FARM FOODS:

OR,

THE RATIONAL FEEDING OF FARM ANIMALS.

FROM THE SIXTH EDITION OF

'LANDWIRTSCHAFTLICHE FÜTTERUNGSLEHRE.'

BY

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AUTHOR'S PREFACE TO THE FIRST EDITION.

As long ago as the year 1868, when the first edition of my 'Practical System of Manuring' appeared, I had pledged myself to bring out a companion volume, in which the nutrition of the body and the economy of Farm Food-stuffs should be treated on similar lines. But at the same time I expressed my intention of reserving the work until the principles underlying its teaching had been placed upon a clear and systematic basis. The science of Agricultural Dietetics was then beginning to assume definite proportions, and from the great energy with which it was being prosecuted it seemed more than probable that in a very short time it would attain a position which would enable it to offer practice a firmer and sounder support for the acceptance of the latest scientific principles. In my opinion that time has now come.

Thanks mainly to the rich harvest of results which has rewarded the zealous labours of the Munich School of Physiology, the general laws of animal nutrition, as well as those of flesh- and fat-formation in the animal body, are now clear and patent; the necessary investigations which were so admirably executed by Voit and Pettenkofer have attained a present conclusion. The formation of salts in food has been explained by new and direct experiments, and the experimental stations have contributed largely to our knowledge of the digestibility of food-stuffs, as well as of the food-requirements of farm animals. With this knowledge it is now possible in practical farming to base calculations upon "digestible proportions" and "real food," and generally to place food and feeding on a scientific basis. Much detail still requires working out, but so good a beginning has been made already that it invites a confident expectation of quick advance in the right direction. The glorious results already to hand in this field of research have clearly proved the value of Agricultural Experimental Stations in strengthening the combined efforts of Physiologists and Agricultural Chemists.

It seems to me that we have at length attained such a position with regard to the results of recent research in Animal Physiology that it is now possible to collect the produce of the last fifteen years into a compact form, which will render them not only of value to the practical man but also of general utility.

The task of sifting and arranging the appalling pile of material and of presenting it in a suitable form is no light undertaking, and I approach it with due diffidence. In writing this book I have constantly kept before me the necessity of a simple and striking presentation of the principles of nutrition, and to fulfil this object I have rigorously excluded all side-issues of a purely scientific and technical character, and have only set forth those fundamental principles of animal nutrition which the farmer must always bear in mind in the rational feeding of his stock. Details as to the housing and general management of stock, the preparation of food-stuffs, &c. are to be learnt by practical experience or in books of a more practical character, and are not dwelt upon here. I have attempted to found a rational system of feeding for the varied requirements of farm animals upon the latest scientific results as to the laws of animal digestion and nutrition, and have restricted myself to a few common food-stuffs, the composition, nature, and effect of which, as well as of their decomposition products in the body, are simple and easily understood. To secure a clearer understanding I have consistently explained the practical methods by which the given results were obtained.

To all farmers and practical men who are trying to feed their farm animals on a rational and economical system I dedicate this book, and it also suggests itself as a suitable text-book for the instruction of the coming generation of practical farmers who are studying at Agricultural Colleges. Most earnestly do I hope that its contents, scope, and form may enable it not only to arouse general interest in the subject, but that the practical application of its teaching may result in great advances in this important branch of the Economy of the Farm.

Hohenheim,
July 1874.

TRANSLATOR'S PREFACE.

In preparing an authorized English translation of the *Sixth Edition* of Professor von Wolff's 'Fütterungslehre,' an attempt has been made to supply English agriculturists and students of agriculture with a book of which only those who have read the original can appreciate the urgent need.

It is significant of the paltry and inefficient way in which England has approached the problem of applying science, system, experiment, and education to agriculture, that such an epoch-making book as this should have been allowed to remain inaccessible to the farming community for 20 years, and to pass through 6 editions in its native German, without finding a translator, or even evoking a feeble imitation, in this country.

Without excuse and with every confidence in the merits and usefulness of the original, I place an English version of this famous little book at the disposal of all thoughtful and intelligent agriculturists. What blemishes of style and wording it may possess are due only to the inexperience of a novice who makes his first essay in book-making.

The reader will hardly fail to be struck with the rather obtrusive fact that the book is simply the record of 42 years' work by the experimental stations of the German government on the feeding of farm animals and the feeding-values of farm foods. As an illustration of the apathy of our own government towards the application of science to agriculture, witness the following returns as to agricultural experiment stations for the year 1892:—

Germany	67
United States	54
France	53
Austria	35
Sweden	24
Italy	17
Russia	14
Belgium, Switzerland, Denmark, Norway, Holland	20

Java, Portugal, Roumania, Spain, Brazil, Japan, and Sumatra possess one apiece. In England such institutions are solely represented by the private enterprises of Sir John Lawes and the Royal Agricultural Society. Two or three of the counties are now employing their Technical Education grants in the direction of Agricultural Colleges, and the results are already becoming apparent. A rapid development in this direction is urgently needed.

With the present low price of food-stuffs, a shrewd farmer can produce milk, mutton, beef, and pork at a cheaper rate than has ever been possible before in modern farming. Many practical men scoff at "balanced rations" and scorn the "albuminoid ratio."

Even the authors of recent text-books for the student evaluate foods by their chemical composition, and deduce albuminoid ratios *not* from the *digestible constituents* but from the *crude* constituents of the food-stuffs.

Wolff makes it possible for every practical man to understand the meaning of *real food*, of digestibility, of digestible constituents, and their mutual proportion as expressed in the so-called "*albuminoid ratio.*" The economic standards for feeding cows, bullocks, sheep, &c., which Wolff lays down have been deduced from exhaustive and accurate experiments. Any farmer of moderate intelligence could easily calculate such a distribution of the food-stuffs at his disposal for the various animals on his farm that each animal shall receive a diet that will give the greatest return with the least waste and at the lowest cost.

This does not mean that the cowman should dispense a rigid ration weighed to half a wurzel, but simply that the diet of each animal should be subject to a general supervision as indicated by the rules laid down in the text with the assistance of the tables in the Appendix.

This book does not assert the dogmatic guesses or opinionated maxims of a self-constituted authority on farm foods, but is simply a digest of the general principles of animal growth and nutrition, the essential constituents of a rational diet, the actual composition of farm foods and their digestibility for farm animals. The latter has been deduced from elaborate experiments which have been steadily continued for more than a quarter of a century.

The experiments carried out at Rothamsted through the munificence of Sir J. B. Lawes, and under the scientific guidance of Sir Joseph Gilbert, have led to several highly important practical conclusions, and the Rothamsted experiments are not only models of accurate and exhaustive investigation in themselves, but have encouraged experimenters in Germany and elsewhere to prosecute a similar line of research.

Perhaps the most valuable feature of the book is that of the tables given in the Appendix. These are universally recognized, and form the basis of most of the data as to foods and feeding given in the agricultural press and general agricultural literature.

I am extremely indebted to my colleague Professor Percival, who has read all the proofs, and has not only been of the greatest assistance as a literary critic, but has also been of much service in matters relating to botany and biology.

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FARM FOODS.

Part I.

THE GENERAL LAWS OF ANIMAL NUTRITION.

CHAPTER I.

THE COMPOSITION OF THE ANIMAL BODY.

§ 1. *Constituents of the Body.*

Water.—The entire animal body is largely composed of water, and the amount in proportion to the live-weight of the animal decreases with its age. Immediately after birth the percentage of water is about 80–85 per cent. of that of the live animal, but during the period of rapid growth this generally decreases to about 60 per cent., while in the mature animal, and especially if fat, the water contained in its body (including the water in the stomach and intestines) is only about 40–50 per cent. of the whole.

All parts of the animal are affected by this alteration in the amount of contained water, the blood least and the bones to the greatest extent. Thus the bones of a new-born animal contain about 70 per cent., while those of a full-grown and well-nurtured beast of the same kind often contain less than 20 per cent. of water. It is clear that these variations must be taken into consideration when the effect of a given diet on the increase in live-weight has to be estimated.

Fluids.—In the animal organism the more or less solid portions—*i. e.* the cellular tissues—are by weight far in excess of the liquids and animal fluids.

The fluids circulating in the blood and lymph-vessels constitute less than 7 to 9 per cent. of the live-weight, and in the case of old or very fat beasts only 4 to 6 per cent. The gastric juices and other secretions and fluid excretions, although produced in large quantity during a space of 24 hours, can hardly be considered a part of the animal body, since they are being constantly produced directly or indirectly from the blood, and after being partially re-absorbed by the blood, pass out of the body in the form of decomposition products. A new supply of food is thus required for their renewal, while the blood, despite constant give and take, remains very uniform in its composition.

Solid Constituents.—Fresh bones constitute, according to the breed, age, and condition of the animal, 6 to 12 per cent. of its live-weight, muscle and sinews 30 to 48 per cent., and fat, as far as it can be separated from the kidneys, bowels and flesh, 5 to 40 per cent. It is to be noted, however, that fresh bones contain 20 to 50 per cent. of water, while muscle contains 60 to over 75 per cent.

If the average of the results obtained by experiments with various farm animals be taken, it appears that

	per cent.
Bones comprise of the live-weight	8·9
Flesh and Sinews........................	40·1
Fat (by mechanical separation)	23·9
Residue.................................	27·1
Total...........	100·0

The residue of 27·1 per cent. represents the blood, skin, hair, and the offal, as well as the contents of the stomach and intestines. The percentage weights of the different portions of Oxen, Sheep, and Pigs are given in Table V. in the Appendix.

I will only observe that the bulk and weight of the contents of the stomach and intestines vary greatly according to whether the animal has been fed on a concentrated or a bulky fodder, and especially, with ruminants, upon their fat or store condition. For example, in some investigations carried on at Hohenheim with sheep of the same breed and age, the following results were obtained:—

Fodder.	Contents of Stomach and Intestines as percentage of live-weight.
Chiefly straw	22·3
Hay with a little beans	15·7
High diet	9·4

Fat pigs gave even a smaller percentage, only 4 to 6 per cent.

The total weights of the various parts of the carcase, after deducting the contents of the stomach, intestines, and bladder, is called the "dressed weight" of the animal.

The Dry Substance of the animal body consists of *organic* and *inorganic* matter, and the former are either *nitrogenous* or *non-nitrogenous* substances.

§ 2. *The Non-Nitrogenous Constituents of the Animal Body.*

Fat is by far the most abundant of the non-nitrogenous material. To a minute extent (0·1 to 0·3 per cent.) it is present in the blood, but although it is found in larger quantity in the nerves and bones, it is chiefly enclosed in special cells or tissues under the skin, in the kidneys, omentum, and mesentery, and in the flesh between the bundles of muscular fibres.

A thin membrane forms the cell-walls of the fat-tissue. This is a nitrogenous substance and constitutes 0·8 to 4 per cent. of the whole tissue—dependent on the richness of the cells in fat. The amount of water in fresh fat is directly proportional to the amount of membrane (5 or 6 to 1), so that the quantity of water may vary from 4 to over 24 per cent., decreasing as the cells become richer in fat.

Most of the fat-cells of a live animal are filled with fat. At the temperature of the body this is liquid and transparent; but its consistency varies in different organs, and on becoming cold solidifies more or less easily to a butter-like or solid mass according to whether the oily or liquid fats predominate. Not only does the appearance, but also the smell and taste of fat obtained from different kinds of animals, or different parts of the same animal, vary exceedingly on account of admixtures of small quantities of colouring-matters and various volatile substances: this, however, has hardly any influence on the elementary composition of fat, which is very constant.

For instance, Schulze and Reinecke at the Weende Experimental Station, found 28 samples of mutton, beef, and pork fat taken from different parts of the body, and from different individuals, to have the following composition :—

	Carbon. per cent.	Hydrogen. per cent.	Oxygen. per cent.
Maximum	76·85	12·16	11·94
Minimum	76·27	11·76	11·00
Average of all the analyses	76·5	12·00	11·5

Almost identical results were obtained as to the composition of the fat of horses, dogs, cats, and human beings.

It is evident from these figures that we are justified in regarding all forms of fat in the body as practically of identical composition despite the many modifications it undergoes in passing from one part of the body to another; and, strange to say, even vegetable fats contained in the food of animals have absolutely the same elementary composition and general properties as animal fat. The quantity of fat which may be stored up in the body is often enormous. In the carcase of a fat beast or pig the amount of fat is often 25 to 40 per cent. of the live-weight, or 2 or 3 times that of the nitrogenous materials. On the other hand, in lean animals the quantity of fat is decidedly less than that of the fleshy tissues.

The other Non-Nitrogenous Organic Substances, other than fat, which exist in the animal body, though insignificant in quantity, play a very important part in the functions of the various organs and active fluids.

Lactic Acid is found in the gastric juice, flesh, and (in minute quantities) in the blood and most animal fluids.

Sugar also occurs in the blood (about 0·1 per cent.), and in larger quantity in the vein leading from the liver to the heart, while the liver itself contains a considerable quantity of a sugary or sugar-producing substance called *Glycogen.* The muscles also contain small quantities of a peculiar substance like sugar in composition and properties, which is known as *Inosite.*

Lastly, a variety of non-nitrogenous organic substances occur in the bile and the so-called "Alcoholic Extract" of the tissues and animal fluids; but their weight is so small, when compared with the vast proportion of fat and flesh in the body, that they are hardly appreciable.

§ 3. *Nitrogenous Constituents.*

Three groups of nitrogenous substances—viz., the *Albuminoids, Gelatinoids,* and *Horny Matter*—are found in the animal body. Of these the albuminoids are by far the most important, since all manifestations of animal life are based on them, or on organs which are made of them, and since they also provide the material from which both the other nitrogenous constituents are formed, while the latter, once formed, cannot be changed back into albuminoids and are unable to nourish the body.

Albuminoids.—The albuminoids are found in many modifications in the various organs and fluids of which they form the chief constituents; and all these forms, under the influence of the vital process, experience a constant alteration.

Three classes of albuminoids must be recognized: Albumen (represented by white of egg), Fibrin (lean meat), and Casein (cheese).

Albumen predominates in all animal fluids, especially in the chyle, in the colourless serum of the blood, as well as in the fluid contents of the blood-corpuscles, where it is tinted red by the colouring-matter of the blood. It also occurs in the juice of the muscles and in the nerves. Albumen is distinguished by the property of coagulating when heated to 70° or 80° C. When coagulated it is insoluble in pure water.

Fibrin is found in the blood mixed with albumen, but is easily recognized by its rapid coagulation at the ordinary temperature. As soon as blood escapes from a living animal, the fibrin forms a clot which entangles the red corpuscles of the blood and separates from the colourless blood-serum. The fibrin of blood differs from the fibrin found as the chief constituent of flesh in that the latter is of a highly organized and cellular character.

Flesh-Fibrin (*Myosin*) behaves somewhat differently in its chemical reactions from blood-fibrin, but both, like all insoluble albuminoids, are easily converted by the action of the digestive juices into soluble albuminoids or "peptones."

Casein is only found in quantity in milk, and as it is a product of the milk-glands only, it cannot be looked upon as a general constituent of the body. It does not coagulate on heating; the tenacious skin which forms on the surface of milk when it is evaporated is a substance which has been produced by the action of the air. When a small quantity of rennet is added to milk, or when warmed with a small quantity of dilute acids or various other substances, as well as in the natural souring of milk, the casein coagulates and separates completely from the rest of the milk.

Composition of the Albuminoids.—All the albuminoids are composed of carbon, hydrogen, oxygen, nitrogen, and sulphur; and the proportion of the constituents is so constant that it is impossible to distinguish the various albuminoids by their composition, samples of the same albuminoid from different sources often differing as much as absolutely distinct and different kinds.

The following numbers give the extremes of variation:—

	per cent.
Carbon	52–54
Hydrogen	7
Nitrogen	15–17
Oxygen	21–24
Sulphur	1–1·5

It is usually assumed that the average amount of nitrogen in albuminoids is 16 per cent., and the total albuminoids in a substance are generally estimated by multiplying the percentage of nitrogen found by the figure 6·25 ($6·25 \times 16 = 100$).

The phosphorus which always accompanies the albuminoids is generally in the form of phosphoric acid, and does not appear to enter into the organic composition or to be an essential constituent of albumen.

Gelatinoids.—These constitute nearly as large a part of the body as the albuminoids. They form the nitrogenous substance of bone and cartilage, and build up the bulk of the tendons, ligaments, connective-tissues, and the skin. By long boiling with water the gelatinoids are dissolved and turned into glue. Their composition is very similar to that of the albuminoids, except that they generally contain rather less carbon (50 to 51 per cent.), and in the case of cartilage less nitrogen (15 per cent.), while the gelatin of bones, tendons and skin is richer in nitrogen (18 per cent.). Sulphur is either entirely absent or is found in smaller quantity than in the albuminoids.

