I have just referred:—

No. 2, containing ·68 per cent. of butter, was made from curd taken by Keevil's apparatus.
No. 16, containing ·18 per cent. of butter, was made from curd taken by Keevil's apparatus.
No. 18, containing ·03 per cent. of butter, was made from curd taken by Keevil's apparatus.

Here, then, we have two samples of whey very poor in butter, and one sample containing more butter than any of the seventeen which I analysed. On the other hand:—

No. 3, containing ·55 per cent. of butter, was made from curd broken by hand.
No. 8, containing ·24 per cent. of butter, was made from curd broken by hand.
No. 14, containing ·14 per cent. of butter, was made from curd broken by hand.

Here, again, we have two well-separated samples of whey, and one rich in butter, all three being made from curd broken by hand.

Passing on from the loss of butter to that in the curd itself, I find that, although no doubt some fine curd is lost when the whey is very milky in appearance, yet as a rule this loss is small in most dairies. Indeed, my analyses prove positively that whey seldom contains much casein or curd which might be retained by ever so careful filtration. I have filtered whey from good milk through the finest blotting-paper, and obtained it as bright as crystal. On heating the perfectly clear whey to the boiling-point, however, a considerable quantity of a white, flaky substance, resembling in every respect albumen, or the white of egg, made its appearance. Collected on a filter, washed with distilled water, dried at 212° F., and weighed, this albuminous or curdlike substance amounted on the average to about ·9 or nearly 1 per cent. in good milk; in very rich milk there may be a little more, in poor a little less. This albuminous matter is contained in the whey in a state of perfect solution, and differs from casein or curd in not being coagulated by rennet. I have called it an albuminous matter, because, like albumen, it separates in flakes from the whey at the temperature of boiling water. Any one may prove the existence of this substance, which, however bright the whey may be, it invariably deposits in abundance at the boiling-point.

Assuming, then, ·9 to be the average proportion of this albuminous matter in whey, and deducting this proportion from the total amount of nitrogenized substances in the eighteen samples of whey, we obtain the amount of curd held in *mechanical* suspension. Thus we get for

No. 1 whey	·30 per cent. of curd, held in a state of mechanical suspension.
No. 2, 4, 8, and 15 whey	none.
No. 3 and 13 whey	·06 per cent. of curd, held in a state of mechanical suspension.
No. 5 whey	·525 per cent. of curd, held in a state of mechanical suspension.
No. 6 and 9 whey	·11 per cent. of curd, held in a state of mechanical suspension.
No. 7 whey	·156 per cent. of curd, held in a state of mechanical suspension.
No. 10, 12, and 14 whey	·01 per cent. of curd, held in a state of mechanical suspension.
No. 11 whey	·03 per cent. of curd, held in a state of mechanical suspension.
No. 16, 17, and 18 whey	·04 per cent. of curd, held in a state of mechanical suspension.

Thus only in one sample out of eighteen there was about $\frac{1}{2}$ per cent. of curd held in mechanical suspension, and one sample containing $\frac{8}{10}$ths per cent., all the other samples, practically speaking, containing no suspended curd. Thus it is not so much the curd as the butter which is lost when whey is badly separated from the curd.

4. When the curd has become sufficiently consolidated and is ready to be vatted, it is crumbled down into small fragments. For this operation every dairy should be furnished with a curd-mill, a simple and inexpensive contrivance, which saves much labour, and produces, generally speaking, a more uniform material than the hand.

5. Cheese is also spoiled occasionally by badly made rennet, that is, rennet which is either too weak or has a disagreeable smell. In the one case the curd does not separate completely, and that which separates remains tender; in the other the milk is tainted, and the flavour of the cheese is affected.

The rennet used in different parts of England varies exceedingly in strength and in flavour. Even in the same locality the usage differs on adjacent farms. Although I have in my possession some dozens of rennet recipes, which were given to me by experienced dairymaids, each as the very best, I shall not give a single receipt for making rennet, as my object is rather to elucidate chemical principles than to prescribe details; and also because, as long as the smell of the rennet is fresh, and a sufficient quantity is used, it matters little, in my opinion, how it is made.

The ordinary practice in Cheshire is to make rennet fresh every morning by taking a small bit of dried skin, infusing it in water, and using this infusion for one day's making. In Gloucestershire and Wiltshire a supply is made from the pickled vells, which lasts for two or three months. Generally the rennet is made in these counties twice in the season. I have had a good deal of discussion with practical men respecting the comparative merits of these two methods. The Cheshire farmers almost unanimously object that the rennet does not keep well when made in any quantity of pickled vells. This, however, is quite a mistake. I have in my possession some rennet which is as nicely flavoured now as it was some nine months ago, when it was made. It has, of course, a peculiar animal odour, but nothing approaching a putrid smell. The spices which are used in some localities, such as cloves and lemons, tend very much to keep the rennet in a good condition and give it an agreeable flavour. The objection, then, of the Cheshire farmers, that rennet, when a supply is made, does not keep, and spoils the flavour of cheese, is certainly untenable. I am much inclined to consider the practice of Gloucestershire and Wiltshire, of making a considerable supply of rennet, a good one; for, when once the strength of the rennet has been ascertained, it is merely necessary to take the proper quantity, one or two cupfuls, to produce the desired effect with certainty; whereas, when the rennet is made day by day, there is not the same certainty of obtaining an infusion of uniform strength.

Scientific and practical writers on milk have stated that the casein is held in solution by a small quantity of alkali; that when in warm weather milk curdles, lactic acid, which is always found in sour milk, is formed from a portion of the sugar of milk; and this lactic acid, by neutralizing the alkali which holds the casein in solution, causes its separation from the milk. Rennet is supposed to act as a ferment, which rapidly converts some of the sugar of milk into lactic acid. Whether, therefore, milk coagulates spontaneously after some length of time, or more rapidly on the addition of rennet, in either case the separation of the curd is supposed to be due to the removal of the free alkali by lactic acid.

This theory, however, is not quite consistent with facts. The casein in milk cannot be said to be held in solution by free alkali; for, although it is true that milk often has a slightly alkaline reaction, it is likewise a fact that sometimes perfectly fresh milk is slightly acid. We might as well say, therefore, that the casein is held in solution by a little free acid, as by free alkali. Newly drawn milk, again, is often perfectly neutral; but, whether milk be neutral, or alkaline, or acid, the casein exists in it in a state of solution, which cannot, therefore, depend on an alkaline reaction. We all know that milk, when it turns sour, curdles very readily. It is not the fact that *a good deal of acid curdles milk* which I dispute, but the assumption that the casein in milk is held in solution by free alkali. The action of rennet upon milk, then, is not such as has been hitherto represented by all chemists who have treated of this subject. Like many other animal matters which act as ferments, rennet, it is true, rapidly induces the milk to turn sour; but free lactic-acid, I find, makes its appearance in milk *after* the curd has separated, and not simultaneously with the precipitation of the curd. Perfectly fresh and neutral milk, on the addition of rennet, coagulates, but the whey is perfectly neutral. I have even purposely made milk alkaline, and yet succeeded in separating the curd by rennet; and, what is more, obtained a whey which had an alkaline reaction.

What may be the precise mode in which rennet acts upon milk, I do not presume to explain. I believe it to be an action *sui generis*, which as yet is only known by its effects. We at present are even unacquainted with the precise chemical character and the composition of the active principle in rennet, and have not even a name for it. Finding the effect of rennet upon milk to be different from that which I expected, I made a number of experiments, which may here find a place.

1*st Experiment.*—To a pint of new milk, slightly alkaline to test-paper, and of 60° Fahr., ¼ ounce of rennet was added.

Result: No coagulation after 3 hours.

Another ¼ ounce of the same rennet was then added.

Result: The milk coagulated 1 hour after this addition, but the casein was by no means well separated, and remained tender and too spongy, even after 24 hours. The whey was *slightly alkaline.*

2nd Exp.—To another pint of milk, neutral to test-paper, I added ½ ounce of the same rennet. The temperature of the milk was 60°, as before.

Result: The curd separated (though imperfectly) after 3 hours. The whey was *neutral.*

N.B.—It will be seen that the curd separated more readily from milk which was neutral, than from that which was alkaline.

3rd Exp.—To 2 pints of skimmed milk (24 hours old), and very slightly acid, I added ½ ounce of rennet. Temperature of milk 59° Fahr.

Result: Curd separated in 2 hours; reaction of whey the same as that of the milk.

Thus, if milk is slightly sour, rennet separates the curd more readily than when it is neutral, though the temperature may be low.

4th Exp.—To 1 pint of milk, slightly alkaline, and heated to 82° Fahr., ¼ ounce of rennet was added.

Result: The milk coagulated in 20 minutes; the whey was slightly alkaline.

5th Exp.—To 1 pint of milk heated to 100°, and neutral on reaction, ½ ounce of rennet was added.

Result: Milk coagulated in ¼ hour; whey perfectly neutral.

6th Exp.—Added to 1 pint of milk ¼ ounce of rennet. The temperature of milk was 110°; its reaction alkaline.

Result: Milk coagulated in 10 minutes; the whey was alkaline.

7th Exp.—Milk was raised to 120° Fahr., and ¼ ounce of rennet added to 1 pint of milk, which was slightly alkaline to test-paper.

Result: Milk coagulated in 10 minutes; the whey had the same reaction as the milk.

8th Exp.—1 pint of milk was heated to 130°, and ¼ ounce of rennet added.

Result: Curd separated in 20 minutes; whey had the same reaction as milk.

The experiment was repeated, and found correct.

It will thus appear that too high a temperature is not so favourable to the coagulation of the milk as a less elevated one. The separation, which at 120° took place in 10 minutes, at 130° occupied 20 minutes.

9*th Exp.*—Heated 1 pint of milk to 150°, added $\frac{1}{4}$ ounce of rennet.

Result: Milk did not coagulate after 24 hours.

10*th Exp.*—Heated milk to 140°, added rennet.

Result: No coagulation.

11*th Exp.*—Heated milk to 135°, added rennet.

Result: No coagulation took place, even after 3 hours. I then added another $\frac{1}{4}$ ounce; the milk by this time had cooled down, and the fresh quantity of rennet caused the separation of curd in less than 20 minutes.

Thus, at 120°, milk coagulates most readily; at 130°, it takes a somewhat longer time; and at 135°, and upwards, it ceases to coagulate.

12*th Exp.*—Heated 1 pint of milk to boiling-point, added $\frac{1}{4}$ ounce of rennet.

Result: No curd had separated when examined, after 24 hours' standing.

13*th Exp.*—Heated another pint of milk to boiling-point, and added $\frac{1}{4}$ ounce of rennet.

Result: Milk did not coagulate after 24 hours. I then added a little more fresh rennet to the cooled milk, and again gently heated it, when the curd separated in less than $\frac{1}{4}$ hour.

Thus the temperature of boiling water, and even a much lower heat, destroys the action of rennet, but does not so permanently change the casein of milk that it cannot be separated.

The whey in the last experiment, again, was neutral, like the milk.

14*th Exp.*—To 1 pint of fresh milk I added 10 grains of carbonate of potash, raised the temperature to 88° Fahr., and added $\frac{1}{4}$ ounce of rennet.

Result: Curd separated in $\frac{1}{2}$ hour. The milk and the whey were strongly alkaline. After 24 hours the whey was neutral, and then it became acid by degrees.

15*th Exp.*—To 1 pint of milk I added 20 grains of carbonate of potash, heated to 90° Fahr., and added $\frac{1}{4}$ ounce of rennet.

Result: The curd separated in $\frac{1}{2}$ hour, but not so perfectly as in the preceding experiment, and in a softer condition. The whey was more milky in appearance, and strongly alkaline. Examined after 24 hours' standing, it was found to be neutral; after a lapse of 2 days, it was acid.

Even a considerable quantity of an alkali, therefore, does not prevent the coagulation of milk by rennet.

16*th Exp.*—To another pint of milk I added an unweighed quantity of potash heated to 84°, and then $\frac{1}{4}$ ounce of rennet.

Result: No coagulation took place.

Much more alkali was used in this experiment than in the two preceding; an excess of alkali, therefore, prevents the separation of curd by rennet.

17*th Exp.*—To some milk, sufficient tartaric acid was added to make it distinctly acid.

Result: No coagulation took place in the cold. On the application of heat, the milk coagulated but imperfectly.

18*th Exp.*—To another portion of milk I added a good deal of tartaric acid.

Result: The milk coagulated after some time, but imperfectly; on raising the temperature, more curd fell down.

In order to precipitate the casein from milk by tartaric acid, it is thus necessary to add a very large excess of acid, and at the same time to raise the temperature of the milk.

These experiments prove thus—

a.—That the action of rennet on milk is not the same as that of an acid, inasmuch as rennet coagulates new milk without turning it sour in the least degree.

b.—That rennet can precipitate curd from milk, even when purposely made alkaline.

c.—That the whey of milk, when produced from perfectly sweet or neutral milk, is at first perfectly sweet or neutral, but rapidly turns sour. If made from milk having an alkaline reaction, the whey at first is alkaline; when from milk slightly acid, the whey likewise is slightly acid.

d.—That rennet ceases to coagulate milk at about 135°, and upwards.

e.—That the action of rennet upon milk is more energetic when the milk is slightly acid. This, perhaps, is the reason why some persons recommend putting some sour whey into the milk before or after adding the rennet.

f.—That an excess of alkali prevents the coagulation of milk by rennet.

g.—That an excess of acid coagulates milk, but not perfectly in the cold.

h.—That a moderate amount of acid does not coagulate milk in the cold, and imperfectly at an elevated temperature.

6. Cheese, again, is sometimes spoiled when bad annatto is employed as a colouring matter. Annatto at the best is a nasty, disagreeable smelling substance; it would be well if it were banished altogether from the dairy. But, so long as a good many people will prefer coloured to uncoloured cheese, annatto will be employed for the purpose of imparting a more or less deep yellow colour.

The annatto of commerce is derived from the Orlean-tree (*Bixa orellana*). The seeds and pulp of this tree appear to contain two colouring matters; one, in a pure state, is orange-red, and is called bixin; the other is yellow, and called orellin. These colouring matters are insoluble in water, but dissolve readily in alkalies, and also in fixed oils and fats. Solid annatto, the annatto cake of commerce, is a preparation, which contains, besides the pure colouring matter, a great deal of potash or soda, carbonate-of-lime, pipeclay, earthy matters, and rubbish of various kinds. Soap, train-oil, and other disagreeable smelling and tasting matters are often used in preparing annatto cake. Hence the annatto of commerce is often a most nauseous material, which, when put into the cheese-tub, is apt to give to the cheese a bad taste and an unsightly colour. Far superior to this annatto, and more handy in its application, is the liquid annatto, which is mainly an alkaline solution of the pure colouring matter of the Bixa orellana. An excellent solution of that description is manufactured by Mr. Nichols, of Chippenham, which is perfectly clear, has a bright yellow colour, and is free from any of the obnoxious and disagreeable substances which are frequently mixed up with annatto cake.

7. *In the next place, I would observe that cheese is occasionally spoilt if too much salt is used in curing it.* Salt is a powerful antiseptic, that is, it prevents fermentation; hence we use it for pickling beef and hams. A certain amount of salt is necessary, not so much for giving a saline taste, as for keeping in check the fermentation to which cheese, like other animal matters, is liable. If no salt were used the cheese would putrefy, and acquire a very strong taste and smell, at least when made in the ordinary way. When an extra quantity of cream is put to the milk, it is not necessary, or even desirable, to salt the curd much; we might even do without salt altogether, for the large amount of fat (butter) in extra rich cheeses, such as Stilton or cream-Cheddar, sufficiently preserves the casein.

If salt is employed in excess, the cheese does not ripen properly, or acquire that fine flavour, which depends upon the fermentation proceeding in a sufficiently active degree. Too much salt, by checking this chemical activity, is thus injurious to the proper ripening of cheese. The saline taste of old cheese, as already explained, is not due so much to the common salt used in its preparation, as to certain ammoniacal salts which are formed during the ripening process. It sounds strange, but it is nevertheless the case, that over-salted cheeses do not taste nearly so saline when kept for six or eight months, as under-salted cheeses kept equally long. If the milk is very rich, somewhat less salt should be used than when it is poor. On no account, however, should more than 2 lbs. of salt be used per cwt. of cheese; 1½ lb. in most cases is quite enough, and even 1 lb. will be found a sufficient quantity when rich cheeses are made.