Horny Matter.—This is formed chiefly on the outer surface of the body, either in a thin layer as the scarf-skin (epidermis), or in well-characterized tissues, such as hair, wool, horn, nails, hoofs, claws, feathers, &c. The average composition of these tissues is very constant :—

	per cent.
Carbon	50–51
Hydrogen	about 7
Nitrogen	16–17
Oxygen	20–22
Sulphur	3–5

Except that they contain more sulphur, their composition is almost the same as that of albumen and gelatin.

Average Composition.—It is thus evident that all the nitrogenous organic constituents of the body have on the average almost the identical composition of the pure albumen from which they have all been directly or indirectly produced in the processes of growth and nutrition. Lawes and Gilbert, who experimented with whole oxen, sheep, and pigs, both in the fat and store condition, also observed this agreement when they estimated the total water, fixed mineral matter, fat, organic matter not fat, and the nitrogen it contained.

The amount of "organic matter not fat" determined directly agreed almost exactly with that obtained by multiplying the quantity of nitrogen found by the usual factor 6·25 (see *infrà*). Thus, all the "organic matter not fat" was found to contain on the average almost exactly 16 per cent. of nitrogen. By taking the average of all the experiments, the "organic matter not fat" comprised 14·67 per cent. of the dressed weight, and the amount of the albuminoids calculated from the nitrogen was 14·83 per cent. This clearly shows that all the nitrogenous organic constituents of the body not included in the three classes we have just considered, such as the liquids in the bile, muscles, &c., are in such relatively small quantity, that they exercise practically no influence on the composition of the organic substance of the body, and especially none on the percentage of nitrogen.

§ 4. *Mineral Matter.*

The ash or mineral matter of the body in round numbers is :—

In Cattle......	4–5	per cent. of the live-weight.
Sheep ...	2·8–3·5	" "
Pigs	1·8–3·0	" "

The lower numbers correspond to a fat, the higher to a lean condition of the animal.

About $\frac{4}{5}$ of this total is composed of phosphoric acid and lime, while the remaining fifth comprises potash, soda, magnesia, iron, chlorine, sulphuric acid, carbonic acid, and a slight trace of silica. Sulphur, which forms a portion of the organic composition of the albuminoids, has been mentioned before and is not included in this category. In the bones, as is well known, the quantity of mineral matter (bone-ash) is very great, and amounts in a full-grown animal to about $\frac{2}{3}$ of the dry, fat-free substance of the bones. Immediately after birth, the dried bones contain only about 50 per cent., but in advanced age often as much as 75 per cent. of ash. The outer and more solid layers are always richer in ash than the inner and porous parts, especially in the hollow bones. Seven-eighths of the total bone-ash consists of phosphate of lime; the rest is carbonate of lime containing a little magnesia, calcium fluoride, and sodium salts. The fat-free, dry matter of bones contains :—

	per cent.
Phosphoric acid	27
Lime	38
Carbonic acid	3–4
Magnesia	0·5–1

Fresh bones are frequently rich in fat, more especially when the animal is old and fat. In certain diseases occasioning an advanced brittleness of the bones, the quantity of fat frequently rises to more than 40 per cent., and while the percentage of phosphate is reduced, that of carbonate of lime is increased.

Lime exists in bones to a larger extent than phosphoric acid, and while this ratio holds good for the whole body, in the softer tissues the phosphoric acid exceeds the lime, though the actual amount is exceedingly small. For instance, fresh flesh free from fat contains 25 per cent. of dry matter, of which 0·6 to 0·8 per cent. is phosphoric acid. In the nerve-tissues about the same amount is found, while in blood, lymph, and digestive juices the amount is much smaller, only 0·1 to 0·2 per cent.

In flesh, blood, and lymph the percentage of lime is hardly appreciable—only 0·01 to 0·02 per cent.,—while in the digestive juices it rises to 0·1 to 0·2 per cent.

Magnesia seems to be an almost unnecessary substance for the growth and maintenance of mammals, at any rate its importance is far less than that of lime, the total quantity being hardly one-thirtieth to one-fortieth of that of the lime in the body. At the same time it is not safe to conclude from the insignificant amount of a constituent of the body that it is absolutely unnecessary for bodily growth and nutrition.

Iron, for instance (calculated as iron oxide), forms only 0·013–0·042 per cent. of the live-weight of a Farm animal, but is nevertheless a necessary constituent of the blood and contained in the so-called hæmoglobin of the red corpuscles. Iron, in fact, is absolutely essential for a healthy condition of the body.

From the researches of Hösslin with puppies of 20 to 40 lbs. weight, it appears that a daily supply of as little as 0·06 to 0·09 grain of iron was sufficient to make the further growth of the body (muscles, liver, &c.) possible, while no increase, or at any rate none in proportion to the growth of the animal, resulted in the proportion of hæmoglobin in the blood. The general results produced were large blisters, a rapid weakening of the animal, and a quickening of the pulse. It was also found that by gradually reducing the quantity of hæmoglobin, the quantity of blood was at first only slightly reduced; but when the amount of hæmoglobin had sunk from the original 14 per cent. to 7 per cent., which is the extreme minimum for the preservation of life, the quantity of blood began to decrease rapidly.

Although the actual amount of Potash, Soda, and Chlorine (generally existing as Salt) is not large, still these substances are necessary constituents of all the secretions and tissues in which the whole process of nutrition is carried out with especial vigour, and which continually undergo destruction and renewal. They thus pass largely into the excreta, and a constant and definite addition is required to maintain the digestive process in its normal condition in all directions.

It is highly remarkable that potash predominates over soda in all vital processes of cell-building, such as in the muscles and nerves, and in the blood-corpuscles as distinguished from the blood-serum, and it is clear that potash plays a prominent part in the mechanism of cell-formation in the tissues in question. On the contrary, in cartilage and bones one finds soda as the predominant alkali, although its actual quantity is very small. Soda in the form of salt is a characteristic constituent of blood-serum, lymph, the digestive juices, and the gummy substances in the body. This peculiar distribution of the two alkalies in the animal organism is very constant in quantity, though only amounting to 3 parts in 1000 of live-weight.

But as the alkalies are continually excreted in the urine, a marked disturbance of the digestive process would result if a fresh daily supply were not provided in the food. This has been demonstrated by experiments carried out at the Agricultural College at Poppelsdorf as well as at Bonn, and by J. Forster at Munich. These researches proved that animals fed with food lacking in salt rapidly became unwell or completely collapsed, and that lack of potash, as well as lack of salt, lime, or phosphoric acid, is a serious deficiency. This was not only observed with young animals still in a condition of rapid growth, but also with fully matured animals.

Salts.—The salts existing in the body are of two kinds. The first, or "Constitutional Salts," form more or less definite compounds with the organic material, and while they comprise the greater proportion of the mineral constituents, are found in very constant quantity. The other kind includes salts which dissolve in the animal fluids in small quantity without definite combination as the result of rich feeding; within certain limits these salts can cause a greater concentration of the digestive fluids, but they can never be collected to any considerable extent. They are rapidly discharged in the urine and are accompanied by the other salts which are set at liberty by the breaking-up or oxidation of combustible materials in the food. These latter are not completely and immediately discharged from the blood in its passage through the kidneys, but partially pass over into the circulation, where they are dissolved and are able to unite with albuminoids, if such substances, as a result of an insufficient supply of salts, pass from the digestive tract into the circulation. The researches of Forster already mentioned have proved that the excretion of salt was smaller when a full diet lacking in salt was supplied, than when the animal was left without food. Thus it seems that the body exercises an economy of constitutional salts and can manage with a minimum; but at the same time the supply of salt cannot sink below a certain limit, as although its excretion can be greatly reduced it never actually ceases to take place. When the supply proves absolutely inadequate, the body continually parts with salt and rapidly collapses.

In practice, in the feeding of mature animals which are to be kept in a medium condition or to be fattened, a lack of the requisite mineral matters is scarcely ever to be feared, as they are usually present in large excess. In certain respects, however, common salt is an exception, as will be explained more fully below.

Young animals rapidly growing of course require a larger supply of lime and phosphoric acid than full-grown animals, and the daily requirements of a young animal can be easily estimated from the amount found in a full-grown individual.

A lamb requires 30 grains per day, a porker 40 grains, and a calf about half an ounce of lime per day, and about the same quantity of phosphoric acid. Since young animals are generally fed on a liberal diet of easily digested food, such as corn, potatoes, and roots, all of which contain much more phosphoric acid than lime, an addition of lime in the form of chalk is often advisable.

The total amount of lime and phosphoric acid must also be considered in the diet of a milch cow, and this is further discussed in Part III.

Common Salt.—Under the general conditions of farming a lack of potash is never likely to affect farm animals, since the supply provided by all farm foods is far in excess of the demand. But it is quite otherwise with soda in the form of common salt. Salt not only plays an active part in the production of cells and digestive fluids, but materially assists digestion by increasing the diffusibility of such substances as albumen and promoting their "resorption" into the circulation from the digestive tract, as well as by stimulating to a certain extent the digestive fluids, promoting active assimilation, and generally increasing the vital energy. For this purpose a certain excess of salt seems to be necessary, which after circulating rapidly through the body is excreted in the urine in quantity proportional to the amount taken.

Salt is more necessary with vegetable than with animal food. Carnivora obtain from living animals almost equal quantities of salt and potash in their food: milk also supplies these materials in suitable quantity; in cow's milk, for instance, the proportion of the two alkalies is about 1 to 4.

In a wild state or when kept on a good permanent pasture, cattle are able to supply themselves with food yielding an adequate supply of Soda; the so-called "salt meadows" are famed for producing an especially strong and nourishing fodder, while most of our domestic animals are fed with a food such as corn, chaff, seeds, and the general coarse fodders, which are frequently rich in potash but lacking in soda. Since salt is a necessary constituent of the body, and actual experiments have proved that excess of potash causes an increased loss of salt in the urine, many foods are apt to promote an increasing lack of salt and a consequently unhealthy condition, and eventually a total collapse of the animal body. For farm animals, as well as for human beings who live on such food as bread and potatoes, salt is not a mere condiment but an essential article of food. It is true that by an automatic economy the body can subsist on a relatively small quantity of salt when the supply is small; but a certain excess is always desirable in the food of animals, as it makes it more palatable.

CHAPTER II.

ORGANIC NUTRIENTS AND THEIR DIGESTION.

The process of animal nutrition, not only in the varied structure and chemical properties of the animal organism, but also in the physiological functions of individual organs, is on the whole a very simple process, and for our purpose its progress and results can be very briefly stated. We are justified in regarding the entire body as a systematic structure of Albuminoids, Fat, Water, and Fixed Mineral matter. A certain amount of these materials is constantly being destroyed by the processes of life and the mutual activity of the tissues and juices; and the force required for the internal and external work of the body, as well as the heat required to make good the continual loss by radiation, are provided by the decomposition of matter. To prevent the complete destruction of the organism, and still more to keep it in a normal condition, a certain amount of Food is necessary to make good the loss of material resulting from the life processes, and a still greater supply is necessary if an actual growth or increased production is to be made possible.

Water and Mineral Salts have been already discussed, and we will confine our attention to the organic combustible constituents only which are supplied in food and altered in the body.

§ 1. *Organic Constituents.*

The organic substances which pass from the digestive tract into the circulation as long as any nourishment remains, or are "resorbed," are practically Albuminoids, Fat, and Sugar. This is strictly true for Herbivora, while flesh-feeding animals, a dog for instance, can maintain a fair condition of nutrition and can make good all bodily waste by a food consisting only of albuminoids (lean meat), water, and the requisite mineral matter. But even the nutrition of flesh-eating animals is much simplified, and a larger and quicker growth promoted, when the meat is supplemented with fat or a mixture of fat and carbohydrates (starch, sugar, &c.), which latter play a very prominent part in the feeding of herbivorous animals as well as of those which take a mixed diet.

Albumen is partly absorbed in its various soluble modifications by the blood and lymph vessels, while the rest remains in the gastric juice in the form of the so-called "Peptone." The latter substance appears from the latest researches to be capable, after resorption, of being again partly converted into albumen, and is then capable of building-up the animal tissues. Even after this change albumen is not resorbed from the stomach alone, but also from the whole length of the intestines by the action of capillary vessels.

Fat passes as such, or in the form of a fine emulsion, by the combined action of the bile and pancreatic juice into the vessels of the body; it is not necessary, as some have thought, that the fat should first undergo complete saponification in the digestive tract. The animal membrane must be permeable by pure fat, or else the concentration of fat in the closed cells of the fat-tissue in the process of fattening, as well as its disappearance from the cells under opposite conditions, would be incomprehensible.

SUGAR passes easily and directly from the digestive organs into the blood, and is partly supplied ready made in the food of Herbivora and animals partaking of a mixed diet, and partly produced from other constituents of food. Starch, as well as the so-called "Nitrogen-free Extract," and perhaps also a portion of the coarse or "woody fibre," is turned by the process of digestion into sugar or a similar substance and can only be "resorbed" after this change has taken place.

§ 2. *The Digestion of Organic Substances.*

RESPIRATION AND DIGESTION.—The constant stream of nutrient material which passes from the digestive system and circulates through all parts of the body meets a continual stream of oxygen in the blood. All the conditions for the phenomena of life are presented by the interaction of the respired oxygen with the food-products and the cell-structure of the body. This interaction supplies power and heat and regulates the building-up and destruction, the laying-up and loss of flesh and fat in the animal body.

The oxygen of the air passes from the lungs into the circulation of the blood, where it is absorbed by the blood-corpuscles, which serve as oxygen carriers and bring it into direct contact with all the organs of the body, and there, as well as in the blood, a destructive or "oxidising" action is set up.

To quote from a memoir by C. Voit and Pettenkofer:—"Blood-corpuscles can be compared to little vans which on the main road (the stream of albumen) daily carry oxygen in one direction, and on the return journey deliver carbonic acid, and this in the body of a full-grown man amounts to a load of 5 lbs. a day. Noiselessly they thus export and import concentrated gases. At night, when the business of carbonic acid export is quiet, the import of oxygen is brisker, and thereby the whole body obtains a store for the labours of the next day."

The Quantity of Oxygen which passes into the blood is by no means determined by the depth and frequency of the breathings, but by the *amount needed in the body*; that is, in the first place, by the rapidity of the decomposition of substances in the blood and tissues, and, in the second place, by the number and quality of the blood-corpuscles. The blood-corpuscles are increased in number by a liberal supply of albumen, and thus render possible a greater absorption of oxygen. Under conditions of powerful nutrition, and with organs of larger size, the absorption of oxygen is increased and a greater "storage" of oxygen can take place in the body.

Numerous researches conducted by Voit at Munich on healthy men, and by Kenneberg at the Weende Experimental Station on oxen, have proved that during rest a certain amount of oxygen is stored up in the body, and rapidly given off again with production of carbonic acid during active work.

According to fixed laws, material is decomposed at first independently of oxygen in the cells by the passage of the animal fluids, in the circulation of the blood (blood-cells or corpuscles), as also in the tissues, and, in fact, wherever cell-growth exists. The decomposition-products having been first produced, seize the oxygen and regulate its absorption in the process of respiration. *The splitting-up of substances* in the body to form simpler compounds must be considered the *primary* process, and the *taking-up of oxygen* as the *secondary*, although it was formerly believed that the opposite was the case. If, by an increased supply of food, or by violent muscular exertion, this decomposition of material is increased and facilitated, then, as a consequence, more oxygen will be absorbed in order to burn these products and remove them from the body.

Decomposition of Nutritive Substances in the Body.

Sugar.—As soon as food passes into the circulation and comes in contact with every organ, the sugar is rapidly decomposed, and is burnt or otherwise changed in the process of respiration. An enormous amount of sugar or sugary substance passes from the digestive tract into the blood of herbivorous animals. For instance, a full-grown ox in the course of 12 hours resorbs 12 to 18 lbs., although the normal blood of the animal contains the minutest traces of sugar (not more than 0·1 to 0·2 per cent.), and no deposition or collection of sugar occurs in the body except as glycogen in the liver.

This is only explained by the fact that during the whole process of digestion sugar is gradually resorbed, and as the blood completely circulates round the body in less than a minute, the sugar undergoes rapid oxidation.

Albuminoids.—The albuminoids in food, as far as they undergo decomposition at all, are resolved by the activity of the cells, directly or through intermediate stages, into *Urea* and *Fat**. In the Herbivora there are also formed varying quantities of *Hippuric acid,* according to the fodder and the species of the animal; but this always represents a far smaller part of the decomposed albuminoids than the urea, and often disappears almost completely from the list of the substances formed and excreted as the result of tissue-change.