8. *Lastly, an inferior quality of cheese sometimes is produced when it is imperfectly salted;* that is, when the salt is not properly applied to the cheese. I have often seen the salt put upon the curd in rough bits; more often proper care is not taken to mix the curd with the salt, and the cheese becomes unequally salted. The consequence is that some particles of the cheese ferment too much, others too little, and that the portions which are too much salted do not stick well together, and acquire a dry and crumbly texture. The salt used in dairies should be of the finest description, and should be sifted evenly through a fine sieve on the curd, after the latter has been passed through the curd-mill, and thinly spread in shallow leads to cool. This plan of spreading the salt saves a great deal of labour, and is greatly to be preferred to the system of pickling the cheese in brine after it is made, or of rubbing in salt. When salt is applied, either in solution or by rubbing it into the cheese after it has been in the presses, the outside is apt to get hard, and close up too much. It is, of course, desirable to get a good and firm coat, but, at the same time, the pores should not be too much closed, so that the emanations which proceed from the cheese cannot escape. Thin cheeses may be salted after they have been in the press; but, in making thick cheeses, it is far better to salt the curd before it is put into the vat.

A rather novel way of salting cheese has lately been made the subject of experiments in America. As the following communication to the pages of the 'Country Gentleman and Cultivator,' an American agricultural paper, may have some interest, I take the liberty of inserting it here:—

"*Important Experiment in Cheese-making.*—The diary season is about commencing again, and I desire the privilege of a corner in your paper, to give the result of extended experiments in cheese-making. In the first place I shall take it for granted that the whole process up to salting is well understood, for it is of *salting* that I wish to speak in this article.

"In June, 1859, I finished a few cheeses after the following manner: When my curd was scalded (I practise thorough scalding), I threw into the vat about 4 quarts of salt—sometimes only 3—for a cheese of 50 to 60 lbs., stirring thoroughly. Those which went into the hoop before being well cooled off, acted badly; but when I took time and means to cool sufficiently, the cheeses were very fine. On the whole, I did not like the process, and abandoned it.

"In 1860 I commenced again, changing the programme as follows: After scalding I drew off the whey, leaving just enough to float the curd, and began to cool off, hurrying the process by pumping in cold water and changing often. Then, to a curd of say 60 lbs., a little more or less, I threw in sometimes 3 and sometimes 4 quarts of salt, and stirred till well cooled—then drew off the salted whey, and threw it on the compost heap—put the curd to press, and pressed rapidly and thoroughly. And now for the result. I lost from my whey tub about three pails of whey and some salt. I gained in this, that my dripping tub under the press never had a particle of cream rise upon it, and in having a cheese that gave me no trouble in curing, and that when sent to market sold for the very highest price, and called forth the unqualified approbation of dealers as being perfect in all respects—fine flavoured, very solid (not porous), and very fat.

"And now let me talk to the experience of dairymen. In the old-fashioned way of breaking up and salting a curd, more or less bruising of the curd to break the lumps, in order to get the salt evenly distributed, is necessary; and when put to press the white whey runs off freely, or in other words the cream runs off, and of course with it the richness of the cheese, and more or less of its weight; and if the curd is very dry you are liable to get your cheese too high salted, and if not, the reverse.

"My experiments clearly prove that a curd salted in whey will retain no more salt than it needs, and that as every particle comes in contact with the brine through the operation of stirring, no bruising is necessary. Whether this is the philosophy of it or not, I am not chemist enough to determine, but I do know that if there is no discharge of white whey, or cream, it is retained in the cheese, adding to it both richness and weight as a remuneration for the extra salt and the wasted whey."

III.—PRACTICAL ERRORS MADE IN KEEPING CHEESE.

The following are some of the practical mistakes that are occasionally made after the cheese has left the presses and is placed in the store-rooms.

1. *Cheese is deteriorated in quality when it is placed in damp or in badly-ventilated rooms.*

When beef or mutton is kept for a day or two in a damp and badly-ventilated place, the meat soon acquires a disagreeable cellar-like taste. The same is the case with cheese. Kept in a damp place, it also becomes mouldy, and generates abundance of mites.

In some parts of Cheshire it is a common practice to keep cheese in dark rooms, carefully shutting out the free access of air. This is an objectionable practice, which no doubt has its origin in the desire to maintain in the store-rooms a somewhat elevated temperature, and to avoid draughts of cold air.

It is quite true that draughts are injurious to newly-made cheese, and a somewhat elevated temperature decidedly favours its ripening and the development of a fine flavour; but the one may be avoided, and the other can be maintained quite well, at the same time that due provision is made for the admission and circulation of fresh air.

During the first stage of ripening, a good deal of water and other emanations escape from the cheeses, which, if not allowed freely to pass away, make the air damp and injure the flavour of the cheeses. Why cheese should be kept in dark rooms is to me a mystery.

2. *Cheese newly made is spoiled by not turning it frequently enough.*

Thick cheeses especially require to be frequently turned, in order that the water which is given off from the interior warmer parts of the cheese may freely escape, and all sides be exposed at short intervals to the air. If this is neglected, that part which is in close contact with the board on which it rests becomes smeary and rots, and by degrees the whole cheese is spoiled. The boards, we need hardly say, should be wiped with a dry cloth from time to time as well as the cheese.

3. *Cheese does not ripen properly, and therefore remains deficient in flavour, if the temperature of the cheese-room is too low.*

The ripening of cheese is essentially a process of fermentation, which may be accelerated or depressed by a proper or by too low a temperature. Any temperature under 60° is unfavourable, and should therefore be avoided.

4. *Cheese is also spoiled if the temperature of the cheese-room is too high.*

If the temperature of the room rises above 75° F. the fermentation becomes so active that a cheese is apt to bulge out at the sides, and to lose the uniform and close texture which characterises it when good.

5. *Lastly, cheese is sometimes spoiled if the temperature of the cheese-room varies too much at different times.*

A steady fermentation, which is essential to the proper ripening of the cheese, can only be maintained in a room which is not subject to great fluctuations in temperature. The more uniformly, therefore, the cheese-room is heated, the more readily cheese can be brought into the market, and the finer the quality will be. For this reason hot-water pipes, which give a very steady, gentle, and lasting heat, are greatly to be preferred to stoves in cheese-rooms; with the latter it is almost impossible to maintain an equable temperature. The cheeses nearest to the stove again are apt to get too much, and those farthest off not enough, heat. Constant attention is moreover required; and firing in the room is always productive of more or less dust and dirt. These inconveniences are entirely avoided by the system of heating by hot-water pipes.

In every dairy hot water is in constant request; the same boiler which heats the water for cleaning the dairy-utensils may be conveniently connected with iron-pipes that pass in and round the cheese-room. Beyond the first cost of the iron-pipes hardly any extra expense in fuel is thus incurred. An extra pipe likewise may be introduced which connects the boiler with Coquet's apparatus, and by this means the curd in the tub may be scalded much more conveniently and regularly than by pouring hot whey or water over it. I have not made a sufficient number of observations to say definitely which is the best temperature to be maintained in a cheese-room; but in my judgment a uniform temperature of 70° to 75° is highly favourable to the ripening process.

The proper regulation of the temperature of the cheese-room, and the general plan of heating by hot water, I believe, is one of greatest of our recent improvements.

These are some of the practical mistakes which I have noticed in our dairies. I have endeavoured to assign reasons why they must be so regarded, and have ventured to point out the appropriate remedies, many of which, however, suggest themselves naturally to any intelligent observer. My object has been, not so much to write a treatise on cheese-making, as to enable those interested in dairy operations to read the various treatises and pamphlets on cheese-making with profit, so as to be able to sift the recommendations which are worth imitating from the heap of empirical rubbish under which they are too often buried. No directions, however carefully given, can ever be of much service in an art which, like cheese-making, does not so much presuppose a great amount of knowledge as practical experience, dexterity, and cleanly habits. Neither skill in manipulation, nor habits of cleanliness, nor experience can be acquired by reading. A good or a sensible pamphlet, no doubt, may be read with benefit even by an experienced hand; but the very best of treatises, in the nature of things, cannot teach a person who wants a rule or a recipe for everything how to make good cheese. A good cookery-book, no doubt, is a useful literary production, but the best cookery-book is incapable of teaching an inexperienced person the art of making light and wholesome pie-crust.

It is the same with cheese-making as with cookery, as we shall do well to bear in mind.

Lest these observations on publications on cheese-making should seem to disparage too much the merits of the different authors, I may state distinctly that a few papers contain valuable and plain directions for making good cheese; but I am bound at the same time to confess that the greater number, and more especially most of the prize essays on cheese-making which I have read, in my humble opinion, are next to useless to the dairy-farmer, inasmuch as they generally contain nothing good but what every dairy-farmer has long known ever since he began making cheese,—and a great deal besides, which, though it may appear novel, ingenious, or feasible, will at once be condemned by any man of sound judgment as visionary and utterly impracticable.

There are many topics intimately connected with the manufacture of cheese on which I have not touched at all, such as the influence of the food on the quantity and quality of milk, an important subject as yet hardly investigated at all. Again the influence of the race on the production of milk deserves to be carefully studied, besides various other points on which practical men may wish to obtain trustworthy information. My passing them over in silence in the present paper will not I trust be taken as an indication of want of acquaintance with the real practical wants of the dairy-farmer.

Hitherto scarcely anything directly bearing on dairy-practice has been done by scientific men: the whole investigation has, therefore, engaged my liveliest attention, and brought to light some unexpected chemical facts which have been recorded in the preceding pages. Others I hope to lay before the readers of the Journal of the Royal Agricultural Society when the researches still in hand shall be in a sufficiently advanced state to warrant their publication.

Royal Agricultural College, Cirencester, June, 1861.

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ON THE

SCOURING LANDS OF CENTRAL SOMERSET.

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[*Report of an Investigation made at the request of the Council of the Bath and West of England Society.*]

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SCOURING LANDS OF CENTRAL SOMERSET.

SCOURING lands, though by no means confined to the lias-formation, occur most frequently in localities where heavy, tenacious, dark-coloured soils rest upon yellow or blue lias clay. Central Somerset unfortunately abounds in pastures which are "tart" and exhibit this peculiarity in a very characteristic and virulent manner. Many of the upland and border pastures on the northern side of the Polden Hills, and immediately skirting the moors forming the great Brue Level, possess in a high degree the property of scouring cattle, more especially dairy cows during the summer months. The Polden Hills, indeed, are notorious for the prevalence of scouring land. Such land occurs to the east of the district just mentioned in the direction of Pilton, Pennard, and Shepton Mallet, but in the northern and western parts of the county scouring pastures are rarely found. Some of the worst land in this respect, I understand, may be found in the parish of Cossington, on the northern side of the Polden Hills. To this locality my attention was particularly directed: I therefore visited this district last summer and personally made inquiries into all the facts and local opinions deemed likely to throw light on the cause or causes of this mysterious peculiarity, which more or less prevails in the neighbourhoods of Walton, Shapwick, Edington, Baltonsborough, Pennard, Pylle, Barton St. David, Puddimore, Load, Othery, Burtle, Butleigh, Street, Edgarly, and other localities.

Scouring land, however, is not confined to Central Somerset, nor to blue lias-clay; for in Gloucestershire and other counties scouring pastures here and there occur. Thus in the neighbourhood of Cirencester certain pastures exhibit this peculiarity, although they are not situated in the lias but in the oolite formation. In every instance that has been brought under my notice, however, I find that scouring land rests on an impervious yellow or blue-coloured clay subsoil of considerable depth. Most frequently the subsoil is a true lias-clay, but examples are not wanting in which scouring land rests on forest-marble clay, Oxford clay, and clays of the great oolite formation.

Respecting the cause why cattle scour during the summer months on certain pastures and not on others, many conjectures have been made and various theories suggested; but not one explanation, however reasonable it may appear in a particular instance, takes into account the multiplicity of facts which really have to be considered in forming a comprehensive and satisfactory theory on this subject. Hence of all the explanations hitherto offered, the best are but partially true, and they are frequently irreconcilable with established facts.

Leaving unnoticed several of the more palpably erroneous surmisings, it may be observed that the *cause* of scouring,—to which cows and calves, and in a minor degree horses and sheep, are liable on certain pastures,—has been referred :—

1. To injurious substances which are supposed to exist in lias-clay and scouring lands generally.
2. To defective or inefficient drainage.
3. To the drinking of water in districts where scouring prevails.
4. To certain medicinal plants, such as the *Linum catharticum*, supposed to abound on scouring land.
5. To injurious constituents of scouring herbage.
6. To the poor and innutritious character of the herbage on scouring meadows.

The critical examination of these six theories may be preceded by some facts gathered during a professional visit to some of the worst scouring land on the Polden Hills, and by several statements contained in Mr. Clarke's highly suggestive Prize Essay on the Scouring Lands of Central Somerset.*

On sifting carefully the practical evidence at our command, little or no doubt, I think, can be entertained respecting the reality of the following classified facts.

a. *Facts connected with the character of Scouring Land.*

1. Scouring land is most prevalent in the lias-formation.
2. Such land is generally *dark-coloured*, and invariably rests on an impervious clay subsoil.
3. There is scouring clay-land resting on similar yellow or blue tenacious clay subsoils, but not belonging to the lias-clays.
4. On the other hand, not every lias-clay soil possesses this peculiarity.
5. No special analytical examination of scouring land and of lias-clay subsoils has as yet been published.

b. *Facts connected with Drainage.*

6. In certain seasons cattle scour on some perfectly well-drained soils, as much as on undrained pastures.
7. In other well-authenticated cases drainage was found a perfect cure.

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* Journal of the Bath and West of England Society, vol. iii. p. 52.

c. Facts connected with Water.

8. Certain waters in districts where scouring prevails appear to have a decided medicinal effect on the health of cattle that drink them.

9. The composition of these waters has not as yet been ascertained.

10. Soft or rain water, and the black ditch-water from peaty land, are preferred by cattle to the hard-water springs of the lias.

11. The black waters from peaty soils are always soft; that is, they contain but a small proportion of mineral and saline constituents.

12. The dark colour of water from peat is not due to any astringent principle, but to compounds of humic and ulmic acids, two organic acids of humus.

d. Facts connected with Herbage.

13. No satisfactory evidence exists showing that in scouring meadows particular plants grow in abundance, which, like *Linum catharticum* (purging flax), possess purging properties.

14. The herbage on many scouring pastures has by no means the appearance of that of poor, hungry pastures, but rather the reverse.

15. It has never been shown that the produce from scouring land contains anything injurious to the health of animals fed upon it.

16. Manures appear to increase the evil in exactly the proportion in which they increase the luxuriant growth of the young herbage.

17. During the driest summer months in the year the upland herbage possesses the greatest scouring property.

18. After the first frost in November the herbage loses more or less completely its prejudicial character, and during the colder and wetter months of the year pastures affected by this evil exhibit it only in a slight degree, or not at all.

We shall presently see the practical bearing of these facts, which to my mind seem well established. They are empirical, but most of them may be explained in a simple, rational manner, and not a few can be subjected to an analytical inquiry, which affords us a clear insight into the causes of this dreadful complaint.

At the request of the Council of the Bath and West of England Agricultural Society, I visited last summer (in company with Mr. Poole, to whose kindness I am greatly indebted) some of the most scouring districts on the Polden Hills; and on that occasion I took on the spot samples of water from a stream of water from the lias-cutting of the Bristol and Exeter Railway at Dunball, and from a stream of water which breaks out at Ford Farm on the south side of the hill between the parishes of Edington and Stawell. Both these waters are known to possess scouring properties: I was therefore particularly anxious to examine them. I further took samples of scouring land situated in the parish of Cossington; likewise hay from scouring land at Meare, and hay from peaty land that does not scour. These different samples and a soil from scouring land on the estate of Sir Alexander Hood at Shepton Mallet, as well as a peat soil at Meare, kindly sent to me by Mr. Poole, were carefully examined in my laboratory. The whole investigation into the causes of scouring so prevalent on certain pastures in Central Somerset engaged my liveliest attention.

The analytical proofs, which require to be mentioned in support of the views entertained by me at present on the subject of this report, may be conveniently incorporated in the examination of the leading theories to which allusion has been made.

For the sake of brevity, the hypothesis which supposes something injurious to vegetation to predominate in lias-clays may be termed the Geological Theory. This will claim our attention in the first place. In the next place the Drainage Theory requires examination; and the rest may be considered together under the general head of Herbage Theories.

Examination of the Geological Theory.

The question whether or not there is anything injurious or abnormal in lias-clay soils admits of a direct solution, which must be sought in the analysis of soils pre-eminently distinguished by scouring properties. Accordingly an analysis has been made of such a soil from Mr. Rugg's farm, in the parish of Cossington. The following results were obtained:—

Composition of Scouring Land from Mr. Rugg's Farm, Cossington. August, 1861.

Moisture	4·73
Organic matter and water of combination	16·57
Oxides of iron and alumina	14·26
Carbonate of lime	5·25
Carbonate of magnesia	3·67
Alkalies	1·04
Insoluble siliceous matters	54·48
	100·00

A second sample, taken from another part of the same field, yielded the following analytical results:—

Moisture	7·12
Organic matter and water of combination	14·76
Oxides of iron and alumina	15·87
Carbonate of lime	2·53
Carbonate of magnesia	2·08
Alkalies	2·60
Insoluble siliceous matter	55·04
	100·00

No constituent which does not occur in good land could be detected in the preceding soils, nor are the component parts present in abnormal relative proportions.

In the next place I examined a soil from notoriously bad land, on the estate of Sir Alexander Hood, at Shepton Mallet. This soil contained in 100 parts—

Moisture	4·54
Organic matter and water of combination	14·40
Oxides of iron and alumina	14·45
Sulphate of lime	·26
Carbonate of lime	14·80
Magnesia	·96
Alkalies	·93
Insoluble siliceous matter	49·66
	100·00

This soil was rather dark-coloured. The dark colour is due partly to protoxide of iron, partly to the large quantities of organic matter. Although not injurious in itself, an excess of inert organic matter, and particularly protoxide of iron, indicates a condition of the soil which is not favourable to the healthy growth of plants. In a porous, well-cultivated soil, freely penetrated by the atmosphere, the accumulation of organic matter never becomes excessive, nor does such a soil contain protoxide of iron in large quantities. The presence of the latter in considerable proportions always shows that the soil is not sufficiently aërated, in order to produce a healthy and nutritious herbage. As protoxide of iron is insoluble in water, I am of opinion it is not injurious to plants, but it indicates a bad physical condition, which affects the herbage more than the chemical constitution of the soil.

The next soil which I examined was a lias-clay subsoil from Cossington. The analysis gave the following results:—

Composition of a Lias-Clay Subsoil from Cossington.

Water	3·05
Organic matter and water of combination	5·11
Oxides of iron and alumina	6·98
Carbonate of lime	40·93
Alkalies and magnesia	2·96
Insoluble siliceous matter (clay)	40·97
	100·00

A large quantity of carbonate of lime enters into the composition of this extremely tenacious clay-marl, but nothing peculiar, or in any way remarkable, occurs in it.

Lastly, an analysis of a peat-soil from Meare gave the following results :—

Composition of Peat-Land at Meare which does not scour.

*Organic matter	97·760
Oxides of iron and alumina	·536
Carbonate of lime	·855
Magnesia	·144
Potash	·131
Soda	·065
Phosphoric acid	·053
Sulphuric acid	·051
Silica	·405
	100·000
*Containing nitrogen	1·428

In its natural state this soil contained no less than 87·95 per cent. of water, which shows how large a quantity of water peat is capable of absorbing.

This soil does not scour. It contains a very large proportion of organic matter and a very small quantity of mineral substances; the latter consist of the constituents usually found in soils of that description. Apart from the excess of organic matter in the peat-land, no essentially characteristic difference can be said to separate the scouring soil from the healthy peaty soil. In the immediate neighbourhood of Cirencester there are hundreds of healthy fields which, in composition, closely approach the three first-mentioned soils. It cannot therefore be said with propriety, that lias-soils possessing scouring properties contain anything injurious, or an excess of a constituent likely to produce an unhealthy growth of herbage. Nevertheless I am inclined to regard the *soil* of scouring land as the source from which the mischief proceeds; but the evil arises from its bad *physical condition*, and certainly not from the presence of any injurious matter in the surface or subsoil. I shall offer a few additional remarks on this point after having considered the character of the herbage of scouring pastures.

2. *Examination of the Drainage Theory.*

In the opinion of some who are well acquainted with the subject, inefficient drainage must be considered as an aggravation, if not the sole cause of the evil. Mr. Clarke, in his Essay,* mentions two well-authenticated cases, and Mr. Poole † another, in which the complaint appeared to have been entirely removed by drainage.

On the other hand, it is asserted that drainage not merely is generally ineffective in curing scouring land, but that in some cases it appears to aggravate the evil. In the absence of positive proofs it may be reasonably doubted whether drainage really increases the scouring properties of land, but it cannot, I think, be denied that it does not always, nor perhaps in the majority of cases, cure the complaint.

It certainly is a fact that in the lias formation the fields adjoining notorious scouring meadows are often perfectly sweet and sound; and that no difference as regards drainage, herbage, supply of water, and general character, can be recognized, which might account for the sound condition of a field and the scouring properties of the adjoining one.

Notwithstanding the great similarity of two such fields, I would observe, an essential difference would perhaps be readily recognized, if we could turn both completely over and carefully examine their subsoils. The scouring field would then be found to rest on a stiff impervious clay subsoil, not very far removed from the surface; and in the second field the subsoil would, in all probability, be of a much more porous character, or be found at a greater depth than that usually penetrated by the roots of grasses.

This difference in the character and position of the two subsoils necessarily must exercise a powerful influence on the agricultural capabilities of the two fields. Both may be equally well drained—both may bear to all appearance the same description of herbage—they may be identical in composition, and yet the one field may be worth a great deal more than the other. This need not cause surprise, for drainage only makes the two fields so far equal as it removes the surface-water from both; there still remains an essential difference in the supposed case. In one field we have

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* Journal of the Bath and West of England Society, vol. iii. p. 52.

† Ibid., p. 60.

a deeper surface-soil resting on a more porous subsoil; and in the other a less deep soil, with a stiff, impervious subsoil. It is quite a mistake to think that drainage necessarily improves every soil in a high degree. It does so in the great majority of soils. But at the same time we cannot shut our eyes to the fact, that whilst drainage often improves one field greatly and another much less, instances are not wanting in which the benefits resulting from draining are scarcely appreciable. Some people evidently think that drainage is a talisman which converts every unproductive soil into a fertile one. But a little consideration will show that the radical changes which draining usually produces in the agricultural capabilities of land cannot take place in every instance, and that the general character of scouring land is, in many cases, not affected by drainage.

Let us look for a moment at two pastures of a similar character in their natural, undrained condition. Both are wet, equally unproductive, and to all appearance there is no difference in the two fields; probably both scour. But we will suppose that in one field we have only 2 or 3 inches of surface-soil, and, under it, say 3 or 4 feet or more of tenacious lias-clay, whilst in the other the same clay subsoil lies at a depth of 18 inches, or still more remote from the surface. Though perfectly equal in their undrained condition, the greatest difference must be produced in the character of two such fields after draining; for with the removal of the surface-water in the one field only 2 or 3 inches of soil are improved, and in the other 18 inches or more. We can without difficulty take away the surface-water equally well from both fields, but we cannot in an equal degree change their general character. If scouring were caused by an excessive quantity of water in pasture-land, drainage would remove the evil in every instance; but as the scouring effects of herbage are most perceptible during dry weather, it follows that the mere presence of surface-water in a field does not account for its scouring properties.

As drainage produces radical changes in the condition of some soils, and as such changes cannot take place in soils in which a thick impervious clay-bed comes close to the surface, we can understand why drainage cures scouring land in one place and not in another.

I am unacquainted with a solitary instance in which scouring land rests on a porous subsoil, but I know many fields in scouring districts where a deep tenacious blue clay subsoil comes very near to the surface. Wherever this is the case, drainage, I am of opinion, will not remedy the evil; and in particular cases I can understand that it may even aggravate it. But should newly reclaimed peat-land or clay-soils, in which the blue lias subsoil lies at least 18 inches from the surface, be found to have scouring properties, I am inclined to think under-drainage will cure the evil on such land.

3. *Examination of the Water Theory.*

It has been stated by trustworthy authorities that certain waters in the lias-formation possess scouring properties. Two statements by Mr. Poole deserve particular attention. In his note to Mr. Clarke's paper,* Mr. Poole says: "Some years ago I carried a stream of water from the lias cutting of the Bristol and Exeter Railway, at Dunball, across Sedgmoor Drain into Horsey Slines (which the writer mentions as a district peculiarly free from this disease), and it immediately began to scour the cattle, and I was obliged to cut off the supply."

Again: "There is a stream of water which breaks out at Ford Farm, on the south side of the hill, between the parishes of Edington and Stawell, and flows through one of the offshoot moors of Sedgmoor, and which, for at least two miles of its course, viz., as far down as Bawdrip, scours the cattle in every field through which it passes. This spring is a strong petrifying spring. The scouring properties of the water are so well known that the watering-places on the course of the stream are frequently fenced off by farmers to prevent their cattle from drinking at them."

Mr. Clarke likewise mentions two cases. "In one instance," he says, "a large piece of pasture-land was found to scour the cows kept upon it, to the great loss of the occupier, until he hit upon the expedient of cutting off the supply of spring-water from a neighbouring brook, and confining the supply to the rain-water held in the ditches,—the result of which has been that very little of the disorder has since appeared upon the land referred to. The other instance was that of a field upon the peat-soil, which is not naturally liable to scour. But during a particularly dry summer the water from a brook, issuing from the blue lias clay, having been let down into this field for drinking purposes, the cattle immediately became affected with a similar disorder to that produced upon the scouring lands."

Mr. Bush, of Weston, near Bath, also informs me that in the parish of Kewstoke, near Weston-super-Mare, there is a piece of land situated upon the moor, close to the north side, the land adjoining being lias; a spring of water rises on the lias, and, till recently, flowed in an open ditch across this field. The tenant frequently found his cattle scour when in the field. About

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* Journal of the Bath and West of England Society, vol. iii. pp. 60-1.

two years ago he conveyed the water across the field in pipes, since which the scouring has ceased, and he attributed the scouring to their drinking the water.

In the face of these well-authenticated facts we cannot reasonably doubt that certain waters in the lias formation possess scouring properties.

I was anxious, therefore, to ascertain whether lias-waters have an abnormal constitution, and to this end I myself collected some of the water from the lias-cutting at Dunball, and from the spring at Ford Farm, to which reference is made in Mr. Poole's note. Both were submitted to careful analysis, which furnished the following results:—

Composition of Water from the Lias-cutting at Dunball.

An imperial gallon evaporated to dryness gave—

202·02 grains of solid residue (dried at 300° F.)

This residue contained—

Organic matters	·96
Mineral saline matters	204·64
Consisting of—	
Lime	60·48
Magnesia	12·20
Potash	2·39
Soda	12·29
Sulphuric acid	91·40
Chlorine	11·20
Carbonic acid and loss	10·10

These constituents, united together in the compounds which in all probability existed in the water, give the following results:—

An imperial gallon of water from Lias-cutting at Dunball contains—

Organic matter	·96
Sulphate of lime	104·77
Carbonate of lime	30·91
Sulphate of magnesia (Epsom salt) ..	36·60
Sulphate of soda (Glauber salt)	5·93
Sulphate of potash	4·42
Chloride of sodium (common salt) ..	18·45
	202·02

It will be seen that the water contains an enormous quantity of mineral matter, and in this mineral matter a considerable proportion of Epsom salt, Glauber salt, and other aperient saline substances. It is an extremely hard water, and essentially differs in composition from ordinary hard drinking waters; for in very hard waters we seldom find more than 40 to 50 grains of solid matter in the imperial gallon, or only one-fourth of the quantity contained in the lias water. In good drinking water, of average degree of hardness, the amount of mineral matters varies from 20 to 30 grains in the gallon, and soft waters contain only from 5 to 10 grains in the gallon.

During the dry and hot summer months, cattle which drink such lias water imbibe with it a very large quantity of mineral and saline substances, which experience teaches disturb the regular functions of the digestive organs, and cause the cattle to scour.

Composition of Spring-Water from Ford Farm.

An imperial gallon was found to contain—

Organic matter	·56
Sulphate of lime	109·87
Carbonate of lime	26·55
Sulphate of magnesia	25·80
Chloride of sodium	6·65
Sulphate of potash and soda	6·17
	175·60 grains.

On comparing the composition of this water with that of the Dunball Spring, a general similarity will be noticed. Both springs contain an abnormally large quantity of mineral and saline constituents which cannot fail seriously to affect the health of cattle that drink them. The spring at Ford Farm is not quite so rich in mineral matters as that from the Dunball cutting, but it nevertheless contains a larger proportion of such matters than many waters which, rising in the lias-clays, are well known to possess aperient properties. The fact, therefore, that certain waters in the lias-formation scour cattle, finds a full and satisfactory explanation in the peculiar composition of the two preceding springs.

The saline mineral substances in these waters, of course, exist in the beds from which the springs rise, or else they would not be found in the water. The blue lias-clay, therefore, must be regarded as the primary source from which the scouring properties of the water arise. In this sense it is, after all, the land which causes the mischief. The large proportion of sulphates in the springs of the lias-clay is worthy of notice, for it explains the peculiar and disagreeable smell which at times characterizes these waters. This smell is due to sulphuretted hydrogen—a gas which is generated when sulphates are brought into contact with organic matters, free access of air being excluded at the same time.

It has been asserted that the coldness of certain waters may be the reason why cattle who drink them scour. But this is not the case; the temperature, as such, has nothing whatever to do with the scouring properties of drinking water. It is perfectly true, however, that the hard lias-springs are invariably cold in summer in comparison with rain, ditch, or peat water. In winter, on the contrary, they are warmer than surface springs. This shows that the lias-springs, which often issue from clay beds of considerable depth (unlike rain or ditch water), are not affected by the temperature of the atmosphere. The former, therefore, have a uniform temperature throughout the year, although they appear cold in summer and warm in winter; whilst the temperature of the latter varies with the seasons, in consequence of which they really are warm in summer and cold in winter. Water which rises in the lias-clay, and is invariably cold in summer, having had to pass through beds of clay of considerable depth in its passage, becomes charged with abundance of saline mineral constituents. To these constituents alone, and not to the coldness, the scouring properties of such waters belong.

Soft springs do not scour, for the simple reason that they are always poor in those saline mineral matters which confer medicinal properties upon the hard lias-waters. If the contrary be maintained, and no substantial proof be given that the water which is supposed to scour is really soft, I can only say that, in the course of my practice as an analytical chemist, I have frequently had waters submitted to me which were described as soft, and on analysis were found to be quite the reverse.

The water from peat-land is always soft. It is supposed to contain tannin, or a similar astringent principle, in virtue of which it becomes a remedy when given to cattle affected by scouring. I do not question that the black ditch-water from peat-land stays scouring; this, however, is not owing to any astringent principle which it is supposed to contain, but simply because, in comparison with spring-water in scouring districts, it is remarkably poor in saline constituents. If hard water is withheld, one of the causes which in some—perhaps not a few cases—produce the evil is removed, and cattle soon recover when they are supplied with peat-water. Tannin occurs in fresh vegetable substances, but as it is a compound which is decomposed with extreme facility, it cannot possibly exist in peat. Direct experiments, moreover, which I have made, proved the absence of tannin, or similar astringent principles in peat, and showed to me that the dark brown colour of peat-water is due to certain combinations of ulmic and humic acid in which peat abounds.

From the preceding remarks it may be gathered that one positive cause which produces scouring in cattle is the abundance of mineral and saline matters in certain springs of the lias-formation. A still more complete insight into the nature of the mysterious complaint is gained by my investigations on the character of the herbage of scouring pastures.

Examination of the Herbage Theories.