The Urea is rapidly taken up by the blood, separated from it again in the kidneys, and excreted in the urine; it ought never to be stored up in a healthy animal. In the normal blood and in the tissues only small quantities of it are found, although the total quantity which is formed daily in the body of a fattening bullock may amount to a pound or even more. Urea is a crystalline substance, easily soluble in water, and it is a remarkable fact that all animal membranes are more easily permeated by crystalline bodies (crystalloids) than by amorphous, sticky substances (colloids) like gum, glue, albumen, &c. Many of the digestive operations are intelligible if considered from this point of view. For instance, the rapid removal of urea, the easy passage of sugar into the circulation of the blood, the rapid resorption and excretion of the salts provided in excess by food, &c. &c.

The nitrogen in 100 parts of water-free albumen can be separated from it in the form of 33·5 parts of urea. The remainder of the albumen, 66·5 parts, after

* See Chapter on the Production of Fat in the Body.

taking up and uniting with 12·3 parts of water, contains the elements for the formation of 51·4 parts of fat and 27·4 parts of carbonic acid.

The Fat produced from Albuminoids is, according to circumstances, deposited in the body of the animal, employed in producing milk, or undergoes a complete combustion in the respiratory process. The fat producible from the albuminoids must always be added to that which is contained ready formed in the food and resorbed from the digestive apparatus, in calculating the results of a particular method of feeding.

According to the results of recent researches, the fat formed in the body from albuminoids appears to unite more readily with oxygen—to burn easier—than the ready-formed fat taken in the food, and this again is more easily oxidised than that which is already deposited in the fat-tissues.

Fat, either ready formed in the food or produced in the body of the animal, does not appear to undergo direct combustion with oxygen to carbonic acid and water, but is first changed into sugar, which is then combusted in the process of respiration.

From 100 parts of pure fat, through the help of oxygen and water, 189 parts of dry grape-sugar (the general form of sugar in the animal body) are produced. This change is clearly exhibited by the disturbed cell-functions caused by the disease known as "diuresis;" but one is forced to allow that in the healthy organism quite as much sugar is produced from albuminoids and fat as by the severest diabetes, but as this sugar is rapidly burnt, hardly any traces of it are excreted in the urine.

We have assumed in the foregoing paragraphs that the changes in the animal body are on the whole of a very simple character: that sugar is the final and only form which can undergo combustion in the respiratory process to carbonic acid and water; that fat is only combusted after having been converted into sugar; that albumen is resolved into urea and fat, and the latter again into sugar. This of course only refers to the final result of the changes, and many intermediate products of change and decomposition which form a part of the tissues or juices, and more or less determine their activity, have been altogether left out of consideration.

CHAPTER III.

EXPERIMENTAL METHODS.

The practical result of a particular method of feeding is represented, if we set aside for the moment the production of wool and milk, by a gain of flesh or fat in the body of the animal or by the amount of work produced by the latter. We have, then, to consider in greater detail the various conditions which are favourable or unfavourable to the production of fat or flesh, and by which a greater or less amount of useful work can be performed by the animal. But, first, it will be advisable to cast a brief glance upon the methods used in practical investigations on the subject—on the actual ways and means by which our knowledge of the laws of flesh-production has recently been enlarged and made clearer.

In 1857 Bischoff and C. Voit, of Munich, first showed clearly that the total Nitrogen of the Food, or its practical equivalent under normal and favourable conditions, was represented in the "sensible" excretions of the animal (urine, dung, milk, hair, wool), and that the Nitrogen in the Urine was an accurate measure of the extent of the decomposition of albumen in the animal organism. From that time a reliable method for the determination of "Laws of Flesh Production," or the laws of the absorption and decomposition of albumen, was available. After this had been proved by feeding dogs on pure flesh, it was soon confirmed for the most various food-stuffs by experiments with oxen, cows, sheep, goats, horses, and men at the experimental stations of Weende, Halle, Möckern, Proskau, and Hohenheim.

§ 1. *Determination of Nitrogen and Mineral Matters.*

The amount of Nitrogen in the form of gaseous nitrogen or ammonia which leaves the body of a healthy animal of good digestion and not over-worked, is so insignificant that it can be completely ignored in calculating the results of "Digestion" experiments. As albumen is the principal nitrogenous constituent of ordinary food, and as we have also found that the average nitrogenous materials in the body have the same composition as albumen or lean meat free from fat, it is clearly possible to compare the carefully determined nitrogen of the food with that of all visible excretions, and thus learn if any and how much flesh (albumen) has been produced in the body or was given up and lost under the influence of the food in question.

In the same way the chemical analysis of the food and the excrement (including milk, &c.) determines the amount of mineral matter (lime, phosphoric acid, &c.) absorbed or rejected by the body.

It is self-evident that the greatest care must be exercised to secure absolutely the whole of the excretions produced, and that especial apparatus and precautions are necessary (stall-fittings, dung-receptacles, funnels, &c.), and that a particular experiment must be carried on for a considerable length of time to get a correct average result for a day of 24 hours. While the influence of a food on the gain or loss of albuminoid on which flesh-production depends can be determined in this way, the extent of the decomposition of albumen can often be found by simply determining the urea.

§ 2. *Determination of Fat and Water.*

To determine the relationship of Fat and Water in the body in addition to the Albuminoids and Salts requires not only a complete examination of the liquid and solid excretions, but also of the gaseous and vaporous emanations from the body.

The products of animal respiration and perspiration can only be accurately determined by the help of special apparatus, such, for instance, as that first constructed in Munich for this purpose, and which is still generally known under the name of "Pettenkofer's respiration apparatus."

The principle on which this apparatus is based is that of the ordinary stove :—"As long as the chimney draws, no smoke escapes from the doors and draughts of the stove, but, on the contrary, the air presses from all sides into the stove to pass out through the chimney. If, in the pipe leading the smoke from the stove to the chimney, an exact measurement of the air were possible, and if also the composition of the air entering the stove and that passing out could be exactly determined in an aliquot part of it, we should have all the factors necessary for determining what had been added to the air by its passage through the fire in the stove."

In the respiration apparatus the place of the stove is taken by a small room constructed of boiler plate, which is used to contain the animal under experiment. This room has windows at the side cemented air-tight, and a door which is provided with slides, through which the outside air has free entrance. The chimney is replaced by large air-pumps kept in uniform motion at any required velocity by powerful clockwork which is kept wound up by a small steam-engine.

The air which is pumped out of the "saloon" is accurately measured by a large gas-meter, and in order to obtain an aliquot part of it, and at the same time to analyse the air as it enters the room, small mercury-pumps are provided which regularly withdraw a certain proportion of the air (about $\frac{1}{4000}$th) before and after leaving the room.

The moisture in the air is absorbed by oil of vitriol and weighed, the carbonic acid by slowly bubbling the air through baryta water of known strength, and lastly it is passed over caustic baryta and the absorbed carbonic acid determined. The difference in water and carbonic acid between the air as it enters and as it leaves the "saloon," calculated to correspond to the whole volume of air passing through the room, represents that produced by the animal. By employing special precautions the amount of hydrogen, hydrocarbons, and possible traces of ammonia given off by the animal can also be estimated.

It will be seen that this apparatus is so arranged that the man or animal experimented upon is under perfectly normal conditions, *i. e.*, under the same atmospheric pressure and in a similar atmosphere to that of a stall or a room. This is a great advantage, because this is the only way in which the experiment can be carried on long enough to obtain normal and reliable results. It is true great precautions have to be observed, and difficulties overcome, especially when experimenting on large farm-animals, but we cannot discuss them here.

The "Feeding Effect" or "Digestion Result" can be ascertained after direct determination of the requisite elements by calculating the difference between the supply and loss. By multiplying the Nitrogen in the daily food and in the total excretions by the factor 6·25 (see page 8), we obtain the actual quantity of Albumen provided and rejected by the animal, and thus the gain or loss of flesh occurring in 24 hours can be determined. In a similar way the total or separate mineral substances concerned can be estimated. To obtain accurate results as to the influence of food on the total fat of the animal, not only the carbon in the dung and urine, but also the respired carbonic acid and the hydrocarbons given off from the body have to be determined.

The difference between the carbon in the total food and excretion must next be corrected by the carbon represented by the loss or gain of albuminoid (containing 53 per cent. of carbon), and the remainder by multiplication with the factor 1·3 (more accurately 1·307), which represents the fat corresponding to 1 part of carbon, and gives the total fat gained or lost by the body.

The alterations in the water contained in the body are easily estimated with fair accuracy by comparing the total of the other constituents (albuminoids, minerals, and fat) with the increase or decrease of the live-weight of the animal.

The atmospheric oxygen employed in the process of digestion need not be directly determined, but can be deduced with fair accuracy from the water-vapour given off from the body, and which can be measured in the respiration apparatus.

To make this clearer, an illustration of a digestion experiment, conducted at Weende by Henneberg, on full-grown sheep of Göttinger breed is appended (p. 32).

The food was entirely hay and water, and the results are calculated out for an average animal of 105 lbs. live-weight for a space of 24 hours; the average temperature of the stall during the experiments was 10° C. It is, of course, self-evident that any loss by the body is placed on the "consumption" side of the account, and any gain on the "production" side.

The excess of water produced over that supplied (274·9 grams) represents 30·55 grams of Hydrogen in the organic matter which have been turned to water.

If we deduct from the total bodily increase the wool (9·5) and the minerals lost by the body (0·8), we get a total of 70·3—10·3=60 grams (2 oz.) as the actual daily gain in the bodily weight as Flesh, Fat, and Water.

In this experiment a bodily increase, though only a small one, resulted, and the food supplied was somewhat richer than was necessary to maintain the animal in an unaltered condition.

*Digestion Calculation.**

	Dry matter (grams).	Water (grams).	Mineral matter (grams).	Carbon (grams).	Hydrogen (grams).	Nitrogen (grams).	Oxygen (grams).
1. CONSUMPTION.							
2936·5 *Food and Drink*:—							
1216 hay	997·3	218·6	67·9	460·1	85·8	18·1	584
6 salt	5·7	0·3	5·7	......	0·03	......	0·27
1714·5 water	1·8	1712·7	1·6	0·1	190·3	......	1522·5
0·8 loss from body	0·8	......	0·8	......	......	......	......
587·6 oxygen from air ...	......	......	......	......	......	......	587·6
Total ... 3524·9	......	1931·6	76·0	460·2	276·2	18·1	2694·4
2. PRODUCTION.							
1814·5 *Excrement*:—							
1257 dung	424·9	832·1	44·0	202·5	117·5	8·45	884·6
557·5 urine	79·7	477·8	31·1	23·2	55·5	7·65	439·9
70·3 *Bodily increase*:—							
9·5 wool (including sweat and fat) ...	7·4	2·1	0·9	3·5	0·7	0·75	3·7
7·8 flesh...............	7·8	......	......	4·1	0·6	1·25	1·9
17·1 fat	17·1	......	......	13·1	2·1	......	1·9
35·9 water	......	35·9	......	......	4·0	......	31·9
1640·1 *Products of Respiration*:—							
780·0 carbonic acid ...	......	......	......	212·7	......	......	567·3
1·5 marsh-gas	......	......	......	1·1	0·4	......	......
858·6 moisture	......	858·6	......	......	95·4	......	763·2
Total ... 3524·9	......	2206·5	76·0	460·2	276·2	18·1	2694·4

* 1 *gram* may be taken to equal 15 grains, or 28 grams = 1 oz.

The mineral matters taken and rejected daily were found to be as follows :—

Excretions.	Potash.	Soda.	Lime.	Magnesia.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Silica and Sand.	Total Ash.
	g.	g.	g.	g.	g.	g.	g.	g.	g.
Dung	1·14	1·43	9·35	3·67	4·03	0·86	...	22·32	42·80
Urine	18·01	3·09	0·40	1·14	0·07	1·31	8·41	0·43	32·86
Wool	0·76	...	0·03	0·01	0·01	0·04	0·05	0·01	0·91
Total Excretions ...	19·91	4·52	9·78	4·82	4·11	2·21	8·46	22·76	76·57
Total Consumption	21·27	5·68	8·44	4·47	4·08	2·46	9·74	19·47	75·61
Difference :—									
Gain	1·36	1·16	...	...	...	0·25	1·28		
Loss	...	...	1 34	0·35	0·03	...	...	3·29	0·96

It should be noted that the excessive quantity of silica and sand in the excretion is not derived from the body, but through accidental impurity in the food. It is thus seen that a small quantity of alkalies and chlorine was retained in the body, a certain quantity of lime and magnesia was lost, while with respect to phosphoric acid no difference occurred in the body.

A similar research on young calves was carried out at the Experimental Station at Vienna by Soxhlet. The calves weighed from 90 to 145 lbs. each, and were entirely fed on fresh milk. Here the investigation was based on an absolutely digestible material which produces rapid growth with young animals, and the results are in interesting contrast to those which we have just considered, in which full-grown sheep were kept in fair condition without much bodily growth on a diet of hay. It was found that the average growth of a calf weighing a hundredweight (50 kilos) averaged 2 lbs. a day, and the following results in grams were obtained for an average animal two to three weeks old, weighing 50 kilos, for a period of 24 hours (p. 35).

For the production of the Carbonic Acid given off by the lungs and skin, 422 grams milk-sugar, 78·5 g. fat in the food, 32·7 g. fat produced by the decomposition of 63·5 g. albumen were employed, and the rest was obtained from the decomposed albumen after separation of fat and urea. The total carbon thus provided

$$(168{\cdot}8 + 60 + 25 + 4{\cdot}8 = 258{\cdot}6)$$

equals the amount found in the carbonic acid breathed out by the animal. The daily increase in the live-weight amounted to 925 g. per day (2 lbs.), and consisted of 168 g. albuminoids, 158 g. fat, 33 g. mineral matter, 566 g. of water. Very nearly 1 pound of increase in the live-weight of the animal was produced by 1 pound of dry matter in the milk provided.

These examples of Digestion Experiments illustrate the great care and labour involved in determining the feeding-effect of even a single food on a particular kind of animal, and it is easily understood that in many directions the progress of the science of feeding farm animals can only go on slowly.

When only the give and take of albuminoids is to be determined, the process is much simpler and less laborious, and consequently, while our knowledge of the laws of "flesh production" is in a fairly advanced condition, we are still greatly in the dark as to the conditions which determine the highest and most economical production of fat and work.

	Dry matter.	Nitrogen.	Albumen.	Carbon.	Fat.	Milk-Sugar.	Ash.	Phosphoric Acid.	Potash.
Food: Milk 8093 grams	965	39·2	245	488	237	422	62	19	15
Discharged in Dung 91 g.	22	2·2	13·5	9	0·5	...	1·6	0·2	0·5
Digested and Resorbed	943	37·0	231·5	479	236·5	422	60·4	18·8	14·5
Percent. of Food taken	97·7	94·4	94·4	98·2	99·8	100	97·4	99·0	96·7
Urine 5370 g.	...	10·2	...	11·6	...	...	27·4	6·0	
Breath 945 g. Carbonic Acid	...	...	...	258·6					
Decomposed in body	...	...	63·5	...	78·5	422			
Stored up in body	...	26·8	168·0	209·8	158	...	33	13·8	14·5
Percent. of Growth to Food taken	...	68·4	68·4	43	66·6	...	53·2	72·6	96·7

CHAPTER IV.

FLESH PRODUCTION.

§ 1. *Circulatory and Organized Albumen.*

The general laws of animal nutrition owe much of their clearness and value to the results of the extensive researches conducted at Munich by Karl Voit, which led to the division of the Albuminoids in the body into two classes, the stable *organized albumen* and the easily decomposable *circulatory albumen* *. Under the latter Voit does not include the total albumen circulating in the blood and lymph, but only the dissolved portion which penetrates into the tissues and saturates the organs with fluid nutriment.

The amount of circulatory albumen under conditions of feeble nourishment is but small, and in a condition of hunger amounts to less than 1 per cent. of the total albumen; its amount, however, increases considerably with a rich supply of albuminoid in the food, and can rise as high as 5 per cent. with flesh-feeding animals. However large or small the quantity of albumen circulating in the juices and through the organs may be, the greater portion of it (generally 70 to 80 per cent.) is inevitably decomposed in the course of 24 hours, and a corresponding quantity of nitrogen in the form of Urea or Hippuric acid is discharged in the urine, while less than 0·8 per cent. of the "organized albumen" suffers

* "Circulations-Eiweiss."

decomposition. This latter quantity has been determined by experiments on starving dogs. Under conditions of starvation or of complete lack of food, the store of circulatory albumen is rapidly exhausted, and after a few days the destruction of albuminoids, as represented by the nitrogen in the urine, is solely due to the quantity of organized albumen which is daily taken into the system and undergoes decomposition. By adequate or liberal feeding the amount of decomposed organized albumen is still less. The old idea that all the organs of the body undergo rapid decomposition, and that in the course of a few weeks the whole organism undergoes complete change and reconstruction is quite false. This state of things only exists in the case of a few cell-systems, as in the blood-corpuscles and the milk-glands, which during the period of their greatest activity are being constantly decomposed and reformed. The majority of organs, when once produced, are very stable in themselves, although the quantity and quality of the contents of the cells vary considerably with the food of the animal. The circulatory albumen, on the contrary, undergoes a continual change.

"A powerful stream of fluid charged with albumen leaves the blood, bathes the organs, and flows back again to the blood. In this way, and by the action of the cells on the plasma, the decomposition of the fluid 'not-organized' albumen is effected, probably in a similar way to that in which we separate chemical compounds in our relatively crude researches by osmosis or by the action of capillary tubes." (*Voit.*)

Further evidence of the fact that organized albumen is stable, while circulatory albumen readily undergoes decomposition, has been given by further direct investigations at Munich and afterwards at Leipzig.

It was observed with dogs that living blood, which as a whole can be considered an organ, when transfused into the circulation of another animal, withstands decomposition much longer than if the same quantity of not-organized albumen was introduced into the same animal in the same way, or if blood was served as food. In the latter case, by the process of digestion, the "organized" albumen of the blood was changed into "circulatory" albumen, and entered the circulation in that form.

§ 2. *The Laws of Flesh Formation.*

The Laws of Flesh Formation were first studied with reference to the Carnivora, *i. e.* with dogs; but they are essentially the same for all the higher animals.

The various species of animals differ in the food which they chiefly eat as well as in their powers of digesting certain foods; but the real nutrients which are resorbed from the digestive system, even under most varied systems of feeding, are always the same, viz., albuminoids, fat, sugar, water, and mineral salts. Since all mammals are very similar with regard to the structure, chemical composition, and functions of their organs, the decomposition process must follow the same course, *i. e.* the substances once resorbed and taken up into the circulation decompose or are deposited in the body according to the same laws.

The laws deduced from experiments with Carnivora have been completely confirmed in their general scope and bearing by recent experiments on Herbivora, though the total amount of material decomposed or stored up in the body varies with the proportion of the different nutrients which the animal is capable of resorbing under normal conditions.

The capacity of Carnivora and Herbivora for resorbing the various nutrients is not, however, so different as is generally supposed. It has been found, for instance, that a dog is able to digest and resorb as much as $\frac{1}{4}$ ounce of starch per lb. of live-weight per day, while a well-fed milch-cow, or even a fattening ox, resorbs from its food not more than $\frac{2}{10}$ to $\frac{3}{10}$ oz. of carbohydrate per lb. of live-weight per day. Although this similarity for the resorption of albumen has been observed, it appears that fat is resorbed in far greater quantity by Carnivora than by Herbivora.

§ 3. *Consumption of Albuminoids.*

It is not always possible to distinguish accurately between the consumption and production of albuminoids in the body; frequently the two increase or decrease simultaneously, and often one varies oppositely to the other. I will now detail the conditions which affect the rate of consumption of albuminoids, while the question of flesh-production or the deposition of albumen I will leave for the present out of consideration.

1. *Supply of Albumen increases Consumption.*

In the first place the quantity supplied determines the consumption of albumen in the body. In a condition of starvation all animals are carnivorous, since they feed on their own flesh and fat, and the consumption of albuminoid is relatively small. For a large dog this amounts to 17 grains of dry albumen per lb. of live-weight per day, for an ox only 5 to 7 grains.

Under conditions of moderate nutrition and a fairly mixed diet a large dog lost 70 grains of albuminoid per lb. of live-weight, a cow 25, a man 28 grains, a full-grown ox at rest only 10, and a sheep 17 grains.

As a result of a liberal diet this quantity can be doubled or trebled, and when sheep or oxen are being fatted amounts to as much as five times that consumed under ordinary conditions of feeding. By feeding dogs exclusively on meat the amount of albuminoid was fifteen times as much as that consumed under starvation conditions.

Experiments on fat sheep conducted by Kern and Wattenberg at Göttingen showed that a continuous increase in the supply of albuminoid resulted in a small quantity only being stored up in the body, while the greater portion of the albumen (87 to 97 per cent.) was decomposed, the nitrogen passing into the urine and the rest under favourable conditions contributed to the production of fat.

2. *"Nitrogen Equilibrium."*

The albumen consumed during fasting is not a measure of the amount required by an animal to maintain itself in a constant condition, as was formerly supposed. The quantity is more often twice or two and a half times as great, and the consumption of albumen rises above this minimum in proportion to the amount taken in the food.

As a matter of fact a condition of "Nitrogen Equilibrium" is set up sooner or later corresponding with the amount of albumen which the animal receives in its food; that is, the amount of nitrogen in the food is eventually represented in quantity by that daily excreted in the dung and urine (as well as milk, &c.).

The excess of albumen resorbed is first turned into "circulatory" albumen, and then undergoes almost complete decomposition. This equilibrium of nitrogen is more quickly set up, the greater the amount of nitrogen in the food and the leaner the animal, and is generally attained more quickly by Carnivora than by Herbivora.

As soon as the equilibrium of nitrogen has been set up, and the body is also in equilibrium through loss or gain of flesh or albumen, the same quantity and kind of food is required every day to maintain this constant condition. Each particular condition of body requires within certain narrow limits a peculiar and corresponding food-supply, and we cannot well speak of a superfluous consumption of food by animals as we do of plants, *i. e.* of a wholly useless and unnecessary excess of some one nutrient.

A *waste of Food,* however, often occurs in practice, when more food is given than is required for the object in view, such as the production of milk or wool, and the feeding of draught animals and young cattle. Even when fattening animals, as we shall see later, the same or a better result may often be produced by a food poorer in albuminoids than one which contains a very large quantity.

3. *Influence of the Condition of the Animal.*

From the preceding paragraphs it will be seen that the total mass of the organs, the proportion of "organized" to "circulatory" albumen, as well as the ratio of the total bodily albuminoid to the fat tissues, or, in brief, the *Condition* of the animal has a powerful influence on the extent of the consumption of albumen, although a much smaller one than the supply of albumen.

When the amount of flesh is large the amount of organized albumen decomposed is large in proportion. It is possible to make this clear by sudden changes in diet—for instance, if a highly nitrogenous diet be suddenly replaced by one poor in nitrogen, then for the first few days the nitrogen discharged is much greater than that received in the food; but when the store of circulatory albumen has been exhausted the excreted and supplied nitrogen again come into equilibrium, until the bodily condition is exactly equivalent to the amount of nitrogen contained in the food provided. When, however, a return is suddenly made to the highly nitrogenous diet, a restoration of the organized albumen to its original amount does not take place, but a condition of nitrogen equilibrium is quickly set up through the more rapid production of circulatory and unstable albumen and the slow and small production of organized albumen. Only under favourable conditions, which we will consider in a future chapter, can the increase of organized albumen and the consequent increase of the animal be effected.

4. *Effect of Salt on the Consumption of Albumen.*

A moderate supply of salt in the daily food increases the flow of the active juices in the body, and consequently the consumption of albumen. Voit, in his experiments, found that with dogs fed on flesh only, salt increased the consumption of albumen 4·5 per cent., and similar results were obtained with vegetable diet and also with cattle. The advantages of salt as an article of food especially for Herbivora has already been spoken of. Adding salt to the food is therefore of especial value when a stimulation of all the vital functions is desired, as in horses, working oxen in good condition, young animals and males for breeding purposes &c.; while in fattening only as much should be given as is required to make the food palatable, and necessary for the normal nourishment of the animal.

Salt is a diuretic and often considerably increases the excretion of urine. This is especially noticeable if the animal is prevented from drinking much purposely or accidentally. For the excretion of the excess of salt more water is necessary, and this is withdrawn first from that excreted by evaporation from the lungs and skin, and, if this is not sufficient, from the body itself. When large doses of salt and little water are given the live-weight can sink rapidly, while if the animal is eventually allowed to drink a large quantity of water, much of it may be laid up in the tissues and the live-weight of the animal may be again increased.

5. *Influence of Water on Albumen Consumption.*

It is not advisable to give animals too much salt, as they are then inclined to drink too much water, with a resulting increase in the consumption of albumen and an increased destruction of valuable food material, especially when the excess of water is not retained in the tissues but is rapidly excreted by evaporation or in the urine.

Experiments with starving dogs at Munich showed an increase of albumen consumption in this way of 25 per cent., and this has been confirmed with domestic animals by Marcker and with men by Mares. Henneberg, of Weende, found that an increase of $\frac{1}{5}$ in the supply of water caused an average increase of albumen consumption amounting to 7·2 per cent. Even this amount is by no means insignificant, as it amounts to a third or perhaps even a half of the albumen which might otherwise have been deposited in the body. In any case, to get the most satisfactory results possible, especially in the feeding of young animals and in fattening, we must avoid everything which involves or conduces to an excessive consumption of water, *e. g.*, watery food, excessive heat of the stall, too much salt, unnecessary movement, &c. This is especially important in the case of sheep, since they naturally drink less water in proportion to the dry matter of their food than cattle.

Animals in milk may be allowed excess of water with less disadvantage, and an increased milk production can be thus produced, but it is not advisable to increase the proportion of water beyond a certain limit.

6. *The Effect of Stimulants*

on the consumption of albumen seems to be inappreciable. At any rate Voit found no effect produced when he supplied dogs in a condition of hunger, or fed on various diets, with coffee. The action on the nervous system seems to be caused by so minute a change of albuminoid matter that its significance is *nil* when compared with the total consumption of albumen in the body. It is quite another and as yet unanswered question whether the increased nervous activity may not cause an increased consumption of fat in the body, such as is produced by muscular effort and severe labour.

It has been actually observed that a mechanical stimulation of the walls of the intestines, as well the nerve stimulus caused by cold air, produces an increased discharge of carbonic acid and a larger consumption of respiration materials.

7. *Influence of Fat.*

An increase in the supply of fat slightly increases the consumption of albumen, as more albumen is put in circulation. But this effect can only clearly be observed when the animal is starving or receiving an inadequate supply of albumen in its daily food. With a large supply of circulatory albumen provided by a liberal diet, fat acts in quite the opposite way and exercises a very material economy of albumen.

§ 4. *The Storage of Albumen in the Body.*

The rapid increase of the absorption of albumen is one of the chief objects of stock-keeping and fattening, since the amount of organized albumen (flesh) in the animal's body which, when once formed, is stable and does not readily undergo decomposition, together with the fat and water represents the increase of the live-weight of the animal. From the facts already given much can be learnt as to means of increasing the storage of albumen, since those conditions which are favourable for the change of albumen must in general be equally favourable for its storage. But it is a matter for serious consideration that there are means of economizing the albumen in the daily food, and of reducing its consumption for feeding-purposes to the lowest minimum, whereby the laying-on of flesh is favoured, and the albumen required for the production of the various valuable animal products expended to the best advantage.

1. *Supply favours production of Flesh.*

It is self-evident that a large supply of a uniform food must produce more increase in the body than a small one; but this effect is not only generally true but also often proportional to the quantity, as Henneberg and Stohmann found at Weende by various experiments on oxen. In one instance, when the total supply of digestible food was increased from $18\frac{3}{4}$ lbs. to $20\frac{1}{2}$ lbs. per day (the proportion of nitrogenous to non-nitrogenous food remaining the same), 32 per cent. of the resorbed albumen was formed into flesh instead of only 18 per cent. with the smaller food-supply.

In other experiments in which the animals were fed with clover-hay in quantity rising from 4 to 5 lbs. each per day, the percentage of flesh formed rose from 9 to 14, and in another instance from 11 to 15 per cent. of the total albumen digested. These facts show how very important it is to take care that fattening beasts receive as large a quantity as possible of the food in question; a little more or less can produce a great difference in the rate of increase, as is often illustrated by the marked slowness or rapidity of the increase of the live-weight of fattening pigs.

2. *Influence of an Increase of Albumen.*

When the albumen is increased while the non-nitrogenous food remains constant, the circulatory albumen is increased and its destruction increased in proportion, but a certain amount of the excess of albumen is laid up in the flesh; after a certain amount of this albumen has been stored in the body, a condition of "nitrogen-balance" is set up—not immediately, but in a shorter or longer time dependent on circumstances. Great care should be exercised in increasing the amount of albuminoids in food, as the loss of albumen is often increased and only a very small quantity stored up in the body as flesh, so that the ration produces little or no effect and results in a dead loss.

The condition and previous diet of the animal must therefore be taken into consideration.

3. *Influence of the Fat of the Body.*

The fat stored up in the body reduces the consumption of albumen, and therefore favours the laying-on of flesh. The absolute quantity of fat is not so important in this respect as its proportion to the flesh in the body. It has been found that with an equal quantity of flesh, the consumption of albumen in the body is less the fatter the animal. For this reason the laying-on of flesh is most easily done by Herbivora, since they are especially adapted for producing fat, and even under ordinary conditions of feeding have much more fat in their bodies than Carnivora. On this same account it is often possible to increase the proportion of albumen in the food of Herbivora with the most satisfactory results. At the same time even with cattle one cannot afford to disregard the appropriate food-supply for the condition of the animal; especially is this the case at the commencement of feeding, since the most suitable food is very different for lean animals out of condition than for others in good condition. The capacity of Herbivora for fattening depends on the nature and method of their normal nourishment, as well as on the quality and quantity of the blood produced, and also perhaps on the size and structure of their organs of respiration. The fatter the animal becomes, the smaller as a rule the consumption of material in the body, the less the absorption of material by the blood and lymph from the digestive organs, and the less the quantity of food required to satisfy the animal.

These facts are especially noticeable in the case of fattening swine, which often suffer from fatty degeneration of the organs; very fat young cattle also eventually cease to grow and increase in a normal manner. Researches conducted at Hohenheim on fat sheep and oxen have shown that it is possible to maintain a well fattened animal in an unaltered condition by a very ordinary diet, if no further increase is desired or the increase of the body-weight has already attained its maximum.

4. *Fat in the Food supplied.*

The proportion in which the different nutrients albumen, fat, and sugar (starch &c. generally included in the term "Carbohydrates") are digested and resorbed has a highly important influence on the economy of albumen in the body. I will first consider the influence of the fat supplied in the food.

If a large dog weighing 65 lbs. be daily fed with a pound of fresh meat free from fat containing 4 ozs. of pure albumen, the supply is insufficient for the needs of the animal, and it rapidly loses flesh and at length nearly dies of starvation. About 3 lbs. of lean meat are necessary to keep such an animal in a normal condition. But if to the one pound of meat 7 ozs. of fat be added, the animal ceases to starve but remains in a healthy and sound condition, and it is even possible for flesh to be formed and the bodily weight to increase. This gain takes place for the most part in the tissues, the organized albumen increases in quantity, thereby increasing the live-weight of the animal. By the addition of 7 ozs. of fat, 2 lbs. of flesh were economized, or a mixture of 1 lb. of flesh and 7 ozs. of fat achieved the same nutritive effect as 3 lbs. of flesh.

It would be quite a mistake to suppose that if the dog which had been fed entirely on 3 lbs of flesh a day were to be supplied with 7 ozs. of fat in addition, that the daily consumption of flesh in the animal would be at once reduced to a pound, and that the extra 2 pounds provided in the food would be stored up as flesh. The consumption of albumen in the first place (see page 39) is increased by the amount of albumen supplied; the greater the amount of meat eaten, the greater the consumption of albumen, quite independently of the addition of fat.

The fat does not protect the albumen from decomposition to any appreciable extent, and when the fat in the food sinks below a certain minimum, even this feeble protection entirely ceases, and the consumption of albumen is increased in order to make good the deficit of fat. The reduction of the albumen consumption (production of flesh) through the additional provision of fat is not very great. Voit found as a result of many experiments with Carnivora which received moderate and large rations of flesh, that it amounted to from 1 to 15 per cent., or on the average 7 per cent. of the total consumption. But this action often goes on for a long time with a constant food supply, so that before equilibrium between supply and consumption has been set up, the total effect of the feeding can be very considerable.

The economizing influence of fat on the albumen consumption of Herbivora is not so evident as with Carnivora, because its action is hidden by a large mass of carbohydrates. The fat in the food of cows ought not to exceed a certain amount. Small quantities exercise generally a beneficial action, while excess produces hurtful effects, and as a result of the disturbance of digestion the animal rapidly loses appetite. At the same time the different kinds and conditions of fat behave very differently in this respect, and it is worth while to pay attention to the fat in the food of young cattle, fattening beasts, and horses, especially when the ration is rather a nitrogenous one.

5. *Effect of the Carbohydrates.*

Carbohydrates have a far greater importance in the feeding of Herbivora, and they effect a greater economy of albumen in the body than fat. This was found in experiments with Carnivora fed with starch and meat to be 9 per cent., while a diet with an equivalent quantity of fat only resulted in an economy of 7 per cent. of the consumption of albumen.

Starch differs from fat in that it does not cause an increased consumption of albumen when fed with an insufficient amount of flesh to an animal in a starving condition. Starch exercises under all conditions a preservative action on albumen, although it can only reduce and is unable wholly to prevent its consumption.