According to the botanical theory the "tartness" of land is caused by one or more particular species of medicinal plants, which are supposed to grow in abundance on scouring pastures, and are not found in sweet and sound meadows.

The purging flax (*Linum catharticum*) has been specially named as the cause of the complaint, but there is no evidence whatever to prove that this plant really abounds in scouring pastures. On the occasion of my visit I carefully looked out for the *Linum catharticum*, but could not find a single specimen in one of the worst scouring pastures—the parish of Cossington. Singularly enough, on my return home, I found the purging-flax near Tetbury-road Station, on a poor piece of pasture, resting on a Bradford-clay subsoil, but I never heard that this land scours cattle.

Carnation-grass is another plant to which the evil is attributed, but as this grass grows quite as abundantly in sound pastures as in scouring meadows, in which latter sometimes hardly a specimen can be found, the origin of the disease cannot be traced to carnation-grass.

Nor can it be referred to the common sorrel (*Rumex acetosa*), the dandelion (*Leontodon taraxacum*), or to meadow-saffron (*Colchicum autumnale*); for the first-named plants are often found in abundance in meadows that do not scour, and on the other hand there are many scouring pastures in which not a single specimen of meadow-saffron occurs.

The botanical theory, in short, is unsupported by any reliable evidence, and even should it be found that in a particular locality the disorder can be traced distinctly to the prevalence of purging-flax or *colchicum* in the pasture, there is abundant practical evidence to prove that this would be quite an exceptional case, and that in the great majority of scouring pastures the origin of the evil must be sought elsewhere.

According to others, the poor character of the herbage of scouring pastures is the real cause of the mischief. Those who describe the character of the herbage as poor, I imagine, use this adjective as descriptive of a thin, wiry, stunted growth, such as may be observed on thin and infertile soils. They cannot mean "poor" to signify the same as innutritious, for, on the one hand, the poorest herbage may be and often is very nutritious, and on the other hand the most luxuriant grass-crops—as for instance, the hay from water-meadows—is by no means so nutritious as hay from common meadows. There would moreover be no other meaning in the expression,—"the herbage of certain pastures scours cattle because it is innutritious"—than is conveyed in the bare statement of a well-known fact.

Everybody knows that the herbage of scouring pastures is innutritious; if it were not so it would not scour. The question is, why is it innutritious? Is it the want of a proper supply of organic and mineral constituents in the soil, which has the effect of producing a stunted, thin, and wiry herbage, supposed to be innutritious? This question may be answered decidedly in the negative. If, in consequence of a deficiency or total want of certain substances which are food to plants, scouring land produced, as is supposed, a herbage deficient in the proper elements of nutrition, the application of manures would remedy the evil, but experience teaches that the use of manures aggravates the mischief instead of abating or curing it.

But it is hardly necessary to bring forward other evidence to show that this theory can only exist in the minds of those who are practically unacquainted with the subject. It ill accords with well-known facts.

The herbage on peat-land is proverbially poor, and yet it does not scour. On the other hand some of the worst scouring meadows produce a herbage to all appearance as luxuriant and succulent as can be desired. Indeed the more luxuriant pastures, in the districts where scouring amongst cattle prevails, are generally a great deal worse in this respect than poorer and less productive fields. However, no man, I believe, be he ever so well acquainted with the subject, by merely inspecting a field, can positively say whether it scours or not. There is nothing peculiar in the appearance of the herbage that distinguishes it from sound pastures, and yet, I imagine, there must be an essential difference between sweet and wholesome grass and that from scouring pastures. In most cases, I believe, the herbage must be regarded as the more direct cause of the complaint. For this reason my attention was specially directed to the study of the chemical characters which belong to sound and scouring herbage. At the same time I have endeavoured to investigate some peculiarities of scouring land, which I have every reason to believe tend to produce immature, abnormally constituted, and on this account unwholesome herbage.

The hay from scouring pastures, when made rather green, appears to possess the same injurious properties which distinguish the grass. But when made less green and rather late in the season, it appears either to be entirely freed from any injurious properties or to produce scouring in a very slight degree. It is important to bear in mind that hay from the same unwholesome meadow, according to the condition in which it is made, affects cattle very differently.

I should have liked to examine the herbage from scouring and wholesome pastures at various stages of growth, but had no opportunity to undertake a series of analytical examinations of the green produce, and was therefore obliged to confine my examinations to hay from sound and from scouring pastures.

Sample, No. 1.—*Hay from Scouring Land on Mr. Rugg's Farm, Cossington.*

Dried at 212° F., 100 parts of this hay gave—
8·94 parts of mineral matter, or ash.

In the same condition 100 parts were found to contain—
1·707 per cent. of nitrogen, which is equivalent to
10·668 per cent. of nitrogenized compounds.

Sample, No. 2.—*Hay from Peat-Land at Meare, which does not scour.*

In a perfectly dry state this hay gave on burning—
7·11 per cent. of ash in one determination, and
7·14 per cent. of ash in a second determination.

A considerable quantity was next reduced to ash, which was submitted to a full analysis, when the following results were obtained:—

Composition of the Ash of Hay from Peaty Land at Meare, which does not scour.

Lime	12·05
Magnesia	3·27
Oxide of iron	·33
Potash	21·36
Chloride of potassium	8·03
Chloride of sodium	9·08
Phosphoric acid	4·61
Sulphuric acid	4·36
Silica	37·34
	100·43

Dried at 212° F., 100 parts of the same hay furnished—
1·414 per cent. of nitrogen, which is equal to
8·837 per cent. of nitrogenized compounds.

Sample, No. 3.—Hay from Scouring Land at Meare.

In a perfectly dry state this hay produced in burning—
10·24 per cent. of ash in one experiment, and
10·38 per cent. of ash in another.

The ash was next submitted to a complete analysis, which furnished the subjoined results:—

Composition of the Ash of Hay from Scouring Land at Meare.

Lime	12·31
Magnesia	2·71
Oxide of iron	·89
Potash	17·47
Chloride of potassium	26·01
Chloride of sodium	1·70
Phosphoric acid	6·42
Sulphuric acid	3·76
Silica	27·22
Carbonic acid and loss	1·51
	100·00

Dried at 212° F., 100 parts of hay, No. 3, were found to contain—
1·782 per cent. of nitrogen, which is equivalent to
11·137 per cent. of nitrogenized compounds.

Sample, No. 4.—Hay from Peat-Land at Meare, earthed over with Scouring Land. Hay scours.

100 parts of this hay in a perfectly dry state furnished—
8·76 per cent. of ash, and
2·354 per cent. of nitrogen, which is equal to
14·712 per cent. of nitrogenized compounds.

A careful perusal of the preceding analytical results suggests several observations.

1. The proportion of mineral matters is greater in the scouring than in the sound herbage. Thus whilst the hay from peat-land at Meare contained only 7 per cent. of mineral matters in round numbers, the hay from scouring-land in the same locality contained as much as 10 per cent. Every 10 lbs. of such hay, therefore, contained 1 lb. of mineral substances, which is a very large quantity indeed.

2. Not only is the absolute quantity of mineral matter greater in scouring than in sound hay, but the ashes of both likewise differ materially in composition. In the ash of hay from peat-land, it will be seen, a very much larger proportion of silica and

much less chloride of potassium occur than in the hay from scouring-land. If the potassium in the chloride is calculated as potash, and this is added to the potash which exists in the ash principally as silicate, the total quantity of potash in the ash of the hay from peaty land will be found to amount to 26·30 per cent., and that of the hay from scouring-land to 36·33 per cent. Again, the percentage of chlorine in the chlorides of these two ashes differs greatly; in the one it amounts to 13·42 per cent., and in the other to only 9·32 per cent. We thus find a much larger proportion of potash salts and less silica in scouring hay than in sweet hay from peaty land.

3. The proportion of nitrogenized compounds in sound hay is smaller than that of hay from scouring land. Thus in the hay from peaty land we have not quite 9 per cent. of these compounds, and in one sample of hay from scouring land at Meare rather more than 11 per cent., and in the second as much as 14¾ per cent. of nitrogenized compounds.

The preceding analytical results therefore show that the organic portion as well as the mineral part of sound and scouring hay materially differ from each other in composition, and I have no doubt that other differences would have been brought to light had the organic portion of hay been more fully examined. I have confined myself to the determination of nitrogen in the hay, because its proportion in vegetable produce affords an excellent indication of its state of maturity, and a more complete organic analysis should be undertaken with the fresh and not with the dried produce.

Not many years ago a high percentage of nitrogen in hay, turnips, mangolds, and other kinds of agricultural produce was regarded as a proof of their superior nutritive value; but a thorough investigation which I undertook on account of the frequent discrepancies in the calculated theoretical nutritive value of various articles of food, and the value assigned to them by practical men, has shown me that the higher proportion of nitrogen in one of two samples of hay, turnips, mangolds, &c., by no means indicates a higher feeding-value, but the very reverse. I have been actively engaged for more than three years with an inquiry into the changes which roots undergo in their various stages of growth, and especially when they approach maturity. In connection with this inquiry a great many collateral experiments were instituted, to which reference cannot be made in this place. Some of the results, however, have so direct a relation to the subject of this report, that I cannot refrain from stating some of the principal.

Amongst other particulars I find :—

1. That the proportion of ash and of nitrogen in unripe turnips, mangolds, grass, young shoots of plants, &c., is very much larger than in ripe and sound roots, &c. A large proportion of ash, and especially of nitrogen, indeed, is an excellent indication of the unripe and unwholesome condition of turnips, mangolds, and vegetable produce in general. To mention only a few examples: whilst unripe mangolds, according to the stage in which they are examined, contain as much as 2½ to 3 per cent. of nitrogen in a dry state, when fully ripe they contain only 1½ to 1¾ per cent. of nitrogen. In turnips dried at 212° Fahr. I find the proportion of nitrogen in roots at an early stage as high as 3½; examined later in the season, the proportion of nitrogen gradually dwindles down exactly in the measure in which they get more ripe, and reaches a minimum when they are perfectly mature.

2. In quickly-grown rank grass from irrigated meadows I find a larger proportion of nitrogen and mineral matters than in good sweet meadow-grass. I need hardly say that the latter is infinitely superior to the former in nutritive value.

3. In turnip-tops and mangold-leaves the proportion of mineral matters and nitrogen is nearly double that contained in the ripe roots, which, of course, are more nutritious than the tops.

4. In unripe roots, grass, leaves, &c., in which a high percentage of nitrogen occurs, I find, comparatively speaking, little sugar, and a considerable quantity of various vegetable acids, such as tartaric, oxalic, malic, and tannic acids.

These are some of the principal results which have a direct bearing on the subject under discussion. We thus see that a high percentage of ash and nitrogen in roots, &c., indicates an immature condition, and is always accompanied by a comparatively small quantity of sugar, and by a large proportion of various vegetable acids. Most of these acids, either in a free state or in their combinations with mineral matters, especially with potash or soda, have a decidedly aperient effect; hence we can account for the scouring effects of unripe mangolds, turnip-tops, mangold-leaves, young unripe clover, Italian rye-grass forced with too much liquid manure, and grass from water-meadows at certain seasons of the year.

The herbage from scouring pastures is unwholesome for the same reason for which unripe mangolds, turnips, and forced grass are injurious to cattle. My investigations show that the hay from such pastures contains more nitrogen and ash than that from sound land; and as more especially a higher percentage of nitrogen indicates a less mature and less nutritious condition than a lower, there cannot remain much doubt that the immature condition of the herbage is the origin of the complaint in nine cases out of ten.

It is worthy of special notice that quickly-grown and very luxuriant-looking clover and grass invariably contain more nitrogen and ash than clover and grass which are more gradually developed, and, further, that the former invariably scour, whilst the latter are wholesome.

Living in the country, I have had ample opportunity of observing this fact, and also that the grass on water-meadows is never more unwholesome than when it grows most luxuriantly. In this condition grass is rich in nitrogenized compounds, in soluble saline substances, and in organic acids.

At an early stage of growth we find in all vegetable produce a much larger proportion of soluble saline matter, organic acids, and other combinations which have an aperient effect, than at a more advanced stage of growth. In the measure in which plants advance in maturity the soluble salts become insoluble, the organic acids disappear, and are replaced to a great extent by sugar; the compounds of nitrogen and the mineral matters decrease in proportion to the bulk of the whole plant, and other changes which cannot be here described in detail take place in the growing vegetable organism. The great difference in the taste of almost every plant at an early and a more advanced period of growth shows that the compositions of ripe and immature plants materially differ from each other. I do not know a single herb which, consumed in quantities in an immature condition, does not act as an aperient; even plants which when quite ripe are good tonics, at an early stage of their growth possess laxative properties.

In many parts of Germany the expressed juice of various herbs, such as dandelion, millefoil, water-cresses, or common meadow-grass, is considered a favourite spring medicine for purifying the blood. It is, however, only in the spring, when vegetation makes, as it were, a fresh and rapid start, that these herb-juices possess the desired aperient effect, and it matters little what kind of herb is employed in their preparation.

Several other facts well known to practical men confirm my analytical investigation of the herbage of sound and scouring pastures, and receive an intelligible explanation by the latter. It is, for instance, a well-known fact that the application of manures to scouring land increases the evil in proportion to the forcing effects of the fertilizers employed and the consequent luxuriant growth of the young herbage.

In scouring pastures there is abundance of plant-food, and hence in the drier summer months the herbage on such pastures grows with great luxuriance. The direct use of manure increases still further this luxuriant growth of the herbage, but at the same time retards its getting mature soon enough before it has to be made into hay. Hence the use of manures generally aggravates the scouring properties of the herbage. An excess of manure under all circumstances retards the ripening process, and tends to produce less wholesome and less nutritious roots, green and fodder crops; whilst a scanty supply of manure on naturally poor soils tends to push on plants to early maturity. It is upon this principle that gardeners act when they require to force flowers into early bloom.

Again, the fact that the complaint ceases almost entirely after the first November frost finds a ready explanation by my views on the character of the herbage from scouring pastures. Like the unripe wood of our fruit-trees, the unripe young clover-leaves and grass-shoots in our meadows are killed much more readily or changed in composition than the older and more matured portions of the herbage. But as the immature young leaves and grass-shoots only have medicinal effects, the pasture becomes either altogether sweet after the first autumnal frost, or the evil is seen in a much more mitigated form on land which scours during the summer months.

It now remains for me to point out how it is that scouring land frequently does not bring the herbage to a sufficient degree of maturity.

In the first place I would observe that lias-clays contain an excess of mineral food, and, being retentive even after draining, they also often contain a large quantity of water. The excess of water and coldness of the soil retard the early development of the herbage. The upland position of all hill-pastures, on which the evil generally preponderates, of course is also unfavourable to an early growth of the herbage. But, more than this, the peculiar tenacious character of the lias-clay subsoils on scouring land, the great depth of these clay-beds, and their near approach to the surface soil, tend to retard vegetation, and to make it very gradual during the colder and wetter months of the year. In many cases under-drainage, besides taking off the surface water, produces little alteration in the condition of the surface soil, for the simple reason that it is too thin, and the clay subsoil bed too tenacious and too deep to be penetrated by the ameliorating influence of the atmosphere.

During many months of the year such thin surface soils in hilly districts, after they have been drained, remain as cold and almost as wet as before. When the temperature of the air becomes more genial to vegetation, and the weather much drier than during the other and greater part of the year, the clay-land on the Polden Hills becomes sufficiently dry and warm to allow vegetation to make a start; and the abundance of mineral food in the land then rapidly pushes forward the herbage, and causes it to grow with much luxuriance, especially if the summer temperature is high, and just sufficient dew or gentle rain falls to keep the clay from cracking. On the hills, and on naturally cold, stiff land, this period of rapid growth takes place much later in the season than in less retentive and warmer soils. In districts where scouring prevails, the haymaking season is generally later than in other localities; but, although delayed, the grass-crop on the worst scouring meadows in most seasons does not quite sufficiently mature, and in consequence of the immature and green condition in which the grass is cut down, the hay scours.

Pastures which do not scour, though situated in the same district where scouring land abounds, either have a more porous subsoil or the blue lias-clay lies at a depth not reached by the roots of plants. On such land the herbage has a chance to make a start earlier in the season, and to grow more regularly and to get more readily matured than on scouring land.