The physiological value of starch is therefore quite apart from its so-called "Respiration value." This latter value, which represents the amount of oxygen required to completely burn starch and fat, is in the proportion of 1 : 2·44, while the economizing action of equal quantities of starch and fat on the consumption of albumen is practically the same. Recent researches by Rubner at Munich have shown that so far as the more important vital functions of the different nutrients are concerned, they can practically replace one another according to their heat-producing value, or are "isodynamic" (see Production of Force).

Herbivora take an enormous quantity of Carbohydrates in their normal food, and on this account they require little albumen to maintain them in condition, so that on a high diet a portion of the digested albumen readily remains in the body and is stored up in the organs as organized albumen. A certain minimum of albumen, however, must be present in the food of cattle, and cannot be replaced by any other food-constituent. The most important and difficult problem which the science of Feeding is slowly solving is that of determining this minimum for all the purposes for which farm animals are kept, and especially that of fixing the necessary quantity and best proportions of nitrogenous and non-nitrogenous materials in the daily food of any animal. In a subsequent chapter the latest contributions to our knowledge of these matters, which are due to the Experimental Stations, shall find a place.

CHAPTER V.

THE FORMATION OF FAT.

§ 1. *Sources of Fat.*

THE Fat of the Food, when digested and resorbed, may, under suitable conditions, remain undestroyed and be stored up in the body; this is now as certain as the fact of the formation of fat from other constituents of the food. I will only refer on this point to some experiments which we owe to the activity of the Physiological Institute at Munich.

Carnivorous animals which, as a result of restricted feeding on flesh, have become rich in flesh and proportionately poor in fat, after a period of complete hunger eventually lose the whole of the fat; the time when all the fat has gone is easily recognized by the fact that the excretion of urea, which during hunger is very constant, at last increases quite suddenly, because, after the disappearance of the fat, more albumen is consumed in the body to replace it. In an experiment by F. Hofmann, such a fat-free dog weighing 40 lbs. was starved for thirty days, and then fed for five days with as large a quantity of pure fat as possible, whereby 13 ounces of pure fat were digested. This is such a large quantity that it is impossible to suppose it to have been completely oxidized in the body, for then

37 ounces of carbonic acid should have been excreted, while direct determinations of the amount excreted by dogs double the size gave far smaller quantities. In the body of the animal, which was killed at the end of the experiment, 47 ounces of fat were found on the various organs, instead of the 5 ounces which, according to other investigations, was the greatest quantity that could have been present in the body after thirty days' fasting, so that in this case about $8\frac{1}{4}$ ounces per day of the fat of the food remained undestroyed and were deposited in the body.

In other researches with dogs which were fed with a more normal diet of fat and flesh, it was proved, with the help of the "respiration apparatus," that as a general thing a considerable amount of the fat in the food was stored up in the body; Voit and Pettenkofer found this to be in three instances $1\frac{1}{3}$ ounces, $1\frac{1}{2}$ ounces, and 4 ounces of fat a day.

The fat, however, must be similar to the animal fats or easily altered into such, since absolutely foreign fats are neither resorbed from the alimentary canal at all or are rapidly oxidized in the animal fluids. This does not, of course, prevent the fat in the food of Herbivora from contributing directly to the formation of fat in the body, since most vegetable fats are very similar in composition and properties to the animal fats.

Formation of Fat in the Body.

No special proof as to the formation of fat in the body from other substances need be adduced, as daily experience in fattening and the production of milk make it sufficiently evident.

But a very important question needs consideration, and this is: "*What food-materials are prominently or exclusively concerned in the production of Fat?*"

Clearly the answer is limited to the albuminoids, the nitrogenous organic substances, and the carbohydrates; for besides these nutrients and fat itself, there are no other substances present in sufficient quantity in the food of either Herbivora or Carnivora to be capable of producing fat.

Formation of Fat from Albuminoids.

It is now generally accepted as a fact that fat can be produced from albuminoids. The fact that the albuminoids by fermentation, as well as by treatment with alkalies and acids and oxidizing agents, produce fat, amongst many other products of decomposition, favours this view.

Former observations that the albuminoids of milk and cheese are converted into fat on standing have not been confirmed, at any rate for cheese, by a recent careful investigation by O. Kellner at Hohenheim. On the contrary, however, it is often found that in the milk of the same cow the quantity of albuminoid decreases as the fat increases and *vice versâ*, which points to a relationship between the two substances.

The production of the so-called Adipocere on dead bodies, and the fatty degeneration of the muscles and other organs in living animals through certain diseases and often from excessive fattening, is a common occurrence with pigs: both point to the same fact.

The fatty degeneration of all the organs of the body as a result of phosphorus poisoning is very marked, and from the researches of J. Baur, of Munich, there is hardly any doubt that the fat is produced from the albuminoid tissues, since urea is produced at the same time and excreted.

A large dog, which had been starved 12 days until practically all its fat had disappeared, was slowly poisoned with phosphorus. Death resulted during the night of the nineteenth day of hunger.

Before poisoning, the nitrogen excreted in the urine had averaged constantly $\frac{1}{4}$ ounce per day; after the phosphorus poisoning the amount of nitrogen in the urine increased rapidly, and eventually reached $\frac{7}{8}$ ounce, or more than three times as much as before. A similar dog, experimented upon under like conditions, gave off in the respiration apparatus only half the normal amount of carbonic acid and only absorbed half the normal quantity of oxygen.

Two changes are therefore produced by phosphorus poisoning—(1) decomposition of albuminoids into fat and urea; (2) a smaller absorption of oxygen and, consequently, reduced oxidation of the fat.

Both processes combine to produce fat in the body, as was proved by observations of the dog poisoned with phosphorus; for in the dry matter of the muscles 42·4 per cent., and in the liver 30 per cent., of fat was found, a quantity three times greater than the normal and ten times as great as the quantity would have been if the dog had not been poisoned and kept without food for twenty days.

The liver of a man who died from phosphorus poisoning was found to contain 76·8 per cent. of fat;

but a rapid collection of fat in the liver may have been made from other parts of the body.

If a doubt still remained as to the formation of fat from albuminoids, it must vanish on consideration of the results obtained with healthy animals fed on a normal and natural food. For example, the eggs of ordinary flies have been allowed to develop on pure blood, and from seven to eleven times as much fat found in the larvæ as was originally contained in eggs and blood together, although the insects had not consumed all the blood: this excess of fat must have come from the albuminoids in the blood. Still more important are the numerous experiments made by feeding dogs on large quantities of pure (fat-free) meat. Thus Voit and Pettenkofer found an excess of $1\frac{1}{2}$ ounces of carbon in the food over the total excretions; the nitrogen in the excretion exactly corresponded to that in the food, a condition of "nitrogen-balance" had been set up, and a certain amount of the carbon in the albuminoid present in the food must have remained behind and been stored up as fat, since no other organic substance is known which can be stored up in the body in so large a quantity.

From the knowledge which we now possess as to the processes of decomposition in the animal body, we can assume that an amount of fat corresponding to the total consumption of albumen (about 51 per cent.), as far as this escapes fermentation in the intestines, is produced in the body, and, together with the digestible fat received in the food, is mostly burnt up in the process of respiration; but under certain conditions it can be completely absorbed as fat-tissue, or be used for the production of milk.

The calculation of the fat-increase produced by any given supply of food must always include the ready-made fat in the food as well as the fat produced by the decomposition of albumen. Only when these two sources of fat are insufficient for the increase of fat observed, can other food constituents be considered in this respect. On this account, a very pertinent question arises as to how the Herbivora, especially the animals of the farm, are so easily fattened although their food contains but little albumen and still less fat. To answer this question, we will examine the results of practical researches in which the feeding effect of a diet was either simply and directly determined by the increase of the live-weight of the animal and the composition of the carcase, or by the method of determining the quantity and composition of the visible excretions.

Production of Milk-fat by Cows.

This was the subject of researches by Voit at Munich, G. Kühn at Möckern, and others carried out at Hohenheim; in the first series a rich diet, and in the two latter a poorer and less nitrogenous diet, was provided.

The proportion of fat resorbed from the food, and of fat which might have been produced from the albuminoid in the food, the total available fat, and, finally, the amount of fat actually found in the milk are given in the following table. The figures are expressed as grams per head per day :—

[28 grams= 1 oz.]	Digestible Fat in food.	Fat obtained from albumen.	Total Fat in food.	Fat found in milk.
Munich experiment	276	308·5	584·5	337
Möckern experiment	183·5	74·5	258	284·8
Hohenheim experiment	168	164·3	332·8	296·9

In the Munich and Hohenheim experiments the fat supplied was more than sufficient to account for that contained in the milk. In Möckern, however, an excess of milk-fat over that in the food was found; but even if this excess had been considerably greater, no definite conclusions with regard to its source could be drawn. Equilibrium between the supply and excretion of nitrogen was certainly established with the animals under experiment at Möckern as well as at Hohenheim; but whether the animals were in equilibrium as to carbon, or whether the fat of the body took part in the milk-production (as is often the case with milch-cows, even when well fed), could only have been decided with certainty by the help of a respiration apparatus.

At any rate, it is very remarkable that in the above experiments, in which good milch-cows were fed on a poor diet, it was unnecessary to take into consideration any appreciable quantity of any other constituents of the food except the crude fat and the fat from albumen to explain the production of milk-fat.

§ 2. *Experiments on Fattening.*

Something more definite as to the source of animal fat may perhaps be learned from the results of fattening experiments on domestic animals, if we conclude from the well-known English experiments of Lawes and Gilbert that the percentage composition of the live-weight in fattening is as follows:—

	Ash.	Albumen.	Fat.	Total dry matter.	Water.
Pigs	0·53	7·76	63·1	71·4	28·6
Sheep......	2·34	7·13	70·4	79·9	20·1
Oxen	1·47	7·69	66·2	75·4	24·6
Average ...	1·45	7·53	66·6	75·6	24·4

Many fattening experiments, for the most part on full-grown sheep, have been carried out at the different Experimental Stations. Generally, the chemical composition of the food and the actual increase in the live-weight were determined, and to get trustworthy results the investigations were continued in each case for a period of 2½ to 3 months. At the end of the experiments the animals were slaughtered and the products weighed. The following average results were thus obtained, although the digestible food-constituents were only directly determined in a few cases and were generally calculated:—

No. of experiments.	Digested per head per day.		Ratio of Food-constituents.	Increase per cent. of live-weight per head per day.		
	Albumen.	Non-nitrogenous Foods.		Total.	Dressed carcase.	Suet from kidneys, &c.
	grams.*	grams.		grams.	per cent.	per cent.
7	110	824	1:7·49	55·5	48	7·2
13	134	779	1:5·81	79	51·9	9·9
20	164	794	1:4·7	94·5	53·5	10·9
19	192	769	1:4·01	103	54·9	11·2

These figures are very eloquent as to the favourable influence of albuminoids in food on fat-production. Although the other constituents of the food were practically constant and could not materially affect the increase in the live-weight, it is clearly seen that an increase of the albuminoids results in a normal and proportional increase in the weight of the animal. This gain is clearly due to the albuminoids, which were provided in excess, since the animals only received in the various experiments from ½ to 2 ounces of actual fat per head per day in their food.

Fat Oxen.—Similar results have been obtained with fat oxen. General experience, confirmed by direct experiments, has shown that within certain limits food rich in nitrogen exerts the most favourable influence on oxen, and that the albumen and fat digested from the food provides the requisite material for laying-on fat. Hitherto in researches on the feeding of ruminants

* 28 grams = 1 oz.

it has never been necessary to regard the carbohydrates supplied in such enormous quantity in ordinary fodder as a direct source of fat-production.

In recent researches by Kern and Wattenberg at Göttingen on sheep of different ages, it was found that the increase of fat was in ten cases 24 to 64 per cent. lower than that theoretically possible from the albuminoids and fat supplied in the food.

In only a single case, that of a full-grown sheep, were other results obtained. This animal laid on fat at such a rate that the production could only be accounted for by recognizing the carbohydrates as an auxiliary source of the fat produced.

The sheep were fed on Lucerne hay, mangolds, maize, and oil-cake, and the fattening lasted for seventy days. By the chemical analysis of one animal at the beginning, and of one at the end of the experiment, it was found that during the process of fattening 21½ lbs. of fat had been collected in the body, while practically no flesh or nitrogenous matter had been laid on.

If the composition of the food be corrected by its digestible ratio, then 15 lbs. is found to be the maximum quantity of fat producible from the albuminoids and fat in the food, and 61½ lbs. or 30 per cent. of the total quantity (4 ounces per day) must have been produced from other food-constituents, that is from the *Carbohydrates.*

From the fact that even after the fullest deductions have been made, the fat-production is not otherwise accounted for, we are forced to the conclusion that fat must have been produced from carbohydrates. Similar observations have been made at Göttingen by Pfeiffer and Lehmann, who fed sheep with considerable quantities of sugar.

Pigs.—In the case of pigs it has long been recognized that fat can be produced from Carbohydrates. A long time ago experiments on pigs were carried out at Proskau, with direct analysis of the animals under experiment, which failed to yield definite results because after a quite insufficient feeding—mostly on potatoes—the growth of the pigs was poor, and in no way a normal one. But in many other instances, first at Rothamstead and then in Germany, it was observed that pigs frequently increased 100 lbs. in weight with a food containing only 10 to 15 lbs. of ready-formed fat and 50 to 70 lbs. of albuminoid. In one investigation, from 82 lbs. of albumen and 14 of fat in the food, 200 lbs. of bodily increase resulted, and the live-weight raised from 78 to 271 lbs. per head. Almost identical results were obtained at Hohenheim by feeding young pigs for 108 days on barley and maize meal and with the occasional addition of pure starch. The digestibility of the food was also determined, and the results in lbs. are given in the following table:—

Increase in live-weight.			Digested food required to produce 100 lbs. live-weight.			
	Total.	Per day.	Albumen.	Fat.	Carbo-hydrate.	Total lbs.
1	41·3	0·382	39·2	9·3	300·8	349
2	53·5	0·495	38·1	8·9	263·3	310

The final weight of the pigs was respectively 174 and 212 lbs. These figures make it quite impossible to explain the increase of fat in the body in any other way than by concluding that the carbohydrates had assisted in its production. In these experiments the digestible fat and albumen in the food could only produce 29 per cent. of the resulting fat-production, while as much as 60 per cent. or more of the increase of live-weight in fat pigs, even when they are still young, was found in these experiments to consist of fat.

The production of fat from carbohydrates by pigs has now been absolutely and definitely proved by Soxhlet at Munich, Tschirwinsky at Moscow, and at Vienna by Meissl and Strohmer; at the first two places by actual chemical analysis of the animals before and after the experiment, and at Vienna on the living animal with the respiration apparatus.

At the Munich Experiment Station three pigs 16½ months old, and weighing 212 to 219 lbs. apiece, were selected. One was first killed and then the other two were fed on steamed rice to the extent of 35·9 lbs. (water-free), as well as 90 grains of salt and a little meat-extract, the albuminoid ratio being 1 : 11. The increase in live-weight was very uniform, 85½ lbs. in 78 days, or 8 ounces per head per day. The chemical examination showed that during this time 35½ lbs. of fat had been formed in the body, and as only 10 ounces was contained in the food, 34 lbs. 14 ozs. had been freshly made. 19 lbs. of albumen were digested from the food, of which 8½ lbs. were stored up in the body, so that 10½ were left to assist in the production of fat, from which, under most favourable conditions, 6 lbs.

(51·4 per cent. of the albumen) might have resulted in body-fat—that is, about $\frac{1}{6}$ of the total fat formed in the body, or nearly $\frac{5}{6}$ of the fat produced, must have been made from carbohydrates.

Exactly the same results were obtained at Moscow by experimenting on farrows of Windsor pigs in 1880–1881, and of the Yorkshire breed in the next year. In the first experiments they were fed entirely on barley-meal, and in 126 days the live-weight increased from 16 lbs. to 53 lbs. 16½ lbs. of albumen and 1½ lbs. of fat were digested from the food, and 3½ lbs. of flesh and 19 lbs. of fat stored up in the body; so that 19 minus 1½, or 17½ lbs. of fat had been freshly produced. The digestible albumen in the food, 16½ lbs., after deducting the 3½ lbs. flesh produced, leaves 13 lbs., which are theoretically capable of yielding $\frac{13 \times 51{\cdot}4}{100}$ of fat, or 6·68 lbs. Deducting from this the amount of fat hitherto unaccounted for, viz. 17·5 minus 6·68, we get a residue of 10·82 lbs., or 57 per cent. of the total increase of fat in the body, which must have resulted from the carbohydrates.

In the second series of experiments the pigs at first had cow's milk, then barley, and later an addition of starch and sugar. In 100 days the live-weight had increased from 24 lbs. 5 ozs. to 54 lbs. 9 ozs. 11½ lbs. of fat had been produced in the bodies of the young pigs, of which only 2½ lbs., or 23 per cent. of the total increase of fresh fat in the body, had been made from the albuminoids in the food, and therefore 77 per cent. of this fat was due to the carbohydrates in the food.

Of extreme interest are the results obtained at the Vienna Veterinary College by experiments which were conducted in the respiration apparatus on a pig 14 months old and weighing 300 lbs. The diet consisted of well-boiled rice, and by comparing the total waste products (dung, urine, and respiration products) with the food-supply, a daily increase of $1\frac{1}{3}$ ounces of albumen and 14 ounces of fat resulted in the body of the animal. For the production of the latter an extreme quantity of $2\frac{1}{3}$ ounces digested and decomposed albumen, equivalent to $1\frac{1}{5}$ ounces of fat as well as $\frac{1}{4}$ oz. of food-fat, can be allowed. Deducting this $(1\frac{1}{5}+\frac{1}{4})$ from the 14 ozs. of fat stored up in the body, we obtain a balance of $12\frac{11}{20}$ ozs. of fat, representing 89 per cent. of the total fat increase, which must have been derived from the carbohydrates in the food.

Experiments on Geese.—The production of fat from carbohydrates in the case of geese has been established by careful chemical analysis, before and after fattening.

The first experiments were made by Weiske and B. Schulze at Proskau, who employed a food consisting of rye-bran and potato-starch, in which the albuminoid ratio is as low as 1 : 5, and from which they proved that the carbohydrates considerably assisted in the production of fat. When all the fat in the food, and that possibly producible from the digestible albumen and asparagine in the food, had been allowed for, there still remained an excess of $2\frac{1}{2}$ ounces, and in another case of 3 ounces, or 13 and 17·6 per cent. respectively of the total fat produced in the body of the goose, which could only have resulted from carbohydrates.

In a still more decisive manner Chaniewski, of the

Experiment Station at Peterhof near Riga, obtained results proving that full-grown geese can fatten on carbohydrates. After 18 days of a diet of barley and rice, there resulted an "excess" of fat, beyond that accounted for by the fat and albuminoids in the food, of $6\frac{4}{5}$ ounces in one case and $17\frac{4}{5}$ ounces in another (or 71·7 per cent. and 78·6 per cent. of the total fat-production), which could only have been produced from the carbohydrates.

In another research, in which geese were starved 5 days until they were fat-free, and then fattened on barley and rice, it was found that in the course of 14 days, 14 ounces of the fat produced in the body, or 86·7 per cent., must have resulted from carbohydrates.

Incidentally it may be mentioned that A. v. Planta and Erlenmeyer, of Munich, found that *Bees* produced wax, which is a similar substance to fat, from sugar; and that O. Kellner, who carried out researches on *Silkworms* in Japan, found they were able to produce fat from non-nitrogenous substances, and even from the digestible constituents of mulberry-leaves.

Experiments on Dogs.—The dog being a carnivorous animal does not appear capable, so far as experiments have gone, of producing fat from carbohydrates. In the course of 22 respiration experiments at Munich, a dog weighing about 66 lbs. was fed on 6 to 22 ounces of dry starch per day, sometimes entirely, and in some cases with the addition of greater or less quantities of meat. The results showed that the fat obtained from the albumen was always more than enough to account for the increase of fat in the body, and that this did not depend at all on the amount of the carbohydrate, but was unmistakably related to the proportion of flesh decomposed. By increasing the starch from 13½ to 22 ounces per day no increase in fat resulted, while by increasing the albumen with a constant supply of starch, the production and laying-on of fat were increased, in one case from 1 to 2 and 5 ounces. At the same time M. Rubner, of Munich, has shown that even Carnivora can form fat from carbodydrates if the organs be supplied with an enormous excess of carbohydrate. By feeding a dog weighing 14 lbs. with 4 ounces of cane-sugar and 3 ounces of starch per day, a production of 3⅔ oz. of fat per day was produced from the carbohydrates. J. Munk also arrived at similar results.* This production of fat, however, is of secondary importance as far as Carnivora are concerned, since they never, or hardly ever, receive a food so rich in carbohydrates as this.

§ 3. *The Consumption of Fat.*

Much still remains to be elucidated with regard to the theory of Fat-formation, by which the various species and breeds of domestic animals may be assisted to an especially rapid and large production of fat; but already the results of exact investigations make it possible to lay down certain general principles which demand careful consideration in the rational feeding of our domestic animals, with especial reference to the most remunerative production of fat.

I will specify these principles by mentioning the con-

[* This hardly agrees with the opening statement.—Tr.]

ditions which favour *the Consumption of Fat,* or which bring about an *Economy of Fat* and consequently an increased store of fat in the animal body.

1. By one-sided increase of the *supply of fat* the total fat-consumption is somewhat increased, but with a sufficiency of fat a greater or lesser quantity is at the same time stored up in the body. A full supply of albumen in the daily food increases the storage of fat.

2. Fat produced from albumen more easily undergoes combustion than ready-made fat; the fat in the food with a small supply of albumen slightly tends to increase the change of albumen, larger quantities to reduce but never to completely protect it from change (see page 45). Fat does not protect albumen from decomposition, while an adequate quantity of albumen can completely prevent the destruction of fat.

3. In the case of a fat animal the total consumption of fat is greater than in a thin animal; a lean animal is more easily fattened than one in which fat has already been considerably stored up.

4. *The water-supply,* if excessive, not only increases the waste of albumen, but creates a greater destruction of food-stuff in the body and increases the amount of carbonic acid given off. When one wishes to bring about the greatest and quickest production of flesh and fat, a fattening beast should not receive food which is too watery or be allowed to drink to excess.

5. *The stall-temperature* should not be *too high,* or else the resulting excessive drinking and evaporation from the body will probably cause the animals to suffer from disturbed rest and appetite; nor should it be *too low,* as an increased oxidation will be necessary to

maintain the bodily heat. A mean stall-temperature of from 45° to 68° Fahrenheit is most suitable for the purposes of economical feeding.

6. *The size of the animal* influences the demands on the food-supply. Small animals require as a rule relatively more food than larger ones, since they present a larger surface for radiation in proportion to their weight, and therefore give off relatively more heat to their surroundings.

With animals of the same kind the heat production or loss corresponds to the surface area of their bodies. For a definite area of surface both large and small animals require the same number of "heat units"*. On the other hand, the intensity of combustion in the bodies of animals of the same size, but of different kinds, is often very different.

Rubner found at Munich for equal body-weight and practically equal body-surface, and at an air-temperature of 15° C., that for one square centimetre of surface a dog required 1136 units of heat per day, a rabbit only 717, and a hen 892.

Similar results have been obtained with farm animals; thus the heat requirements of oxen, sheep, and goats do not depend only on the size and external surface of the animals.

As the average of direct experiments, a full-grown ox consumes for 1000 lbs. of live-weight about 0·6 lb. of albumen and 7·4 lbs. of non-nitrogenous foods, a full-grown sheep 1·2 lbs. albumen and 10·5 lbs. non-nitro-

* A "heat unit" is that quantity of heat required to raise 1 gram of water from 0° to 1° C.

genous material (calculated as starch) to maintain its bodily temperature.

7. *Muscular effort* and every mechanical exertion considerably increase the fat consumption, as we shall see worked out in the next Chapter, and on this account the movements of fattening beasts and milch-cows should be carefully avoided.

8. *Loss of Blood* increases the consumption of albumen, but at the same time decreases the absorption of oxygen, the giving-off of carbonic acid, and the consumption of fat, so that the fat contained in the food or produced in the body is more easily stored up. Practical experience supports the conclusion that a poverty of blood in the body is especially conducive to the production of fat, and in many districts it is the custom to occasionally bleed fattening beasts. At the same time the amount of oxygen taken up by the blood is determined by the digestion, and not *vice versâ*, and the particular maximum of oxygen capable of being absorbed at any moment is determined by the quantity of the blood, and especially by the number of corpuscles or the amount of hæmoglobin it contains, and this is directly reduced by a diet poor in nitrogen. In this way the generally superior capacity for fattening exhibited by the Herbivora, and again that of different kinds and breeds, can be traced among other factors (such as powers of circulation, lung capacity, &c.) to a smaller amount of hæmoglobin in the blood.

9. *The influence of Carbohydrates* on the consumption and storing-up of fat is a very important consideration for the purposes of the Stock-keeper. They act similarly to the fats in food, since they reduce the con-

sumption of the body-fat; supplied in larger quantity, by economizing the fat in the food and that produced from the albumen, they bring about a complete storage of the fat. According to Voit the carbohydrates exercise a greater effect than that corresponding to their respiration-value; so that 175 parts of starch instead of 244 (the respiration-value) are equivalent in this respect to 100 parts of fat. Even if this is not the case, the carbohydrates (sugar for instance) are more easily burnt in the process of respiration than fat, and thus protect the fat from more rapid destruction.

It is possible to determine the smallest quantity of albumen and carbohydrates which will enable the body to maintain its store of albumen and fat—that is, in a normal condition or in equilibrium of nitrogen and carbon. If the quantity of albumen supplied is kept at a minimum and excess of carbohydrates be provided, fat is stored up, but only in small quantity. If the quantity of carbohydrate is kept at a minimum and the albumen increased, more albumen is consumed and only a small quantity of albumen and fat is stored up in the body. If plenty of albumen as well as carbohydrate is supplied, the storing-up of albumen increases, and especially that of fat, because ample material is then supplied for the production of fat and a favourable proportion of nutrients is provided in the daily food.

The general laws of flesh and fat production clearly show us that for the most satisfactory and complete attainment of the ends of stock-keeping, not only is a sufficient supply of food essential, but also a definite ratio of albumen to carbohydrate, or of nitrogenous to non-nitrogenous food constituents, must be observed.

We must reserve the detailed consideration of this question for a future occasion. I will only here observe that productive feeding is most favourably carried out under a moderate "Albuminoid Ratio." If the albumen be too small, the energy of digestion is reduced, and a deficit of material for the rapid and extensive production of fat and flesh results. Excess of albumen in the food distinctly increases the stream of circulatory albumen, and thereby the decomposition of valuable nutriment. A proportional deficit of carbohydrate conduces to a lesser protection of albumen from decomposition, and a reduction in the amount of fat stored up from that produced from the albumen. Too much carbohydrate results in its unnecessary decomposition without rendering any practical service. It may even cause injury to the system, since the latter is unable to continually deal with so much material, and frequently a considerable quantity is discharged in the dung quite undigested.

Only with a medium Albuminoid Ratio is it possible to expect under otherwise suitable conditions that the largest amount of flesh and fat may be produced from the food. We can only discuss the influence of variations in the Albuminoid Ratio on the feeding of farm animals after we have learnt the composition and digestibility of the commoner farm foods, and more especially their content of real food-stuffs or "nutrients."

CHAPTER VI.

THE PRODUCTION OF FORCE.

It was formerly believed, in accordance with Liebig's teaching, that *mechanical work* and continued *activity of the muscles* resulted in a considerable wear and tear of the organs, and produced a double or even treble consumption of albumen. Since then researches by Voit and Pettenkofer at Munich have shown that this is not the case, but that with a constant supply of food, or even without food, the consumption of albumen in the body is no greater under conditions of muscular exercise than those of perfect rest, provided the animal be in fair condition, the exercise not too violent and its duration not too protracted.

Although more albumen may be consumed in the specially active organs by the flow of a larger quantity of blood, this is balanced by the proportionately inactive condition of the other organs, so that the total consumption of albumen by the whole body remains practically unaltered. On the contrary, the consumption of fat, and especially that of carbohydrates, is decidedly increased by arduous work, since more carbonic acid is produced in the respiration process, and increased heat is generated with a corresponding increase of evaporation and loss of heat to the surrounding air.

The first experiments in this direction were made with a large dog weighing about 32 kilos (70 lbs.). The work which it performed on working days (by running in a treadmill) was very considerable, being estimated at 12 foot-pounds * per second for the whole twenty-four hours; while the work performed by a man eight hours in twenty-four is estimated at only 16 foot-lbs. per second, or little more than for the dog.

A slight increase of the consumption of albumen was found for the day's work, which represented 11·5 per cent. of the albumen consumed in a condition of complete rest, when the animal received no food, and 4·8 per cent. when it received a large amount of meat. This increase is partially explained by the fact that the working animal required more water, whereby more urine was excreted and the consumption of albumen somewhat increased (see p. 43).

In other experiments on a strong and healthy man, this source of error was removed by regulating the supply of water. The experimental man on working days turned a heavy wheel fitted with a brake for 9 hours, which made him feel as tired at the end as if he had done a hard day's work or a long march.

With the aid of the respiration apparatus the following numbers, which refer to 24 hours and give the food consumption under conditions of work and rest, were obtained :—

* A foot-pound is the force required to raise 1 pound 1 foot high.

Results in grams per 24 hours.

	Albumen consumed.	Total consumed.	Carbonic acid excreted.	Oxygen taken up.	Water excreted.	
					In urine.	Evaporated.
Fasting.						
Rest	79	209	716	762	844	821
Work.........	75	380	1187	1072	746	1777
Average diet.						
Rest	137	219	928	832	1056	931
Work.........	137	320	1209	1006	1155	1727

These figures clearly prove that the consumption of albumen is no greater during work than rest, but, on the contrary, the consumption of fat and the consequent excretion of carbonic acid and taking-up of oxygen is greatly increased, as also the amount of water evaporated from the lungs and skin. In hunger the difference between the carbonic acid produced in rest and in work is more considerable (471 grams) than on an average diet (281 grams); the oxygen shows a similar result, 310 g. against 174 g., while the differences in the water evaporated are relatively less, viz., 956 g. : 796 g.

Hirschfeld confirmed Voit and Pettenkofer in the conclusion that with a large supply of food either rich or poor in nitrogen, the consumption of albuminoids was not increased by muscular activity; while

Argutinsky found a very severe form of muscular exercise, such as climbing hills for several hours at a stretch, produced a decided increase of albumen consumption which could not be prevented by an increased supply of sugar.

Excretion of Nitrogen as Gas.

It has sometimes been asserted that in severe work a portion of the nitrogen arising from the destruction of albumen is excreted in the form of gas from the skin and lungs, and that consequently the consumption of albumen cannot be calculated from the nitrogen in the urine. According to this, the close agreement found in the above and many other experiments between the nitrogen in the urine on the days of rest and work is entirely accidental—a thing not only very improbable in itself, but which is disproved by the following considerations and experimental results.

If, as a result of work, the total consumption of albumen is considerably increased, there must be a correspondingly increased excretion of sulphuric and phosphoric acid in the urine; for with every portion of albuminoid tissue destroyed, the sulphur and phosphorus which it contains must be oxidized to sulphuric and phosphoric acids, and finally leave the body in the urine, since these substances cannot assume the gaseous form at the temperature of the body. In the above experiments the quantity of these acids was determined in the experiments made on an average diet, and the following results were obtained:—

	Sulphuric acid.	Phosphoric acid.
	grams.	grams.
Rest	2·61	4·19
Work....................	2·57	4·11

From which it appears that their quantity under conditions of work and rest was absolutely constant and equal. In the face of these results and others obtained by the most careful and accurate determination of the total visible and gaseous excretions from the body, one is obliged to treat other contradictory observations as of little consequence or value.

All experiments have confirmed the increased consumption of fat and excretion of carbonic acid during work, and this was well illustrated by Henneberg's experiments on full-grown sheep at Weende. He found that without any unusual muscular work more carbonic acid was produced by *day* than at *night*, the difference being due to the increased activity of the muscles concerned in swallowing and chewing. When the animals were fed in the daytime, as usual, 54 per cent. of the total carbonic acid was given off in the 12 hours of the day; but when the animals were fed at night with the same quantity of hay, only 46 per cent. of the carbonic acid was produced during the day, and 54 per cent. during the night.

With reference to the large increase of fat consumption, as a result of muscular work, it is indifferent whether the source of the fat is that provided in the food, that stored up in the tissues of the body, the fat produced by the decomposition of albumen, or the equivalent quantity of carbohydrate supplied in the food. At any rate the greatest care must be exercised to prevent the animals from any excessive movement or muscular exercise if they are to be fattened as quickly and profitably as possible.

In the experiments on a man already alluded to, the consumption of albumen was unaltered by work either in a condition of hunger or on a normal diet. Of course it is clear that this could only hold good if the bodily condition were good and for a short time only, and would cease when the rapid consumption of organic matter produced by the hard work was effected at the expense of the fat of the body. If the daily food is insufficient, after a certain time the flesh-tissues of the body will be attacked, at first slowly and then more rapidly, and an increased excretion of nitrogen in the urine will result.

The Hohenheim Experiment on a Horse.

Instead of restricting the experiment to 24 hours, as at Munich, at Hohenheim the time was considerably extended. The day's work was measured by a special apparatus, and calculated as kilogramme-metres.