Lias clay-land thus often scours, not because it is too poor or because it is too wet, or because it contains something or other inimical to vegetation—but because it is very abundant in plant-food; and, from the peculiar position of the subsoil on scouring land, its depth and impervious, highly tenacious character cause a too luxuriant growth of the herbage during the warmer summer months. Consumed in this condition the herbage is immature and scours, even when made into hay.

But should the summer be long and warm, and a farmer have the discretion to delay haymaking, he will find that scouring land will produce, in his case, good wholesome hay. In wet summers, and during the rainy part of the year, the evil ceases either altogether, or is much less aggravated than during the dry and warm summer months. This is perfectly intelligible, for it is during the warm and dry summer months that young immature clover-leaves and grass-shoots are most abundantly developed on scouring land. For the same reason the grass on water-weadows scours most during the summer months, and not during the winter and early part of the spring.

The preceding analytical proofs and agricultural facts warrant the conclusions that will be found in this paper. For the convenience of the readers the leading conclusions may here be briefly recapitulated :—

1. Lias-clay soils contain nothing injurious to vegetation.

2. These clays contain abundance of mineral plant-food.

3. The waters in the lias-formation are very hard ; many possess medicinal properties, and, no doubt, scour cattle that drink them.

4. In some exceptional instances land scours on account of being inefficiently drained.

5. In most cases, however, the evil can be traced directly to the immature condition in which the herbage is consumed by cattle on scouring land, or made into hay.

6. This immature condition of the herbage is most notable during the drier summer months, when the young herbage grows very luxuriantly.

7. The immature condition in which the herbage on scouring land is usually consumed, is principally caused by the peculiar character and relation of the subsoil to the surface-soil of scouring pastures.

8. No positive evidence exists, showing that the complaint is due to a particular species of herb.

A clear recognition of the causes which produce certain evils generally leads to some cure, or to means which are calculated to mitigate what cannot be cured. This report would not be complete if no allusion were made to the means at our command, either to cure scouring land or to mitigate the complaint to which cattle are subject on certain pastures. But as the report has become already more bulky than I intended to make it, the briefest allusions to this matter must suffice. I would therefore observe—

1. It is highly advisable to cut off the supply of hard lias-springs and to provide cattle with soft drinking water.

2. Rain-water tanks, for the supply of soft water, should be constructed in localities where cattle are obliged to drink hard waters that rise in the lias-clay.

3. In some, though I fear exceptional cases, more efficient drainage will mitigate the evil.

4. It is desirable to keep cattle from scouring pastures in

those months of the year when the young herbage appears very luxuriant.

5. The haymaking season on scouring pastures should be delayed as long as is possible in practice, in order to give the herbage a better chance of acquiring maturity.

6. There are, however, many scouring pastures on which neither drainage, nor any other available means will have any material effect in bringing the herbage to an earlier and better state of maturity; and as the unripe condition of the herbage is by far the most common proximate cause of the evil, the best thing perhaps that can be done with such pastures is to plough them up.

Royal Agricultural College, Cirencester,
Jan. 1862.

[NOTE.—I am of opinion, from what I have tried and observed on the "tart" lands at Pylle, where, I regret, the Professor has not made an inspection, that the plough is the true remedy, and all "tart" lands should be converted into arable lands. The clover-hay, the pasture on the clover-ley, and the roots fed by sheep on such land have no scouring properties; and, after a fair trial of some bad scouring lands, I have advised my tenant to break up and cultivate several scouring fields, which will, as I believe, be profitable instead of noxious land.—PORTMAN.]

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ON THE

COMPOSITION AND NUTRITIVE VALUE OF STRAW.

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COMPOSITION AND NUTRITIVE VALUE OF STRAW.

Both Mr. Mechi and Mr. Horsfall have done good service to agriculture by the publication of their experience in feeding and fattening cattle with food, a considerable portion of which consisted of straw-chaff. In whatever light Mr. Mechi's experience in fattening cattle or Mr. Horsfall's dairy management may be regarded, the merit cannot be denied to these gentlemen of having succeeded in directing the attention of the British farmer to the use of straw as an economical feeding-material.

Many farmers form much too low an estimate of the feeding value of every kind of straw, except pea-haulm. On the other hand, the views of others respecting the nutriment contained in straw are so unmistakeably exaggerated that, with some degree of justice, they are made a laughing-stock at the market-table. The main anxiety of the first-named class seems to be how to tread into manure all the straw grown on the farm; that of the second, how to stuff stock with all the straw at their disposal: the creed of the former being that neither little nor much will do their cattle any good, whilst the latter hold that any appropriation of it for litter is an intolerable waste.

The sober-minded, observant, and intelligent agriculturist, however, knows full well that whilst wheat, oat, and barley straw when cut into chaff possess a certain feeding value, particularly when this bulky material is combined with some concentrated or more readily digestible food, they are not the less essential on the generality of farms to the production of good farmyard manure. On most farms, indeed, the want of straw is felt much more on account of the difficulty of preserving the most valuable constituents of the liquid and solid excrements which arises from an insufficient supply of litter, than because an economical substitute for this kind of bulky food cannot be found.

Were it the object of this paper to discuss specially the use of straw as a manure, or rather a manure-producing and preserving agent, I might show that on most farms it is not only the cheapest but also the most efficient and valuable of the bulky materials at command for converting the excrementitious matters of our domestic animals into good yard-manure. But as I intend to direct the attention of the reader more particularly to the feeding properties of straw, I shall offer only a few observations on its manurial properties.

The intrinsic fertilising value of the straw of our cereal crops —that is, its fertilising value as far as this is dependent upon the presence of certain organic and mineral constituents—is, I conceive, very insignificant. Its chief merits are as an absorbent of the most valuable portions of the excrements of animals, and as the best fixer of the ammonia which is always generated when excrementitious matters in contact with porous materials and a sufficient quantity of moisture enter into active fermentation. The action of straw in fixing ammonia may be thus explained. During the fermentation of dung the woody fibre of straw is converted by degrees into ulmic, humic, and similar organic acids, which impart to liquid manure or to the drainings of dungheaps a more or less dark brown colour. The gradual resolution of the nitrogenised part of the excrements into ammoniacal compounds proceeds simultaneously with the formation of organic acids belonging to the humic acid series. All the acids of that series possess great affinity for ammonia, in virtue of which they unite with the ammonia of the volatile carbonate of ammonia, which, without the addition of a proper quantity of litter, would evaporate from a heap of fermenting excrements. Straw thus furnishes the raw material for the production of a number of organic acids, which, by laying hold of ammonia, preserve that most valuable constituent in our manure.

The indirect fertilising value which attaches to this important property of straw, in virtue of which rotten straw prevents the loss of ammonia in dungheaps, in my opinion, is far greater than its intrinsic manuring value, which is dependent upon the various small proportions of nitrogen, potash, phosphoric acid, silica, and other constituents which it contains. These constituents can, I believe, be supplied in various artificial manures and refuse materials, more economically than in straw. But I do not see clearly how the most valuable portion of the dung is to be preserved without straw, and how the comfort of cattle is to be secured without a sufficient quantity of litter, or what economical and available substitute can be found for straw applied as litter. I am therefore inclined to attach much more value to straw than most theoretical men, and yet can go a long way with those farmers who broadly and somewhat vaguely state that it is not manure but only litter.

As straw contains only from 14 to 17 per cent. of moisture, there is in it about as much solid matter as in meal and other kinds of dry food, although it is considered to be worth only from 20*s.* to 30*s.* per ton.

The bulk of straw, however, includes a large proportion of woody fibre, which, if digestible at all, is only partially assimilated in the system. Still, assuming that not more than one-third of the weight of straw is digested by cattle and probably less by horses and sheep, and granting that the assimilable part is not food of the most nutritious character, straw will still have to be regarded as a more economical feeding material than any other which can be supplied. It is undoubtedly a fact that some practical feeders are in the possession of the secret of converting considerable quantities of straw into beef. What this secret is, perhaps, is not known even to themselves. It may be that the combination in which straw is given, or the preparation to which it is submitted before it is placed in the feeding-troughs, has something to do with the success that attends its use; but it is yet more probable that on farms where straw is largely and economically cut into chaff and given to cattle, its condition, from early harvesting and other influences, is better than in other localities where the practice prevails of allowing corn to become over-ripe before it is cut. In consequence of this mischievous practice, straw gets more woody and less digestible than it would have been had the corn-crop been cut earlier. Further on several analyses will be given to show how much the composition and nutritive value of straw depend on the condition in which it is harvested. Indeed, the differences in the composition of somewhat under-ripe and over-ripe wheat or oat straw, are greater than the variations which may be noticed on comparing with each other the composition of wheat, oat, and barley straw. No very broad or permanent distinction, in fact, exists between wheat, oat, and barley straw. It would appear that in certain districts each variety in its turn becomes superior as food—each kind is preferred and exclusively retained for that purpose; whilst, in other districts, each is consumed for litter. Moreover, the natural preference shown by stock for one kind or the other affords a practical evidence that the farmer in each case may have a good reason for the choice which suits his locality. We must therefore always expect to meet with great diversity of opinion amongst practical men respecting the nutritive value of wheat, oat, and barley straw. That pea-haulm is too good to be trodden into manure is admitted by all. When properly got in, pea-straw is, indeed, a valuable feeding substance. With respect to the nutritive properties of bean-stalks, again, great diversity of opinion prevails—some considering them almost as nutritious as clover-hay, and others only fit for litter.

The ash or the inorganic part of many varieties of wheat, oat, and barley straw, as well as of bean and pea straw, has been carefully examined by different chemists. Whilst we have on record a large number of reliable ash-analyses, comparatively speaking few organic examinations of straw have been made. With but few exceptions the published organic analyses are not sufficiently explicit for practical purposes, and hence it is not surprising that men who base their opinion on such imperfect or partial analyses should make exaggerated statements respecting the high feeding value of straw. In most of these analyses we find the components grouped together in the following manner:—

1. Water.
2. Nitrogenised substances.
3. Non-nitrogenised substances.
4. Mineral substances (ash).

1. The amount of water in well-harvested straw when the corn is stacked varies from 25 to 36 per cent. After stacking a good deal of water evaporates, and the amount soon sinks to 16 or 18 per cent. Straw being a very hygroscopic substance is much damper in autumn and spring than in summer, or in a wet than in a dry month. I have found as little as 8 per cent. and as much as 19 per cent. of water in straw of the same kind taken at different times from the outside of the same stack. Making every allowance for variations depending upon the state of the atmosphere and on the age of the straw, 16 per cent. may be taken as fairly representing its average proportion of water.

2. The group of nitrogenised substances includes albumen and vegetable casein—two compounds soluble in water—and vegetable fibrin and other albuminous compounds, which are insoluble in water, but readily rendered soluble by weak alkaline solutions. All the nitrogenised compounds contain about 16 per cent. of nitrogen, and, besides carbon, oxygen, and hydrogen, small quantities of sulphur and phosphorus. They resemble each other so closely in composition and properties as to be scarcely distinguishable. As the type of this interesting class of compounds we may regard vegetable albumen—a substance analogous if not identical in properties and composition with the white of eggs. On account of the close resemblance of vegetable casein, fibrin, &c., to albumen, the compounds of this group are often called albuminous matter. By a simple chemical process all furnish a substance which its discoverer, Professor Mulder, named protein. According to this illustrious chemist, albuminous substances are combinations of protein with small quantities of sulphur and phosphorus, and hence they are termed frequently protein compounds. Not only are these vegetable substances nearly identical in composition and properties, but they likewise resemble so intimately animal casein, albumen, and fibrin, or those materials of which the flesh and blood of animals principally consist, that they have been called with

much propriety flesh or muscle forming principles. As the animal organism has not the power of constructing these combinations, so essential to the support of life, from other materials, although the latter may contain nitrogen, it is evident that all good vegetable food must contain a fair proportion of albuminous substances. Except in the case of pea-haulm, the proportion of albuminous matter in straw is not large. It varies considerably in straw of the same kind, according to the state of maturity in which corn is harvested, it being larger in straw not fully ripe. The average percentage cannot be precisely determined, but on the whole we may say that well-harvested straw of good feeding quality contains from 2 to 3 per cent., and inferior samples from 1½ to 1¾ per cent. of albuminous substances. In some cases the amount exceeds 3 and even 4 per cent.

3. The *non-nitrogenized substances* are as follows:—
   - *a.* Oil, fatty, and waxy matters, with more or less chlorophyle.
   - *b.* Sugar.
   - *c.* Gum and mucilage.
   - *d.* Extractive matters, and occasionally bitter principles.
   - *e.* Cellulose; and, lastly,
   - *f.* Woody fibre.

In some published analyses starch is mentioned as a constituent of straw, but this is a mistake. Neither the straw of our cereals nor that of peas or beans contains any starch—a fact which any one may readily ascertain if he will either apply tincture of iodine directly to a fragment of straw; or, better still, if he boil down a quantity with water and add a few drops of tincture of iodine to the perfectly cold and clean filtered decoction, when the non-appearance of the characteristic blue colour of iodide of starch will indicate the absence of every trace of starch.

It is much to be regretted that writers on agricultural matters, and even persons who by the public at large are considered scientific men, often employ distinct chemical terms in a very loose manner, and that they frequently leave the sure ground of ascertained facts, on which alone in chemistry opinions can be based, to launch into the realms of fancy and unauthorised assumption. When it is stated in many published analyses that straw contains some 15 to 20 per cent. of starch, the practical men experienced in the fattening properties of barley-meal and similar starch-containing food, on comparing that experience with the results obtained by straw-feeding, cannot but have their confidence in chemistry greatly shaken.

Again, misconceptions appear to exist in the minds of some of the advocates of straw as to the amount of fat and oil which it contains. These, together with a small quantity of wax and chlorophyle, seldom exceed 2 per cent., and are often less than 1 per cent. But it has been stated that straw contains as much as 20 per cent. of fat, from a confusion between fat and fat-forming matters—a term sometimes applied to the whole group of the non-nitrogenized substances. Such mistakes are often disseminated by non-scientific men, who meddle with subjects on which they are but imperfectly informed; in which case their theoretical deductions, resting on no sound basis, naturally do not tally with the observations of practical men. Due account being taken of the mischief which palpable errors in science produce in the popular mind, it becomes as much the duty of the scientific chemist to expose errors as to enrich our treasury of chemical knowledge by fresh discoveries.

Little need be said respecting the gum and mucilage in straw. Their proportion, though not large, is appreciable, especially in somewhat under-ripe samples, in which much more sugar is likewise found than in over-ripe samples. Indeed, in the latter the amount of sugar is scarcely appreciable.

Cellular or woody fibre constitutes the bulk of straw, being, of course, less valuable than any of the preceding constituents. The various non-nitrogenized substances which enter into the composition of straw contain, without exception, a large proportion of carbon, for which reason they are sometimes called carbonaceous matter. Their use in the animal economy is of a twofold character—either to supply the materials for the formation of animal fat, or to support respiration and consequently animal heat. These different carbonaceous substances are not, however, equally well adapted to either of these uses, and may be divided, according to the fitness and readiness with which they fulfil the one or the other function, into—

1. Fat-producing substances.
2. Heat-producing or respiratory substances.
3. Indigestible substances.

To the first belong the oil, fat, and waxy matter, which in straw, as already mentioned, seldom amount to much more than 1 per cent. Oily and fatty vegetable substances are eminently well adapted to the laying on of fat in animals, inasmuch as the composition of vegetable fat is analogous if not identical with the several kinds of fat found in the bodies of animals. The fatty matters of food, without undergoing much change, are therefore readily assimilated by the animal organism, and applied when given in excess to the storing up of animal fat. On the other hand, substances rich in starch are specially fitted to support respiration. Oily and fatty matters, however, when given with a scanty supply of starchy food, become available for the support of respiration; and again, gum, starch, and sugar, when given to fattening beasts in excess, are transformed into animal fat. There is thus no essential difference between the fatty or starchy constituents of food in so far as their uses are concerned, but each according to circumstances can lend itself to the work which is the more peculiar province of the other. The proportion of carbon in fatty matter amounts to rather more than 80 per cent., and is much larger than in gum, sugar, or starch. Oil and fat, for this reason, are not only better producers of fat than starchy and sugary compounds, but are likewise more powerful agents for the support of respiration and the maintenance of animal heat—the heat generated in the body being proportionate to the amount of carbon consumed in a given time during respiration. Gum, sugar, mucilage, starch, and a few similar compounds may be represented as consisting of carbon and water only, and on account of the simplicity of their composition they are well adapted to support respiration. The quantity of carbon consumed by the respiration of animals varies at different times and in different species, according to the rapidity of their breathing and their mode of living. Under all circumstances, however, it is considerable, especially in the case of ruminating animals. Thus cows consume four-ninths of the carbon contained in their ordinary daily food by respiration, and throw it off in their exhalations in the form of carbonic-acid gas. Hence the absolute necessity of supplying large-sized animals with abundance of carbonaceous food.