In one series of experiments the horse received daily during the whole course of the experiments 11 lbs. hay, 13 lbs. oats, and 3 lbs. wheat and chaff. The amount of digestible matter in the food remained practically constant the whole time, and amounted to 12·89 lbs. per day with a ratio of 1 : 6·57. Each period of experiment lasted 8 to 14 days, and the following results were obtained :—

Period	I.	II.	III.	IV.	V.
Day's work (kg.-m.*).	475,000	950,000	1425,000	950,000	475,000
Nitrogen in urine per day (grams)	99	109·3	116·8	110·2	98·2
Live-weight (lbs.) ...	1174	1166	1150	1116	1140

In a second series of experiments the periods were longer still, extending 3, 4, and 8 weeks. A highly nitrogenous food was provided consisting of 16½ lbs. hay and 9 lbs. beans per day, and the amount digestible was kept constantly at 11⅘ lbs. with a ratio of 1 : 2·96.

The results obtained were as follows :—

Period	I.	II.	III.
Day's work (kg.-m.*) ...	810,000	2,430,000	810,000
Nitrogen in urine per day (grams)	198·6	228	199·9
Live-weight (lbs.)	1093	1019	1008

In the second series the difference of the albumen consumption as represented by the nitrogen in the urine was greater than in the first series; and while the day's work was decidedly greater, the amount of

* 1 kilogramme-metre (kg.-m.) =7 English foot-pounds.

digestible matter in the daily food was somewhat smaller, though the albuminoid ratio was much higher. The original condition of the horse was better in the first than in the second series of experiments; and as the period of actual work was greater in the second series, the animal must have further deteriorated in condition.

In the course of the second series a clear illustration of the increased combustion of organic matter during work increasing the consumption of albumen in the body is given: the hardest work began on March 12th, and the following amounts of Nitrogen were found in the urine at various times :—

Time.	Grams Nitrogen in urine per day.	Live-weight.
		lbs.
March 18–24	211·3	1060
" 25–29	220·7	1034
March 30 to April 14	229·1	1032
April 5–10	234·3	1018

The live weight of the horse on March 11th was 1093 lbs. There is no doubt that if the experiment had been carried on longer the horse would have further lost condition owing to increased consumption of the albumen of the body.

It is clearly evident that very hard work increases the consumption of albumen to a greater or less extent, dependent on the original condition of the animal. From the first experiments it is seen that a horse even in a fair condition exhibits an increase in the consumption of albumen, although the amount is insignificant when compared with the largely increased oxidation of body-fat and the non-nitrogenous constituents of the food.

The Sources of Muscular Power.

The great increase in the combustion of fat during work has led to the assumption that this constitutes the chief source of muscular energy, that the work done is the result of the heat produced, and that in the animal body a conversion of *heat into force* takes place, just as the steam-engine produces work through the heat of the burning fuel by the intervention of steam, or as the hot-air engine executes work by means of the heated air. The non-nitrogenous food-stuffs are directly concerned in this heat-production, and it has been calculated that 20 per cent. of the heat produced by their combustion is converted into work, which is a far larger proportion than that yet attained by the most efficient steam-engines, which only convert about 10 per cent. of the heat they receive into work. It is open to question, however, whether the heat produced in the body can be directly converted into mechanical work as in the case of the air-engine, or can even be considered its direct source, since the necessary conditions of alternate heating and cooling of the whole or a part do not hold good in the animal body, and make a comparison between the two impossible. It is also a well-known fact that nothing is more hurtful to the health of the animal system than alterations in its normal temperature, and any material alteration of the body temperature results in rapid death. If a simple conversion of heat into work really takes place in the body, then the increased oxidation of organic matter which takes place during work must result in a continual and renewed source of muscular power and render external work possible without any cessation whatever.

The increased production of heat during work and the increased respiration are but *secondary* effects—the result of work—and can by no means be regarded as its primary or *direct* cause. The increased heat produced in work is dissipated in evaporation from the body and by greater heat radiation, and is eventually reduced again to the normal.

But apart from the question as to the way in which force is produced in the body, a measure or equivalent for the work performed or to be performed in the day is found in the increased combustion of the body-fat or in the increased quantity of food or generally in the increased material required.

The Hohenheim experiments on the horse already described clearly show that with a constant diet for a lengthened period, the nitrogen in the urine, *i. e.* the combustion of albumen, increases at first slowly and then very rapidly if the daily work remains constant or is increased for a sufficiently long period. Other experiments with the same horse have shown that the increased consumption of albumen ceases at once when the daily ration is adequately increased with fat and carbohydrate. It is possible to determine how much of these latter must be added to maintain a balance of nitrogen in the body despite the increased muscular effort, and also to compensate for the increased demands of respiration, *i. e.* to set up a balance of carbon as well as of nitrogen, and thus maintain the animal in an entirely constant condition.

The food required to produce work varies with the form of muscular activity or the work done. Katzenstein, for instance, found that work done by men turning a wheel with the arms produced a greater expenditure of material in the body than the same work done with the legs. The volume of oxygen used per kilogram-metre of work done with hand-labour amounted to 1·96 cubic centimetres, but when the work was done with the legs only to 1·19 to 1·51 cubic centimetres.

Further, the degree of practice in a particular kind of work influences the expenditure of material in the body, as Max Gruber found in experiments on himself; the carbonic acid produced every 20 minutes amounted to the following:—

	Rest.	Walking.	Climbing: out of practice.	Climbing: in practice.
Carbonic Acid ...	12·83 g.	22·42 g.	38·83 g.	31·00 g.
Work	......	......	7376 kg.m.	7639 kg.m.

The carbonic acid excreted is not a measure of the work done by a man, because its production decreases with practice.

Zuntz and Lehmann obtained similar results in their experiments on the horse. "It can be deduced from the total experimental results that no constant relationship can be set up between the production of work and consumption of food; the entire organization of an animal, its individual and variable peculiarities and condition, &c. create great differences in the economical employment of its power in doing the same piece of work; with the same individual the quality and intensity of the work produces great differences, and further researches are required to reduce the variations in question by regular use to an individual and perhaps a typical average value."

The essential sources of muscular power are seen in the decomposition processes in the body, *i. e.* in the destruction which portions of the body or the food resorbed from the digestive tract undergo by the passage of the plasma through the tissues. To this end, as we have already seen in the case of fat-production, both nitrogenous and non-nitrogenous substances contribute.

As these materials are resolved by the influence of oxygen into simple groups of atoms, the energy of chemical force which previously linked the atoms together in more complicated groupings is set at liberty, and can be employed as kinetic energy for the external work of the body. In a condition of rest this energy serves for the internal work of the organs, or is converted into electric currents, &c. The animal body often stores up a certain amount of energy; as soon as this store has been rapidly exhausted by work, a period of rest is necessary to enable fresh material to flow through the tissue-cells and generate fresh energy for the production of more active work.

The force-production and all phenomena resulting from the combustion of organic matter in the animal body must obey the law of the conservation of energy, as was first proved by Dr. J. R. Mayer of Heilbronn.

Less work is produced as a result of the combustion of food-material in the body than that represented by its "mechanical equivalent" (1000 heat-units = 424 kg.m. of work). And, as has been already mentioned, we are not justified in regarding the animal body as comparable to an air-engine and capable of directly turning the heat which has been produced and set free into living force.

A striking discovery is that made by Max Rubner that the relative quantities of fat, albumen, and sugar required to make good the loss of material in a starving animal, as far as their "dynamic equivalent" is concerned, are practically equal to their "calorimetric" or "heat-values" as found by Stohmann, and afterwards more accurately by Rubner.

The latter found that 100 parts of fat (92400 heat-units) are equal to:—

	Directly determined from the animal.	Calculated from the heat-value.	Difference per cent.
Albumen ...	225	213 = 4424 heat-units	+5·6
Starch	232	229 = 4116 " "	+1·7
Cane-sugar .	234	235 = 4001 " "	−0·4
Grape-sugar.	256	255 = 3692 " "	+0·4

The agreement is practically absolute in the case of the carbohydrates, not so good in the case of albumen, but still not such as to render the application of the rule doubtful—viz., that food-stuffs of equal thermal value are equivalent or isodynamic for the purposes of the vital functions.

According to Stohmann and Langbein the values directly determined by the combustion of a gram each of albumen, fat, and starch are as follows:—albumen = 5715 (according to Berthelot and André 5691), fat = 9431, and starch = 4116 heat-units. The values for fat and starch are in the proportion of 100 : 299, so that the usual factor (calculated from the oxygen required for combustion) employed for calculating the equivalent of fat as starch (2·44) is too high.

Recent determinations of the heat-value of albumen make it equal to starch, viz. 4116 heat-units, while the figure hitherto employed for albumen after the production of urea has been 4820 heat-units.

Rubner has experimentally proved, however, that the *physiological* heat-value of albumen is rather lower than this, since other decomposition products besides urea are produced in the urine, and a certain amount of its heat-value is lost in the excretions in the dung. The ultimate result is only 4386 heat-units, or 76·8 per cent. of the "gross combustion-value" of 5715 heat-units. Further, for 1 gram of dry extracted flesh this value is 4233, and for 1 gram of vegetable albumen, such as the gluten in rye or wheaten bread, only 3960 heat-units. But since other vegetable albuminoids possess a higher heat-value, and as the digested albuminoids in experiments with farm animals is determined by the difference between food and dung, and as nothing can be deducted on account of the dung constituents, for the present the heat-value of albumen in the food of both Herbivora and Carnivora can be taken as identical with that of starch—*i. e.* 4116, or in round numbers 4100 heat-units,—the same value which Rubner calculated as that of albumen in human diet containing 3 parts [60 per cent.] of animal albumen to 2 parts [40 per cent.] of vegetable albumen,

$$\frac{60 \times 4233 + 40 \times 3960}{100} = 2540 + 1584 = 4124 \text{ heat-units.}$$

Zuntz and Lehmann found the digestible material required by a working-horse in excess of that in a condition of rest, expressed in grains per 1000 lbs. of live-weight, to be as follows :—

(*a*) Walking on a level road per yard ...	0·9420
(*b*) Trotting " " " " ...	1·3725
(*c*) Going up hill per step	1·3483
(*d*) Drawing a vehicle on a level road 3500 ft.lbs., per step	1·4924

The average of (*c*) and (*d*) = 1·4203, and this multiplied by 4100 = 5823 heat-units; and as 1000 heat-units = 2968 foot-pounds, the work theoretically possible = 11,116 ft.lbs. The work done (3500 ft.lbs.) is only 31·5 per cent. of this theoretical amount.

The figures thus obtained for the work produced were considered to be rather too high by the author, as the duration of such experiments was relatively short and the consumption of food and oxygen was always greater at the beginning of a piece of work, and the horse, moreover, was somewhat disturbed by the apparatus and its surroundings.

In other experiments it has been found that the mechanical equivalent of heat in the animal body never exceeds 33 per cent. of that theoretically possible. Recent feeding experiments at Hohenheim on a horse, carried out with a dynamometer arrangement (which renders possible a more accurate measurement of the work done than formerly), have given similar results.

By the quiet and regular movement of the horse round the winch, as well as by excluding all source of interference with the extra foods supplied in addition to the food really required to keep the animal in condition, it was possible to obtain satisfactory results. Thus it was found that for every gram of food about 3850 ft.lbs. of work were produced (Lehmann found 1 gram food = 3885 ft.lbs. work), or about 31·5 per cent. of the heat was converted into work.

By "food" here is understood the digested organic matter of the food after deducting the cellulose (see later on, "Digestibility of Crude Fibre" and "Feeding of Horses"); the albuminoids and carbohydrates are taken as of equal value, and the fats multiplied by 2·40 are reckoned as carbohydrates.

Although the non-nitrogenous food-stuffs, *i. e.* Fats and Carbohydrates as well as the Albuminoids, contribute towards the production of force, still the latter have special functions to fulfil, and a certain quantity plays a highly important part in the vital processes of the body.

Many observations justify the conclusion that the albuminoids are capable of producing and making possible the production of force in the body. No one expects much work from men or animals fed on a diet poor in nitrogen, such as potatoes and rice.

Fatness of body is never considered a sign of muscular strength.

A dog fed largely on bread and fat is lazy and sleepy, while one fed on a full supply of meat is brisk and able to do hard work. A horse in hard work is given plenty of oats every day, and sometimes the highly nitrogenous food beans in addition.

The lively temperament of the Carnivora in contrast to the dull and phlegmatic attitude of Herbivora appears to be largely due to the difference in diet.

Much albumen in food increases the total energy of tissue-change in the body, and it is quite possible that a highly nitrogenous food exerts a greater stimulus towards active movement than one poor in nitrogen, and that particular muscles may be thus assisted to the performance of greater mechanical work.

A rich *supply* of food is not in itself sufficient for the production of much work, but the *apparatus* required for its digestion and the conversion of the force produced is also a necessity.

Only by a high bodily condition, a high diet of nitrogenous food, and a resulting intensity of digestion is it possible to generate sufficient energy for the production of extreme and protracted muscular exercise. Feeble folk and convalescents cannot perform as much work with the same food as powerful labourers with fully developed muscles; the former must gradually recover strength by good food and exercise before they can produce their full maximum of work.

But since the muscular activity increases the requirements of respiration, a large supply of non-nitrogenous food is required for this purpose.

A highly liberal diet is absolutely necessary to preserve the flesh and fat in the body, and at the same time to keep it in a powerful condition. An addition of fat, which is the most intense respiration material, is often a desirable addition and nearly as important as albumen; and it is a suggestive fact that the working classes have a decided taste for fatty dishes, and that oats—a food proportionately rich in fat—are recognized as an excellent food for horses.

PART II.

THE FOOD OF FARM ANIMALS.

CHAPTER I.

THE CONSTITUENTS OF FOOD.

Classification.

UNTIL recently foods were distinguished as *plastic* and *respiratory,* and a distinction was drawn between "force-producing" and "heat-" or "fat-producing" foods. The albuminoids were included in the former category, while the latter represented the fats and carbohydrates. It was considered that mechanical work used up the organs and muscles of the body and rapidly destroyed them, while the absorption of oxygen by the blood was regarded as the primary cause of the combustion of corresponding quantities of bodily substance. According to this conception the albumen in the food was solely employed in repairing the wear and tear of the organs caused by work. A supply of fat and carbohydrates was considered necessary for the appropriation of the inspired oxygen and the generation of the necessary amount of heat, as well as for the provision of material for the formation of fat. We now know, from the results obtained at the Physiological Institute at Munich, that the decomposition processes in the animal body are carried out in quite a different way, and that we are only justified in classifying the "nutrients" or food constituents according to their general characteristics, or their effect on the maintenance and growth of the animal organism.

The decomposition of material in the body does not take place because heat or mechanical work are necessary, but solely because, under the conditions obtaining in the body, complicated compounds are no longer capable of existence.

The absorbed oxygen is not the cause of decomposition, as the latter would still occur if there was no work required, or if the body could manage with less heat. Oxygen is attracted by the products of decomposition, and their quantity determines the amount equable absorbed. The resulting heat is a *secondary* phenomenon, and it is possible, in spite of the equable temperature of the body and the surrounding air, for the most variable quantities of heat to be produced according to the method of feeding and bodily condition, to be again as rapidly equalized by a corresponding loss of heat from the body.

Only a small portion of the albumen taken in the food is stored up in the cells and tissues or becomes "plastic," the largest portion mixes with the circulatory albumen and is decomposed without ever having become "organized."

Fat can be produced from albumen and may then be stored up in the organs. Carbohydrates as well as fat in the food tend to economize both albumen and fat, and under favourable conditions may effect a production and increase of fat in the body. Digestion is not limited to albumen alone, but fat and carbohydrates are also concerned, and for the growth of individual organs, as well as for the maintenance of their vital activity, water, fat, and mineral matter are as absolutely essential as albumen.

All nutrients must be considered "plastic" from this point of view, and all organic food-stuffs, albumen included, provide material for respiration by their decomposition. The distinction between "plastic" and "respiratory" nutrients is clearly erroneous, and we will content ourselves with the simple classification of organic nutrients as "Nitrogeneous" and "Nitrogen-free." The first class includes the Albuminoids and Amides, the latter the Carbohydrates and Fats.

Definitions.

Nutrient.—Any single chemical compound which influences animal growth and nutrition in a definite direction, and at the same time provides the material required, is called a "*nutrient.*"

Food-stuffs are mixtures of the different nutrients in very variable proportion, and it may often happen that a particular food-stuff may require suitable addition to adapt it to the especial needs of growth or maintenance for which an animal is being fed. We are principally concerned with the feeding of Herbivora, that is with stock-keeping; and to attain all the ends in view, it is often necessary to provide animals with a mixture of several food-stuffs, so as to secure the most favourable and profitable proportion of nutrients in the daily fodder. But before we can go into the details of Feeding, we must first familiarize ourselves with the foods of the farm in general use, and get some idea of their general composition and constituents.