As straw contains no starch and but a small proportion of gum, mucilage, and sugar, and thus is deficient in the better kinds of respiratory constituents, it cannot rank high as a heat-producing material, unless it can be shown that cellular and woody fibre can be assimilated and used for the same purpose for which starchy compounds are usually employed in the animal economy.

The question then arises—and it is an important one—is cellular or woody fibre digestible or not? and upon a correct and trustworthy answer to this question mainly depends the decision whether or not straw is really as nutritious as some maintain. To arrive at as trustworthy a reply to this question as can be given in our present state of knowledge, we have to inquire, in the first place, what is understood by woody fibre?

If any vegetable substance—straw, for instance—is treated successively with cold and boiling water, next with alcohol and ether, then with a dilute solution of caustic potash, and finally with dilute sulphuric acid, an insoluble residue is obtained, differing in quality and texture according to the original material used in the experiment. This insoluble residue is called by chemists indiscriminately cellular or woody fibre. It is in reality generally a mixture of cellulose, the substance of which the walls of the cells of plants consist, and of woody substances which are deposited around the original cell-walls. These woody substances—"incrusting matter," as they are called by vegetable physiologists—constitute the true wood or woody fibre of plants. In their composition they closely resemble cellulose, which is more abundant in young plants than in those of more advanced growth. The older and harder the plant, the more woody or incrusting matter it contains. In green herbage, the insoluble residue which is obtained by the above-mentioned treatment chiefly consists of cellulose or cellular fibre; whilst in fully matured and over-ripe herbs, this insoluble residue principally consists of incrusting matter or true wood. In intermediate stages between a green, succulent condition and a dry, hard, fully matured stage of growth, we obtain variable mixtures of cellulose and woody fibre. The same process, it will be noticed, which is employed for preparing woody fibre, likewise furnishes cellulose. Unfortunately we possess no means of separating the two from each other, and hence the chemical processes by which the woody and cellular fibre in plants is determined in our laboratories are not calculated to give us more than at the best a very crude idea of the true character of the insoluble matter which constitutes the bulk of straw. No difficulty is experienced in determining with precision the amount of starch or sugar in a plant, but when we attempt to ascertain in two or three separate portions the amount of woody fibre in each, it is next to impossible to obtain corresponding results. But although we speak of cellulose and of woody fibre as of two separate and distinguishable substances which exist in plants under conditions as variable in texture and other physical peculiarities as in their physiological effect upon the animal, the chemist is not in a position to distinguish the one from the other by means of analysis; and it should be remembered that the physical and chemical properties and general character of many organic bodies are often extremely different, whilst their chemical composition is precisely the same. The mere composition of cellulose or woody fibre, therefore, does not afford a sufficient insight into their true character, and leaves altogether untouched the question whether these substances are digestible or not.

As long as we are unacquainted with more perfect analytical methods, we cannot expect to ascertain by analysis whether cellular and woody fibre is digestible, wholly or in part, and to what extent. Here, as in so many other matters which have scarcely been touched upon by scientific men, the agriculturist must be guided by his own experience, and not by the rash counsels and exaggerated statements of theorists, who are incompetent to form a sober and unbiassed opinion on a moot question. We know, indeed, that the condition of the woody fibre affects the nutritive value of all food in no mean degree. Whilst in root-crops left too long growing on the land, or the fibre of grass and clover left standing until dead-ripe, these tissues are not readily digested, there can be no doubt that the soft fibre of young grass, clover, and roots is readily assimilated in the animal organism, and transformed into starch, sugar, and finally into fat. For this reason grain-crops, more especially oats, when harvested early, produce straw which is greatly more nutritious than that of an over-ripe crop. In some parts of Scotland it is customary to cut the oat when the top of the haulm is still quite green; and it is upon straw of that description that store cattle are kept during the winter almost entirely. The variable condition in which grain-crops, as well as peas and beans, are harvested in England, fully explains the various shades of opinion which are entertained by practical men respecting the feeding properties of the straw of these crops, and the contradictory statements of writers on this subject.

For the same reason the *practical* solution of the question whether woody fibre is digestible or not, is surrounded by peculiar difficulties. Taking experience for our guide, it may be answered with equal truth in the affirmative or in the negative; for in a young, tender condition we know from experience that cellular and woody fibre is digestible, whilst in a hard, dry, over-ripe state it is for the most part indigestible. Direct feeding experiments, highly desirable though they may be, will leave much uncertainty, however carefully they have been made, unless special regard is paid to the condition in which the straw is given to the animals; and after all, as it is not possible to describe with absolute precision its state of maturity and condition, no practical feeding experiment, be it ever so carefully conducted, can afford absolute numerical results, indicative of the extent to which the woody fibre is digestible in all, or even the majority, of instances.

Feeding experiments instituted for the purpose of ascertaining to what extent the woody fibre of food is assimilated in the animal organism are highly desirable, but at the same time they are most laborious and costly. They require to be undertaken on a tolerably large scale, and cannot well be executed by a practical farmer, for want of scientific appliances, nor even by an agricultural chemist, who cannot specially provide all the expensive arrangements and command all the assistance necessary to render chemico-physiological experiments applied to agriculture thoroughly satisfactory. A further difficulty arises from the fact that the same description of food which is assimilated in a great measure by one kind of animal often remains to a much greater extent undigested when given to another. Thus it has been proved by direct experiments that cows can extract a great deal more nourishment from straw-chaff than horses, and that sheep do not appear to digest chaff so readily as cattle.

Although chemical analysis cannot decide with anything like precision the most interesting and practically important point on which the whole controversy of the feeding value of straw hinges, we must not suppose that it is altogether useless to submit to analysis the various kinds of straw used on the farm. I hope to be able to show that the investigation undertaken by me at the request of the Chemical Committee of the Royal Agricultural Society has brought to light several matters of considerable practical importance, and is suggestive of others of interest. The following points, at all events, can be readily ascertained. In the first place, we can determine with precision the amount of oil, certainly the most valuable constituent of straw; secondly, the proportion of albuminous or flesh-forming matters; and thirdly, the amount of organic substances soluble in water, such as sugar, mucilage, gum, extractive matters, &c. The mineral portion or ash, of course, is easily ascertained by burning a known quantity of straw in a platinum capsule, and weighing the ash which remains behind.

The proportion of oil is easily obtained by exhausting a weighed quantity of straw in an appropriate apparatus with ether, and evaporating the ethereal solution of oil to dryness. Albuminous compounds are now usually determined in the indirect manner by combustion with soda-lime, and multiplication of the percentage of nitrogen by 6¼. A weighed quantity, exhausted with cold and afterwards with boiling water, produces the proportion of soluble matter, consisting of sugar, mucilage, extractive matter, and soluble saline matters. If the portion of straw previously exhausted with ether and water is subsequently boiled with a solution containing 1 per cent. of caustic potash, the insoluble albuminous compounds are dissolved; and by treating the residue left after boiling with potash-solution, with dilute sulphuric acid, and finally washing again with water, we obtain the amount of cellular and woody fibre in the straw.

It has been stated already that this process does not furnish corresponding results in two or three separate determinations. Nevertheless it is desirable in detailed analyses to have recourse to this process, which at least allows us to form some idea of the readiness with which the part of straw which is insoluble in water, and which may be termed crude woody fibre, is attacked by dilute alkalies and acids. There can be no doubt that the different alkaline and acid secretions in the animal organism exercise similar, probably even more energetic effects, than this upon the crude woody fibre. The treatment with dilute alkalies and acids, therefore, affords a better insight into the digestibility of the bulk of straw than the mere exhaustion with water.

At the same time, however, it may be noticed that the method of Sinclair, who endeavoured to determine the nutritive value of different grasses by ascertaining the proportion of matters soluble in water, furnishes comparative results which enable us to form a tolerable good opinion of the feeding value of straw. Indeed I find that the more nutritious samples invariably produce the largest amount of watery extract.

In many of the published analyses nothing more than moisture, ash, and albuminous compounds are determined; all the rest is arrived at by difference. It is evident that such imperfect analyses must lead to practical errors; for in these analyses oil, sugar, and other soluble matters are thrown together with crude woody fibre, and the whole group is said to consist of fat and respiratory constituents, although only a portion of the whole exists in reality in a condition in which it can be assimilated by animals.

WHEAT-STRAW.

The following results were obtained on analysing a sample of well-harvested wheat-straw, which was neither under nor over ripe:—

General Composition.

Water	13·33
Soluble organic matters	5·54
Soluble inorganic matters	1·13
Insoluble organic matters	76·92
Insoluble mineral matters	3·08
	100·00

Detailed Composition.

Water	13·33
Oil	1·74
*Albumen and other soluble protein compounds	1·28
Sugar, mucilage, extractive matters, &c. (soluble in water)	4·26
Digestible fibre, &c.	19·40
Soluble inorganic matter	1·13
†Insoluble protein compounds	1·65
Indigestible woody fibre	54·13
Insoluble inorganic matter	3·08
	100·00
*Containing nitrogen	·206
†Containing nitrogen	·264
Total percentage of nitrogen	·470
Equal to protein compounds	2·93
Total ash	4·21

A glance at these analytical results will show that hard and dry as wheat-straw appears to be, this sample, nevertheless, yielded no less than 5½ per cent. of organic matters to cold and boiling water. The portion insoluble in water, or th crude woody fibre, amounted to exactly 80 per cent.; a very large quantity—of which, however, when treated with dilute caustic potash, and afterwards with dilute sulphuric acid, nearly 20 per cent. was rendered soluble. The portion thus rendered soluble is described in the preceding and following analyses as digestible fibre. After the separation of the insoluble albuminous compounds, mineral matters, oil, and digestible fibre, the proportion of woody matters, as given in the detailed composition, amounted to 54 per cent. in round numbers. This is described as indigestible woody fibre, but it is quite possible that a considerable portion of it may be assimilated in the animal organism. At any rate it is an interesting fact that a substance so dry and unpromising-looking as straw, yielded to water and dilute alkaline and acid liquid nearly one-half of its weight.

Another point of interest is the appreciable quantity of oil; it is a nice yellow, sweet-tasting oil, which no doubt renders straw more palatable, to a certain extent more digestible, and certainly more nutritious than it would be without this constituent. In the instance before us we have 1¾ per cent. of oil; a ton of straw accordingly contains 39 lbs. of oil.

Again, attention may be directed to the albuminous compounds, which amount to 3 per cent. in round numbers. It will be seen that rather more than one-half of these compounds is insoluble, and the rest soluble in water.

On the whole, wheat-straw having a composition similar to the sample analysed by me is nutritious, and when cut into chaff may be used with advantage as a feeding material. Several partial analyses of other specimens have shown me that this and other kinds of straw vary exceedingly in composition, and consequently also in quality.

That the composition of the straw is, indeed, influenced by the degree of maturity in which the corn is harvested, will appear clearly on comparison of the following analytical results, obtained on the examination of two samples of wheat-straw, the one fairly ripe, the other over-ripe:—

General Composition of Wheat-straw.

	Ripe.	Over-ripe.
Water	8·14	9·17
Substances soluble in water	8·77	4·81
Substances insoluble in water	83·09	86·02
	100·00	100·00

Detailed Composition.

Water	8·14	9·17
Oil	1·10	·65
*Soluble protein compounds	·50	·06
†Insoluble protein compounds	1·62	2·06
Gum, sugar, and extractive matters	6·28	3·46
Crude woody fibre	79·31	82·26
Soluble mineral matters	1·99	1·29
Insoluble mineral matters	1·06	1·05
	100·00	100·00
*Containing nitrogen	·08	·01
†Containing nitrogen	·26	·33
Total percentage of nitrogen	·34	·34
Equal to protein compounds (flesh-forming matters)	2·12	2·12
Percentage of ash	3·05	2·34

In explanation of these results, it is necessary to state that both samples were kept in a warm room for some days before they were analysed, which accounts for the small percentage of moisture found in them. The principal points of interest to be remarked are—1st, the greater amount of sugar, gum, and extractive matters (nearly twofold); next, the greater amount of oil; and lastly, the smaller proportion of woody fibre found in the fairly-ripe sample as compared with that which was over-ripe, by which the superiority of the former as feeding material is sufficiently proved. Indeed, whereas the former is nutritious and well fitted for cutting into chaff and mixing with sliced or pulped roots, the over-ripe sample is hardly suited for feeding purposes, and should be trodden into manure.

A striking difference will be noticed in the relative proportions of soluble and insoluble albuminous compounds in the fairly-ripe and in the over-ripe specimens; in the latter there is scarcely any soluble albuminous matter, nearly the whole having become insoluble. In both samples the total amount of albuminous or flesh-forming compounds is smaller than that given in the preceding full analysis of another sample. The percentage of ash in both these last specimens is unusually low.

The ashes of several varieties of wheat-straw have been analysed by Messrs. Way and Ogston, who give as the mean result of ten analyses the following numbers:—

Potash	12·14
Soda	·60
Magnesia	2·74
Lime	6·23
Phosphoric acid	5·43
Sulphuric acid	3·88
Silica	67·88
Peroxide of iron	·74
Chloride of sodium	·22
	99·86

The ash of wheat-straw, it will be seen, is very rich in silica—a constituent found in the straw of all cereals in preponderating proportions. The amount of phosphoric acid and of potash is not large. The percentage of ash in wheat-straw varies exceedingly; on an average it amounts to about 4½ per cent., but I have found it as low as 2½ per cent. When I first met with this small percentage I took the precaution of repeating the determination, and obtained from each trial closely agreeing results. It is worthy of remark that the straw in question was by no means weak, but as stiff as could be desired. It may therefore be doubted whether the weakness of straw arises, as is generally assumed, from a deficiency of mineral matter, more especially of silica.

This is a subject well deserving further investigation, which I hope to take up at a future period. But whilst reserving for future discussion the causes of weakness of straw, I cannot refrain from stating in passing that I have never met with a single instance in which the application of silicate of soda to wheat has had the slightest effect upon the crop; and that therefore, as far as my practical experience extends, I am bound to say that silicate of soda does not answer the purpose for which its use has been suggested, viz., that of strengthening the straw of wheat, oats, and barley.

WHEAT-STUBBLE.

Although wheat-stubble is not used for feeding purposes, its analysis may here find a place, for it may be useful to compare the composition of stubble with that of wheat-straw.

The sample from which the following analysis was made was gathered on a dry day in the middle of December, from a field of the College Farm, Cirencester. Examined directly afterwards it was found to contain 17½ per cent. of moisture, and was thus drier than wheat-straw before stacking. This stubble contained in 100 parts:—

General Composition.

Moisture	17·66
Substances soluble in water	5·83
Substances insoluble in water	76·51
	100·00

Detailed Composition.

Water	17·66
Oil	·42
*Albuminous compounds	2·94
Extractive matters (soluble in water)	5·01
Crude woody fibre	71·04
Mineral matters (ash)	2·93
	100·00
*Containing nitrogen	·47

Stubble, then, contains as much nitrogenized matters as straw, which it closely resembles in other particulars, the chief difference being its somewhat smaller proportion of oil.

It has been stated by practical men that stubble has no direct value as a manure, and not much as litter. If this be so, it follows inevitably that wheat-straw has no *direct* value as a manure, for both straw and stubble contain as nearly as possible the same proportions of nitrogenized and carbonaceous and mineral matters.

BARLEY-STRAW.

Barley, especially if good malting barley, is generally allowed to turn more yellow in the field than any other grain-crop. The barley-straw on our farms, therefore, is seldom so nutritious as it might be, if the crop were cut down in a less advanced stage of maturity. The following analysis was made of barley-straw, which I am inclined to term dead-ripe, although it is the usual condition in which it is seen in our neighbourhood:—

General Composition.

Water	15·20
Soluble organic matter	2·92
Soluble inorganic matter	2·88
Insoluble organic matter	77·62
Insoluble mineral matter	1·38
	100·00

Detailed Composition.

Water	15·20
Oil	1·36
*Albumen and other soluble protein compounds	·68
Sugar, mucilage, extractive matters, &c. (soluble in water)	2·24
Digestible fibre, &c.	5·97
Soluble inorganic matter	2·88
†Insoluble protein compounds	3·75
Indigestible woody fibre	66·54
Insoluble inorganic matter	1·38
	100·00

*Containing nitrogen	·11
†Containing nitrogen	·60
Total percentage of nitrogen	·71
Equal to protein compounds	4·43
Total percentage of ash	4·26

These results suggest one or two remarks.

In the first place: That the appreciable quantity of oil contained in barley, as in wheat-straw, must contribute to its nutritive value.

Secondly: That the amount of sugar, gum, and other soluble matters in this sample is very small indeed. This I find always to be the case, not only with this, but with other kinds of over-ripe straw.

Thirdly: That this specimen contained a good deal more indigestible woody fibre than wheat-straw, to which it is altogether inferior in feeding qualities. Barley-straw is usually considered superior to wheat-straw as a feeding substance, but the preceding analyses show plainly that this opinion does not hold good in every instance.

Fourthly: It is worthy of special notice that the part of barley-straw which is insoluble in water, or the crude fibre, on treatment with dilute caustic-potash solution and dilute sulphuric acid, is diminished in quantity to a much smaller extent than the wheat-straw which I submitted to the same process. Whereas these re-agents extracted in round numbers 20 per cent. of digestible fibre from wheat-straw, they furnished not more than 6 per cent. in the case of barley-straw. I do not think, however, that in the latter straw there is anything of a peculiarly hard nature which protects it from the action of these solvents; but that the difference in this respect is due entirely to the over-ripe condition of the barley-straw and the better condition in which the wheat-straw was examined. Reverse the condition of the two kinds of straw, and it will be more than probable that opposite results will be obtained.

Lastly: It may be remarked that the proportion of flesh-forming matters in the specimen analysed is considerable, and larger than in wheat-straw.

Barley-straw yields, when burnt, on an average from 4 to 5 per cent. of mineral matters thus combined.

Average Composition of the Ashes of Barley-straw reduced from Three Samples.

Potash	18·40
Soda	·68
Magnesia	4·13
Lime	8·08
Phosphoric acid	3·26
Sulphuric acid	2·13
Silica	54·56
Peroxide of iron	1·81
Chloride of sodium	6·95
	100·00

In contrast with the preceding analysis of over-ripe barley-straw, I will now mention the results obtained on analysing a fairly-ripe specimen grown on our farm last season.

Barley-Straw (not too ripe) taken from Farm Buildings, October 31.

General Composition.

Water	17·50
Substances soluble in water	12·40
Substances insoluble in water	70·10
	100·00

Detailed Composition.

Water	17·50
Oil	1·17
*Albuminous compounds	5·37
Mucilage, sugar, extractive matters, and cellular fibre	71·44
Mineral matters	4·52
	100·00
*Containing nitrogen	·86

In this analysis it will be seen no less than 12½ per cent. of matters soluble in water, and containing a good deal of sugar, were obtained, thus showing plainly to what extent the solubility, and with it no doubt the digestibility, of different samples may vary.

Let it be remembered that the analyses were not made with picked samples, but with samples such as I found them in the rick-yard on our farm. The inferior and over-ripe sample was grown in 1860, the other in 1861. Now any farmer who, with a view to testing practically the nutritive quality of barley-straw, tried feeding experiments in 1860, would have found that it was very poor stuff, hardly fit for food; whilst in 1861 the same kind of straw would have given most satisfactory results. Thus it happens that the same kind of straw is denounced by one man as only fit for the dungheap, and by another elevated to almost equal rank with hay.

In my opinion barley-straw, not too ripe, is nearly equal to oat-straw reaped in the same state of maturity, and superior to wheat. It is usually richer in albuminous compounds than wheat-straw, although the larger proportion of albuminous matters found in barley-straw is in part due to some clover and grass which gets mixed up with the barley-crop. Barley-straw then should not be wasted as litter, but given to cattle, especially young stock, both on account of its softer texture and its larger proportion of nitrogenised matter, with which young growing stock require to be more liberally supplied than fatting beasts.

OAT-STRAW.

A specimen of oat-straw, grown in 1860, was submitted to a complete analysis, and furnished the following results:—

General Composition.

Water	13·70
Soluble organic matter	8·04
Soluble inorganic matter	2·76
Insoluble organic matter	72·84
Insoluble mineral matter	2·66
	100·00

Detailed Composition.

Water	13·70
Oil	1·69
*Albumen and other soluble protein compounds	·44
Mucilage, extractive matters (soluble in water)	7·60
Digestible fibre, &c.	29·27
Soluble inorganic matter	2·76
†Insoluble protein compounds	2·31
Indigestible woody fibre	39·57
Insoluble inorganic matter	2·66
	100·00
*Containing nitrogen	·07
†Containing nitrogen	·37
Total percentage of nitrogen	·44
Equal to protein compounds	2·75
Total ash	5·42

On burning, oat-straw leaves on an average 5 to 5½ per cent. of ash, which has the following composition:—

Ash of Oat-straw.

Potash	19·14
Soda	9·69
Magnesia	3·78
Lime	8·07
Phosphoric acid	2·56
Sulphuric acid	3·26
Silica	48·42
Peroxide of iron	1·83
Chloride of sodium	3·25
	100·00

Like all the ashes of the straw of cereal crops, oat-straw contains a large proportion of silica, and but little phosphoric acid.

It will be seen that oat-straw contains about as much oil, and the same proportion of albuminous compounds, as wheat-straw. There are, however, some remarkable differences between them; for in oat-straw—at least in the specimen analysed—there is much more sugar and other soluble matter than in wheat-straw. It likewise appears that the crude woody fibre of the former is more easily attacked by dilute alkalies and acids; so that by this treatment 29 per cent. of digestible fibre was obtained, and the indigestible fibre was reduced to 30½ per cent; whilst in wheat-straw no less than 54 per cent. of woody fibre was found to be indigestible. It may be safely inferred from this that oat-straw is assimilated by animals to a larger extent than wheat-straw; and as it contains moreover more sugar and mucilage than the latter, and as much oil and albuminous matter, the specimen analysed by me is decidedly more nutritious than the sample of wheat-straw which I analysed. In all probability the difference is due to the fact that oats, on account of the readiness with which they shed the grain, are generally reaped in a less matured condition than wheat.

Another sample of oat-straw, grown in 1861, submitted to a less complete analysis, furnished the following results:—

Oat-straw from Farm-buildings.

General Composition.

Water	19·50
Substances soluble in water	10·85
Substances insoluble in water	69·65
	100·00

Detailed Composition.

Water	19·50
Oil	1·54
*Protein compounds	2·75
Mucilage, sugar, cellular fibre, &c.	71·39
Mineral matters (ash)	4·82
	100·00
*Containing nitrogen	·44

These results agree perfectly with the preceding in regard to the proportion of oil and albuminous matter, and tolerably well in the amount of substances soluble in water.

Having found that the nutritive properties of straw are greatly affected by the state of maturity at which the crop is harvested, and come to the conclusion that it is very desirable to reap oats in a somewhat green condition, I took an opportunity carefully to investigate the nature of the differences which are exhibited by oat-straw in a green, in a fairly ripe, and in an over-ripe condition. In 1860 it will be remembered that our grain crops ripened rather unequally. This circumstance enabled me to examine oat-straw in both a green and a fairly ripe condition. In that year Mr. Coleman, Professor of Agriculture in the Royal Agricultural College, Cirencester, thought it desirable to begin the oat-harvest, whilst the straw was yet somewhat green, inasmuch as the oat-field was large, and this crop, when too ripe, is very apt to shed its seed. This field was reaped on the 20th of August, and on that day I selected some of the oats in a still somewhat green condition, and likewise some in a fairly ripe state. In the green oat-straw, examined directly after the crop was cut down, I found as much as 77 per cent. of moisture; and in the fairly ripe sample, gathered on the same day, 46½ per cent. in round numbers. In perfectly ripe straw, taken directly from the field, the proportion of moisture amounts to 30 to 40 per cent.

Both samples were submitted to complete analysis. The first—that is, the straw which was somewhat green throughout its length, and decidedly so in the upper portion, yielded the following results:—

Oat-straw (Green).

General Composition.

Water	77·14
Soluble organic matter	6·29
Soluble mineral matter	1·59
Insoluble organic matter	14·72
Insoluble mineral matter	·26
	100·00

Detailed Composition.

Water	77·14
Oil	·43
*Soluble protein compounds	1·50
Sugar, gum, mucilage	4·36
Digestible fibre	7·17
†Insoluble protein compounds	·81
Indigestible woody fibre	6·76
Soluble mineral matter	1·57
Insoluble mineral matter	·26
	100·00
*Containing nitrogen	·24
†Containing nitrogen	·13
Total percentage of nitrogen	·37
Total percentage of ash	1·85

Notwithstanding the large quantity of moisture in this sample, a very considerable amount of sugar and other substances soluble in water was obtained, and nearly as much albuminous matter as in ripe oat-straw, with only 14 per cent. of moisture. The fairly ripe sample gave the following results:—

Oat-straw (fairly ripe).

Water	46·64
Soluble organic matter	9·06
Soluble mineral matter	2·30
Insoluble organic matter	40·28
Insoluble mineral matter	1·72
	100·00

Water	46·64
Oil	·67
*Soluble protein compounds	1·67
Sugar, gum, mucilage	6·72
Digestible fibre	19·17
†Insoluble protein compounds	·93
Indigestible woody fibre	20·18
Soluble mineral matter	2·30
Insoluble mineral matter	1·72
	100·00
*Containing nitrogen	·26
†Containing nitrogen	·15
Total percentage of nitrogen	·41
Total percentage of ash	4·02

The great difference in the proportions of water in these two samples makes it difficult to compare these analytical results with each other. Deferring for the present such a comparison, I will now give the analysis of a third specimen taken from a portion of the crop of the same field, which was left standing until the 20th of September, or just one month longer, when, as might have been expected, the straw was over-ripe.

Oat-straw (over-ripe).

General Composition.

Water	35·20
Soluble organic matter	4·42
Soluble mineral matter	1·75
Insoluble organic matter	55·48
Insoluble mineral matter	3·15
	100·00

Detailed Composition.

Water	35·20
Oil	·97
*Soluble protein compounds	1·00
Sugar, gum, mucilage, &c.	2·45
Digestible fibre	21·41
†Insoluble protein compounds	1·81
Indigestible woody fibre	32·26
Soluble mineral matter	1·75
Insoluble mineral matter	3·15
	100·00
*Containing nitrogen	·16
†Containing nitrogen	·29
Total percentage of nitrogen	·45
Total percentage of ash	4·90

When taken from the field, even in an over-ripe state, straw, it will be seen, contains rather more than one-third of its weight of water. The preceding analyses are interesting in several respects. They have a direct practical bearing, which, however, will become more manifest when the proportion of moisture is become the same in each sample—or, in other words, when we examine the three samples after having been stacked for some time. In this state straw contains on an average 16 per cent. of moisture. In the following table I have, therefore, calculated the composition of these three samples with 16 per cent. moisture, and have likewise given the composition of each in a perfectly dry state (dried at 212°):—

Table showing the Estimated Composition when Dried.

	Oat-straw cut in Green Condition, Harvested on the 20th of Aug., 1860.		Oat-straw cut when Fairly Ripe, Harvested on the 20th of Aug., 1860.		Oat-straw cut when Over-Ripe, Harvested on the 20th of Sept., 1860.	
	Calculated Dry.	Calculated to contain 16 per cent. of Moisture.	Calculated Dry.	Calculated to contain 16 per cent. of Moisture.	Calculated Dry.	Calculated to contain 16 per cent. of Moisture.
GENERAL COMPOSITION.						
Water	..	16·00	..	16·00	..	16·00
Soluble organic matter	27·52	23·12	16·97	14·25	6·82	5·72
Soluble mineral matter	6·95	5·84	4·32	3·63	2·71	2·27
Insoluble organic matter	64·39	54·09	75·48	63·41	85·61	71·92
Insoluble mineral matter ..	1·14	·95	3·23	2·71	4·86	4·09
	100·00	100·00	100·00	100·00	100·00	100·00
DETAILED COMPOSITION.						
Water	..	16·00	..	16·00	..	16·00
Oil	1·88	1·57	1·25	1·05	1·49	1·25
*Soluble protein compounds ..	6·56	5·51	3·13	2·62	1·54	1·29
Sugar, gum, mucilage, and extractive matters	19·08	16·04	12·59	10·57	3·79	3·19
Digestible fibre	31·36	26·34	35·94	30·17	33·04	27·75
†Insoluble protein compounds ..	3·54	2·98	1·74	1·46	2·79	2·36
Indigestible woody fibre	29·57	24·86	37·81	31·78	49·78	41·82
Soluble mineral matters	6·88	5·76	4·32	3·64	2·71	2·26
Insoluble mineral matters ..	1·13	·94	3·22	2·71	4·86	4·08
	100·00	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	1·05	·88	·48	·40	·24	·20
†Containing nitrogen	·57	·47	·28	·23	·44	·36
Total percentage of nitrogen ..	1·62	1·35	·76	·63	·68	·56
Equal to protein compounds ..	10·10	8·49	4·87	4·08	4·33	3·65
Percentage of ash	7·09	6·79	7·55	6·34	7·57	6·36

The attentive perusal of these analytical results suggests the following observations:—

1. In the first place, the large proportion of albuminous compounds in green oat-straw deserves to be specially noticed: it is as large in amount as occurs on an average in ordinary meadow-

hay. Oat-straw, so harvested, ought therefore to be as useful in repairing the waste of muscle of working oxen and horses as common hay. It is indeed much relished by animals, especially by working horses, who have good reasons for their predilection, one no doubt being the larger proportion of flesh-forming matters that it contains, and another probably its more succulent and palatable condition.

2. The greater proportion of the albuminous or protein compounds exists in the green straw in a condition in which they are soluble in water, and therefore in all probability more easily digested than they are in an insoluble state.

3. Towards maturity the amount of albuminous and nitrogenised compounds dwindles down to about one-half. Thus, whilst green straw contains $8\frac{1}{2}$ per cent. of nitrogenised matters, that which is fairly ripe contains only 4 per cent. The soluble and insoluble protein compounds likewise appear to diminish at precisely the same rate.

In green straw we have, in round numbers, $5\frac{1}{2}$ per cent. of soluble nitrogenized matters against 2·6 per cent. in the fairly ripe sample, and 3 per cent. of insoluble protein compounds against $1\frac{1}{2}$ per cent.

The question arises, what becomes of all the nitrogenised matter, which disappears with extreme rapidity when our cereal crops arrive at maturity? Although I have not made any special experiments with a view of ascertaining this point, it does not appear to me likely that this matter is all stored up in the grain; and I have not much doubt that, as observed by Messrs. Lawes and Gilbert, a considerable loss of nitrogen takes place in the growth of corn-crops, which loss is particularly noticeable when the crop arrives at maturity.

4. In over-ripe oat-straw a still further, though inconsiderable, diminution of nitrogenised matters took place. But whereas, in the two other samples, the soluble nitrogenised matter greatly preponderates over the insoluble, the reverse is the case in the over-ripe specimen. In this sample it will be seen that the insoluble protein compounds amount to $2\frac{4}{10}$ per cent, and the soluble to only $1\frac{8}{10}$ per cent.

Over-ripe straw then is not only absolutely poorer in albuminous or flesh-forming matters than fairly ripe samples, but it likewise contains these important constituents in a less soluble, and therefore less digestible, form.

5. The proportions of oil in the three samples differ but little.

6. Of sugar, gum, and other matters soluble in water, not less than 16 per cent. occurs in the green straw, as against 3 per cent. in the over-ripe straw. In the fairly ripe sample $10\frac{1}{2}$ per cent.

of sugar, gum, &c., were found, or a proportion which exceeds that given in the first analysis by 3 per cent. According to the state of maturity, I thus found in four samples of oat-straw the following proportions of sugar and other soluble matters: 1st sample, 16 per cent.; 2nd sample, 10½ per cent.; 3rd sample, 7½ per cent.; 4th sample, 3 per cent.

Of all the constituents except oil, I consider sugar and other soluble matters by far the most valuable. Quite apart from the larger proportion of albuminous matter, green oat-straw will be found much more nutritious and palatable than fully ripe samples, because it is more succulent, and contains a great deal more sugar and other readily digestible matters.

The longer the oat-crop is left in the field, the more the proportion of sugar and other soluble organic matters diminishes, and with it its nutritive value. Hence it is bad policy to let this crop become too ripe before cutting it down. The loss in nutritive substances in that case is much more considerable than most farmers believe. Practical men, therefore, cannot be too strongly urged to cut their oat-crop before it turns quite yellow, both for the sake of the grain, which is so easily shed, and of the straw, which is so rapidly deteriorated. As soon as the haulm of oats begins to turn yellow, in about two-thirds its length, though the tops be still decidedly green, the harvest should be begun. I have had opportunities of observing over and over again that a larger yield of corn and a better sample will thus be obtained, as well as a far more nutritious straw. The deterioration in the quality of the straw and corn in warm seasons takes place so rapidly that it makes a great practical difference whether the harvest is begun a week sooner or later.

7. In the less succulent samples a larger proportion of indigestible woody fibre may naturally be expected. That it exists, this series of analyses places beyond a doubt; for whilst the green sample contained only 25 per cent. of indigestible woody fibre, the fairly ripe contained 32, and the over-ripe 42 per cent. in round numbers.

Every feeder of stock knows that hard woody matter is not easily, if at all, digested, and that sweet-tasting, succulent food containing much sugar is very fattening. It must, therefore, be his interest to prevent as much as is possible the conversion of sugar into woody fibre. Where oats are grown for home consumption, I am not at all sure that it is not more advantageous to cut down the crop when the seed is fully formed, but still milky, and the straw is still green, and to make the whole into hay, than to let the crop get ripe, and afterwards to thresh out the corn. I am inclined to think an acre of oats made into hay will furnish more nutriment to horses, which are very fond of oat-hay, than when harvested in the usual way. A good deal of expense incurred in threshing the crop and cutting it into chaff would be saved were this plan adopted.

8. We see that the crude woody fibre of oat-straw is rendered soluble to a considerable extent by dilute alkaline and acid liquids. Indeed it appears to be more easily acted upon by these solvents than that of wheat-straw; and the preference given to oat-straw as a feeding material may be partly due to this circumstance.

9. The proportions of mineral matters here exhibited do not greatly vary; but there is a material difference in the *qualitative* composition of the ash. In the green sample nearly 6 per cent. of soluble ash-constituents, and only 1 per cent. of insoluble mineral matters, exist; whilst the fairly ripe contains $3\frac{6}{10}$ of soluble, and $2\frac{7}{10}$ of insoluble, mineral matters, and the over-ripe only $2\frac{2}{10}$ per cent. of soluble, and 4 per cent. of insoluble.

PEA-STRAW.

An excellent sample of pea-straw, grown in 1860, on analysis, gave the following results:—

General Composition.

Water	16·02
Soluble organic matter	11·28
Soluble inorganic matter	2·72
Insoluble organic matter	67·77
Insoluble mineral matter	2·21
	100·00

Detailed Composition.

Water	16·02
Oil	2·34
*Albumen and other soluble protein compounds	2·96
Sugar, mucilage, extractive matters, &c. (soluble in water)	8·32
Digestible fibre, &c.	16·74
Soluble inorganic matter	2·72
†Insoluble protein compounds	5·90
Woody fibre	42·79
Insoluble inorganic matter	2·21
	100·00

*Containing nitrogen	·474
†Containing nitrogen	·945
Total percentage of nitrogen	1·419
Equal to protein compounds	8·86
Total percentage of ash	4·93

Pea-straw on an average contains about 5 per cent. of ash. The composition of the ash has been ascertained by Hertwig, who gives it as follows:—

Potash	11·78
Soda	6·55
Lime	40·34
Magnesia	8·30
Oxide of iron	1·03
Phosphoric acid	8·26
Sulphuric acid	6·76
Silica	10·66
Chloride of sodium	6·32
	100·00

The ash of pea-straw differs mainly from the ashes of oats, wheat, or barley straw by containing much less silica, and more lime and phosphoric acid.

Pea-straw, it will be seen, is richer in oil and albuminous or flesh-forming matters than the straw of the cereal crops; and as it moreover contains less indigestible woody fibre, and when properly harvested is tender and much liked by sheep and cattle, it is much preferable as a feeding material. Good pea-straw indeed is a capital article of food for ewes at the lambing season, for it contains almost as much flesh-forming matter as meadow-hay, and, under favourable circumstances, a large proportion of sugar and mucilage. The preceding analysis agrees tolerably well with the following results, obtained in analysing a specimen of pea-straw:—

Pea-straw taken from the Farm-buildings, October 31st, 1861.

General Composition.

Water	17·40
Substances soluble in water	11·77
Substances insoluble in water	70·83
	100·00

Detailed Composition.

Water	17·40
Oil	1·57
*Albuminous compounds	6·44
Gum, sugar, and crude cellular and woody fibre	68·63
Mineral matters	5·96
	100·00
*Containing nitrogen	1·03

This specimen, it will be seen, contains less oil and nitrogenised matter than that grown in 1860, to which it is decidedly superior in feeding qualities.

On the whole pea-haulm is the most nutritious of all kinds of straw. Its superiority over bean-straw is admitted by all practical farmers; although, according to an analysis by Professor Way, bean-straw would appear greatly to surpass pea-straw, and to approximate to the value of hay, if not to surpass it.

BEAN-STRAW.

I have examined two samples of bean-straw, one grown in 1860, the other in 1861. The composition of the first was as follows:—

Composition of Bean-straw and Bean-pods.

General Composition.

			Bean-pods.
Water	19·40		19·02
Soluble organic matter	5·69	*Organic matter	73·66
Soluble inorganic matter	2·31	Inorganic matter	7·32
Insoluble organic matter	71·20		
Insoluble mineral matter	1·40		
	100·00		100·00
		*Containing nitrogen	1·05
		Equal to albuminous compounds	6·56

Detailed Composition.

Water	19·40
Oil	1·02
*{Albumen	·47
*{Other soluble protein compounds	1·04
Mucilage, extractive matters, &c., soluble in water	4·18
Digestible fibre, &c.	2·75
Soluble inorganic matter	2·31
†Insoluble protein compounds	1·85
Woody fibre	65·58
Insoluble inorganic matter	1·40
	100·00
*Containing nitrogen	·243
†Containing nitrogen	·297
Total percentage of nitrogen	·540
Equal to protein compounds	3·360
Total percentage of ash	3·710

The ash of bean-straw, according to Messrs. Way and Ogston's analyses, published in the ninth volume of this Journal, contains, in 100 parts—

Silica	3·86
Phosphoric acid	7·35
Sulphuric acid	3·21
Carbonic acid	22·73
Lime	21·29
Magnesia	4·88
Peroxide of iron	·90
Potash	21·26
Soda	4·56
Chloride of sodium	9·05
Chloride of potassium	·90
	99·99

In its general character the ash of bean-straw resembles intimately that of pea-straw. Like the latter, it is rich in carbonate of lime, and it also contains a good deal of phosphoric acid and potash, and but little silica. My results differ widely from Professor Way's analysis of bean-straw, as given by Mr. Horsfall, in his Essay on Dairy-farming, where the composition of bean-straw is given as follows:—

Moisture	14·47
Albuminous matter	16·38
Oil and fatty matters	2·23
Starch and gum	31·63
Woody fibre	25·84
Mineral matters	9·45
	100·00

It will be observed among other particulars—

1. That I do not find more oil in bean than in wheat straw.

2. That the proportion of albuminous matters which I found in a very fair specimen is not quite so large as in good oat or barley straw, and that it amounts to scarcely one-fourth the quantity which Professor Way is reported to have found in bean-straw.

3. That I do not mention starch as a constituent of bean-stalks.

4. That instead of only 26 per cent. of woody fibre, as stated in Professor Way's analysis, the bean-straw analysed in my laboratory contained no less than 65½ per cent. of indigestible woody fibre.

5. The proportion of matters soluble in water is by no means large.

6. Lastly, that the crude woody fibre of the bean-straw examined by me was very little acted upon by dilute alkaline and acid liquid, and, therefore, produced but very little digestible fibre.

The second sample, on analysis, gave the following results:—

Bean-straw, taken from the Farm-buildings, October 31*st*, 1861.

General Composition.

Water	17·75
Substances soluble in water	6·86
Substances insoluble in water	75·39
	100·00

Detailed Composition.

Water	17·75
Oil	·41
*Albuminous compounds	5·06
Mucilage, extractive matters, and woody fibre	73·46
Mineral matters	3·32
	100·00
*Containing nitrogen	·81

This sample is somewhat richer in albuminous compounds and poorer in oil than that grown in 1860; but the differences are not great. On the other hand, both specimens agree in furnishing but a small proportion of matters soluble in water.

I would direct particular attention to the fact, clearly brought out in my investigations on straw, that the crude woody fibre (the part insoluble in water) of bean-stalks is very little acted upon by dilute caustic potash and dilute sulphuric acid; that the woody fibre of wheat-straw is more easily affected by these reagents than the bean-stalks; and that barley, or oat straw, is acted on by the same agents in a still higher degree. We cannot therefore doubt, that whilst a large proportion of the crude woody fibre of pea, barley, and especially oat straw, is assimilated by ruminating animals, bean-stalks are digested to much less extent.

As far as my own analytical results allow me to form an opinion, bean-stalks cut up by themselves into chaff, though useful as food when harvested in a good season, are decidedly inferior to any other description of straw. If I am not mistaken, these analytical results fully confirm the practical experience of the farmers in our neighbourhood, who, like most of their class, put a low estimate on the feeding value of bean-stalks. Bean-pods, it will be seen, contain a considerable proportion of albuminous compounds; they are, moreover, more tender and, no doubt, more easily digested than the hard stalks. When, therefore cattle or sheep are allowed to pick out the pods and softer portions of bean-stalks, they do very well, for these parts are much more nutritious than the lower and harder parts. The preceding analysis, it should be remembered, has been made of the whole bean-stalks without the pods.

FLAX-STRAW.

In the neighbourhood of flax-mills a refuse material, which is called "skimp," is produced in considerable quantities, which is nothing more or less than flax-straw chaff. A specimen, on analysis, furnished the following results :—

General Composition of Flax-chaff.

Water	14·60
Soluble organic matter	8.72
Soluble mineral matter	4·07
Insoluble organic matter	69·25
Insoluble mineral matter	3·36
	100·00

Detailed Composition of Flax-chaff.

Water	14·60
Oil	2·82
*Protein compounds	4·75
Sugar, gum, mucilage, &c.	8·72
Digestible fibre	18·56
Indigestible woody fibre	43·12
Soluble mineral matter	4·07
Insoluble mineral matter	3·36
	100·00
*Containing nitrogen	·76
Total percentage of ash	7·43

It will be seen that this flax-straw contained nearly 3 per cent. of oil and fatty matters, nearly 9 per cent. of substances soluble in water, and about as much albuminous matter as good barley-straw. In addition to these valuable nutritive constituents, it furnished 18½ per cent. of digestible fibre. I have, therefore, little doubt that, mixed with sliced or pulped roots, it may be advantageously given to cattle. As far as it is allowable to judge by its composition, flax-straw is more valuable as a feeding material than wheat and barley straw and bean-stalks; it ought, therefore, not be employed as litter.

CLOVER AND MEADOW-HAY.

As it may be useful for some purposes to compare the composition of straw with that of hay, I have made, in connexion with these investigations on the feeding qualities of different kinds of straw, two complete analyses of hay—one of well made clover-hay, and another of good meadow-hay, and obtained the following results:—

Composition of Clover and Meadow-hay.

General Composition.

	Clover-hay.	Meadow-hay.
Water	20·50	16·66
Soluble organic matter	18·07	17·79
Soluble inorganic matter	4·43	4·37
Insoluble organic matter	54·38	57·78
Insoluble mineral matter	2·62	3·40
	100·00	100·00

Detailed Composition.

Water	20·50	16·66
Oil, wax, and chlorophyle	3·59	5·01
*Albumen and other soluble protein compounds	5·00	1·81
Sugar, mucilage, extractive matters, &c., soluble in water	13·07	15·98
Digestible fibre, &c.	16·42	28·88
Soluble inorganic matter	4·43	4·37
†Insoluble protein compounds	8·75	6·25
Indigestible woody fibre	25·62	17·64
Insoluble inorganic matter	2·62	3·40
	100·00	100·00
*Containing nitrogen	·80	·29
†Containing nitrogen	1·40	1·00
Total percentage of nitrogen	2·20	1·29
Equal to protein compounds	13·75	8·06
Total ash	7·05	7·77

It appears from these analyses—

1. That hay, especially clover-hay, is much richer in albuminous or flesh-forming compounds than straw.

2. That it contains also more oil and fatty matters.

3. That both clover and meadow-hay, when well made, are much richer in sugar and other soluble matters than straw. Good meadow-hay especially contains a good deal of sugar, and is sweet to the taste.

4. That the proportion of indigestible woody fibre, particularly in meadow-hay, is much smaller than in straw; and

5. That good meadow-hay contains more digestible fibre than clover-hay.

For these reasons, both clover and meadow-hay are, as feeding substances, superior to straw.

The kinds of straw that approach in composition the nearest to hay are green oat-straw and pea-haulm.

It has been stated already that the state of maturity in which straw is harvested materially affects its composition and feeding value; likewise, that probably the climate and character of the land have great influence in producing the most nutritious kind of straw. It is, therefore, impossible to pronounce in a general way whether wheat, oat, or barley straw is the most valuable for feeding purposes. Assuming, however, the land and climate to be equally well adapted for producing the best kind of straw in each case, and the crops to have been harvested in the same stage of maturity, I am inclined to place the different kinds of straw in the following order, beginning with the most nutritious, and ending with the least valuable for feeding purposes:—

1. Pea-haulm.
2. Oat-straw.
3. Bean-straw with the pods.
4. Barley-straw.
5. Wheat-straw.
6. Bean-stalks without the pods.

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INDEX.

16 On the use of Lime, Marl, and Shell-Sand in Agriculture.

17 On Paring and Burning.

18 Experiments upon Swedes, with Remarks on the Manures employed.

19 On Liquid Manure.

20 On the Changes which Liquid Manure undergoes in contact with different Soils of known Composition.

21 On Anbury, and the Analysis of Diseased Turnips.

22 On the Composition of a Mangold Wurzel kept for Two Years.

23 On the Composition and Nutritive Value of Cotton-Cake.

24 On the Composition and Nutritive Properties of Mangold-Pulp, (the refuse of Beet-Root Distilleries.)

25 On the Composition of two varieties of Kohl-Rabi, and of Cattle Cabbage.

26 Experiments with different Top-Dressings upon Wheat.

27 On the Composition of Sorghum Saccharatum (Holcus Saccharatus), or North China Sugar-Cane.

28 On the Chemical Properties of Soils.

29 On the Composition of Purton Saline Water.

30 On the Composition of the Yellow Lupine, and a Soil suitable to its culture.

31 The Composition and Value of Norwegian Apatite, Spanish Phosphorite, Coprolites, and other Phosphatic Materials.

32 Reports on the Constituents of Manures.

33 Experiments on Swedes.

34 On the Composition of Cheese, and on Practical Mistakes in Cheese-Making.

35 On the Scouring Lands of Central Somerset.

36 On the Composition and Nutritive Value of Straw.