The following "food-constituents" (besides water) are generally recognized :—

1. Albuminoids (nitrogenous organic substances).
2. Crude fibre (woody fibre).
3. Crude fat (ether extract).
4. Nitrogen-free extract (carbohydrates).
5. Minerals (pure ash).

We will now discuss in order their chemical composition and the way in which they are estimated in Food Analysis.

1. Nitrogenous Constituents.

These, representing the total nitrogenous organic substances in food, are calculated by multiplying the nitrogen directly determined by analysis with the factor [6·25]. Very different substances are thus included, and as not even the whole of the albumen is completely digested in the body, the amount of albuminoids present cannot be taken to represent "real food," or be regarded as a criterion of the feeding-value of a food-stuff. The albuminoids and amides are principally concerned in nutrition, while such inorganic nitrogenous substances as ammonia and nitrates have little or no significance as food constituents.

(a) *Vegetable Albumen.*

The albuminoids of plants, like those of the animal body, can be divided into three groups :—

1. Vegetable Albumen.
2. Vegetable Casein.
3. Glutens, or Vegetable Glues.

Recent researches on the albuminoids occurring in seeds by Ritthausen, R. Sachse, and others, necessitate the subdivision of groups 2 and 3.

The constituents of the group of *Glutens* are:—

(a) *Gliadin*, or *Vegetable Glue*;
(b) *Mucedin*;
(c) *Gluten Fibrin.*

They are all found in the seeds of cereals; and while wheat contains them all, the other cereals contain them singly or in pairs.

The subdivisions of the *Vegetable Casein* group are :—

(a) *Legumin*, chiefly found in the seeds of leguminous plants.
(b) *Gluten-Casein*, in oil-seeds.
(c) *Conglutin*, in lupines and sweet and bitter almonds.

Vegetable Albumen is found in all seeds, and especially in the sap of all green plants. The individual albuminoids of green plants have not yet been investigated in detail.

These albuminoids differ considerably from one another in composition, especially as to the amount of carbon (50·2 to 54·3 per cent.), nitrogen (14·7 to 18·4 per cent.), and sulphur (0·4 to 1·6 per cent.) which they contain.

Legumin and gliadin contain more nitrogen than vegetable albumen; and the vegetable albuminoids as a class are richer in nitrogen and poorer in carbon than the animal albuminoids. On this account the calculation of albuminoids by multiplying the nitrogen found by [6·25] (equivalent to 16 per cent. of nitrogen) does not always yield accurate results.

It would appear that a result more in agreement with the actual truth would be obtained in the case of the seeds of cereals, leguminous plants, and "oil-seeds" by employing the factor [6].

But as vegetable glue contains 18 per cent. of nitrogen, this factor gives still too high results for the albuminoids in wheat, and even as low a factor as [5·5] might well be employed for the albuminoids in lupines and almonds. It is very difficult to come to a definite conclusion on this point, since these researches have shown that the individual albuminoids vary in composition according to their occurrence, and a different factor is really necessary for each kind of seed and plant. Of course this is too cumbrous a process to be of practical use. In the case of the green parts of plants and roots the usual factor employed for crude albumen [6·25] is still further out of agreement with the reality.

Whether the individual vegetable albumens exercise a different nutritive effect as constituents of food, and whether under equal conditions they vary in their adaptability for flesh-formation, are questions that are still unanswered owing to the complete lack of digestion experiments in this direction.

It is clear, however, that a difference of 3 or 4 per cent. in the amount of carbon would cause a corresponding difference in the amount of fat produced from the albumen, and an albumen with a high percentage of carbon would have greater influence in this direction.

The different albuminoids also yield different quantities of such products of decomposition as Leucine, Tyrosine, Glutamine, Aspartic Acid, Ammonia, &c., and on this account they probably produce a different nutritive effect.

It cannot be granted that all vegetable albumens are equally good substitutes for animal albumen. At any rate for human beings the latter are more easily digestible than vegetable albumen. Gabriel found in his experiments on sheep at Breslau that animal albumen (flesh-meal, albumen, and casein) had a more favourable influence on flesh-production than vegetable albumen (rye, peas, and conglutin). At the same time the difference is not very great, and in some experiments at Hohenheim, and others at Kuschen by E. Wildt, it was found that no perceptible difference resulted from feeding pigs with animal or vegetable albumen. Similar results were obtained at Göttingen by Kern and Wattenberg, who compared the effect of conglutin (lupines) with that of flesh-meal on sheep. In the present state of our knowledge we are therefore forced to regard the vegetable albumens, so far as resorption and digestion are concerned, as of uniformly equal value.

(b) *Other Nitrogenous Constituents.*

Asparagus-shoots, the sprouts of leguminous seeds, certain roots and tubers, and generally all green plants in a condition of early and rapid growth, have been found to contain large quantities of different nitrogenous substances which are not albuminoids, but which must be regarded as their decomposition products, or as alteration products of the nitrogenous material in the food. These substances are the *Amides* (amides of the acids, or amido-acids), *Peptones,* nitrogenous *Glucosides,* and *Alkaloids.*

Peptones.—These hardly occur at all as food constituents, and are only found in small quantity in germinating seeds, such as malt. Kellner found in some experiments at Hohenheim that even the tender shoots and sprouts of young plants did not contain the slightest trace of peptones. At the same time, as they are so similar to albumen in their composition and relationship to the animal organism, and are produced directly from albumen by the action of the gastric juice, it is quite rational to include the two substances in the same group. It is customary to express the nitrogen in the albumen as well as that in any peptone that may be present as a single item and to distinguish it from the nitrogen existing in other forms.

Alkaloids are only rarely found in farm food-stuffs. Lupine-seeds contain *Lupinine,* but only in quantity amounting to about 2 per cent. of the total nitrogenous matter, and the amount in green lupine-plants is probably about the same.

Nitrogenous Glucosides, such as amygdaline, solanine, &c., are found in larger quantity in many plants, especially in many leguminous and oily seeds. At the same time our knowledge of their occurrence and properties is very meagre, and they can only be considered in a qualitative sense as food constituents. At the present time we can only distinguish two classes of nitrogenous nutrients, " albuminoids " and " non-albuminoids."

Amides are the chief constituents of this latter class, and the term includes all the acid amides or amido-acids which occur as crystalline organic compounds. The commonest amides met with are asparagine and glutamine, which are found in beets in conjunction with betaine, leucine, and tyrosine. Certain colouring-matters, such as chlorophyll and indigo, also occur.

Some amides are poorer, others richer in nitrogen than the albuminoids. Asparagine contains 18·66 per cent. of nitrogen in the crystalline condition and 21·2 per cent. when dehydrated; Glutamine 17·07 per cent., dehydrated 19·2 per cent.; Betaine 11·96 per cent.; Leucine 10·68 per cent.; Tyrosine only 7·73 per. cent. Other amides richer in nitrogen, such as Vernine with 24·8 per. cent and the Xanthine compounds with 36·8 per cent. to 46·4 per cent. of nitrogen, are only found in such small quantity that they represent, according to E. Schulze, only 0·1 to 0·2 per cent. of the nitrogen of the dry matter of the food. Amides with a medium percentage of nitrogen, such as asparagine and glutamine, are in such great preponderance that the non-albuminoid nitrogenous materials in all ordinary food-stuffs can be assumed to contain an average of 18 per cent. of nitrogen *.

* For the nitrogen of the usual food-stuffs expressed as albuminoids and non-albuminoids see Table III. in the Appendix.

It is known that the amides in the vegetable world are not only decomposition products of the albuminoids, but in the presence of non-nitrogenous substances, such as the carbohydrates, they continually undergo a change into albumen, and can be considered crude material for the production of albumen.

We are, however, still in the dark as to their relationship to the animal organism; we only know that very often they are produced as intermediate products in the decomposition of albumen before its final excretion as urea, and we are quite ignorant as to whether under suitable conditions a reversion to albumen is again possible. Recent researches at Proskau by Weiske, Kennepohl, and B. Schulze, and still more recently by Gabriel, on sheep, rabbits, and geese, have shown that asparagine causes an economy of albumen and increases its storage in the body, and that it acts like albumen in improving the digestion of crude protein in a diet in which carbohydrates or non-nitrogenous foods are in large excess. It also has a beneficial action on the milk-production of sheep and goats, and even when a half of the albumen in the ration was replaced by asparagine, little or no alteration resulted in the milk-supply.

Schrodt and Hansen of Kiel also observed that the albumen in the food of milch-cows could be replaced to a certain extent by other nitrogenous nutrients (in mangolds and malt-sprouts) without perceptibly reducing the quality or quantity of the milk produced. The results of work by J. Munck and C. Voit, and the more recent work of Politis and Mauthner, as also that of Zuntz and Hagemann as to the economy of albumen produced by amides, in which rats and dogs were used for the experiments, are not in complete agreement with the results obtained by Weiske.

According to the latter it made no difference, at any rate in the case of full-grown cows, whether all the nitrogen in the food was in the form of albumen or whether a part was replaced by asparagine or other amides. It cannot be supposed that this favourable action of asparagine is due to its direct conversion into albumen as in plants, but rather to its decomposition in place of albumen, whereby the demands on this valuable material are reduced. Its action as an economizer of albumen is similar to that observed with gelatin in the case of Carnivora, and both these substances must be regarded as true nutrients, although they cannot replace or be considered equivalent to albumen in all processes of the animal body.

2. Crude Fibre

is the term applied to the substance remaining after treatment of the food-stuff with dilute acid and alkali, after allowance has been made for the small quantities of mineral and nitrogenous matter which it contains. "Crude Fibre" is by no means a single substance, but invariably a mixture of cell-tissue or *Cellulose* with more or less "lignification material" or *Lignin*. Cellulose has the same percentage composition as starch and contains 44·4 per cent. of carbon; while the percentage of carbon in Lignin is much higher, varying from 52–59 per cent. and averaging 55 per cent. The composition of crude fibre obtained in this way from different sources varies considerably: the fibre of hay and cereal straw, for instance, contains 46–47 per cent. of carbon, while that of clover-hay and the straw of leguminous crops contains 48–49 per cent. of carbon, due to a larger proportion of lignin.

3. Crude Fat.

There is still more uncertainty with regard to the "Crude Fat," which is the term applied to the total matters extracted by ether from the dried substance. The ether-extract of most of the cereals and cereal products can be taken to be fairly pure fat, but in the case of all other coarse and green food-stuffs it consists of a mixture of the most various substances. Besides the fat itself, other waxy and resinous substances, especially chlorophyll, are usually present in variable quantity. These latter substances play a very different part in the digestive process, and are also practically indigestible.

Fortunately fat plays a very secondary *rôle* in the nutrition of Herbivora, and the amount of fat in most green and crude fodders is only from 1 to 3 per cent. of the dry matter.

4. The Nitrogen-free Extract

is the term given to everything in the dry substance which remains after deducting the directly determined or calculated amounts of crude albuminoids, crude fat, fibre, and pure ash. Its amount is therefore simply determined by difference. With grains and roots its nature is fairly simple, and it consists principally of starch, sugar, the so-called *pectin* substances, and occasionally mucilage, which has a similar composition and nutritive action to starch. In the case of the green and crude fodders variable quantities of gummy substances occur, and especially the lignification material (Lignin) just alluded to. This latter substance, though partly dissolved by the alternate action of dilute alkali and acid, does not appear to be capable of resorption from the alimentary canal or of contributing to the nutritive effect of food.

We shall presently see that, with the exception of fat, all the non-nitrogenous constituents of green and crude fodder which are capable of resorption have the same composition as starch, and that the non-nitrogenous constituents of food can be practically regarded as carbohydrates. The proportion of their total amount to that of the digestible albuminoids constitutes the "Albuminoid" or "Nutrient Ratio" of the food. The organic acids which occasionally occur in minute quantity do not materially affect this generalization.

5. Pure Ash

represents the "crude ash" minus the charred matter, sand, and carbonic acid it contains. The latter is first produced by the combustion of the organic matter, and its quantity often varies with the temperature at which the ash was produced and especially when much phosphoric acid or silica is present. The carbonic acid in the ash is not, from this point of view, a constituent of the plant minerals which we are at present considering.

From the foregoing paragraphs it is evident that our methods for the chemical analysis of food-stuffs, as well as our knowledge of the peculiar properties and proportion of different food-constituents, leave much to be desired. At the same time the results thus obtained are too valuable to be held in light esteem, and rapid advances on the beaten track of the science of Agricultural Dietetics forebode a future of the highest promise.

CHAPTER II.

THE DIGESTIBILITY OF FOOD.

Method of Determination.

To determine the digestibility of a food-stuff, both the food and the dung of the animal are carefully weighed and analyzed. The difference found between food and dung gives the total quantity of all or one of the digestible materials which have been resorbed from the alimentary canal and have passed into the circulation of the animal fluids. It is evident that extreme care is necessary in weighing and dispensing the food, as well as in collecting the excrement and in preparing trustworthy samples for chemical analysis. In practice a high degree of accuracy in "digestion experiments" has been reached by the help of various apparatus, such as stall-fittings and other arrangements. This accuracy is shown by the results of control experiments, and has been very marked when the animal is adapted for the attainment of exact results. Small animals are the best for this purpose. Sheep permit of a firm fixture of "excrement receptacles," whereby the dung can be collected absolutely without loss for a considerable period of time and are peculiarly suitable for such experiments.

The Time occupied in Digestion with ruminants is comparatively long. It has been found by numerous uniform observations, made in various ways, that after a sudden change of diet the remnants of the former fodder are still found in the excrement for as long as five days. It is essential on this account to precede a digestion experiment by a "preparatory" feeding of the animal for at least 7 days on the same fodder, before the excrement can be considered the direct result of the fodder and before a sample can be taken for chemical analysis.

This preparatory period is the more necessary since the fodder undergoes a much more intimate mixture in the body of a ruminant than in that of a dog or a man, in which latter the dung produced from a previous diet can often be sharply distinguished and separated from the rest by its colour or in other ways.

The process of digestion in the case of horses and pigs is more rapid than that of ruminants; but even these demand a certain "preparatory period." Ellenberger and Hofmeister found that a horse required 4 days for the passage of the food along the digestive tract and the complete excretion of the undigested residue.

Sources of Error.

The amount of solid matter digested must be *at least* equal to the difference between food and dung. The weight of the dry matter of the dung is increased by the addition of certain products, especially of portions of bile which escape resorption. Some idea of the amount of these nitrogenous substances and the consequent error in the determination of the digestibility of the albuminoids may be obtained by determining the nitrogen in the ether and alcohol extracts of the excrement, as well as the sulphur in organic combination contained in the aqueous extract. The constituents of the bile are mostly soluble in alcohol and ether, "Taurine" being the only important constituent which is not soluble in this way, though this is easily dissolved by water. Taurine is distinguished by a large percentage of sulphur (25·6), while that of the nitrogen it contains is only 11·2. In this way it is not difficult to find the extreme amount of nitrogen in the dung which may possibly be due to the presence of biliary substances.

Some experiments made at Weende by E. Schulze and M. Märcker showed that in the case of sheep fed entirely on hay this nitrogen only constituted 4 per cent. of the total nitrogen in the excrement, and equalled only 2 per cent. of that in the fodder, so that it could not cause a very considerable error in the determination of the digestibility. In the excrement of pigs, which generally receive easily-digestible food, and therefore excrete comparatively little solid matter in their dung, the quantity of biliary matter is relatively great, and tho nitrogen contained, from experiments at Hohenheim and Kuschen, amounts to $\frac{1}{4}$ or $\frac{1}{5}$ of the total nitrogen in the excrement; but owing to the highly-digestible nature of the food, only 3 to 6 per cent. of the nitrogen in the latter.

These biliary and other products can only materially affect the accurate determination of the digestibility of the albuminoids in such foods as straw, potatoes, &c., which are unusually poor in nitrogen. Besides the biliary products, the dung of animals is impregnated with gummy substances (mucin, &c.), which are due to tissue changes. O. Kellner found that 0·36 per cent. of nitrogen in dry sheep's dung was due to this source, and that a considerable source of error was thus introduced in determination of the digestibility of albumen in poor foods by the method of difference.

These facts have no bearing, however, on the calculation of the requirements of animals (feeding standards) from the results of digestion experiments, since the loss to the body by the excretion of these substances has to be made good by the food-supply.

Digestibility of Fat.

The determinations of the digestibility of fat hitherto made in digestion experiments are much less accurate than those of the digestibility of albuminoids. Most of the biliary products are soluble in ether, and as the ordinary food of farm animals contains but a small amount of fat, the estimation of these products, together with the actual fat contained in the excrement, makes it appear that the digestibility of the fat is much less than it really is, and the more so the less fat there is in the food.

In some experiments at Hohenheim on pigs fed entirely on potatoes—a food containing little fat—the total quantity of crude fat in the excrement (or, more correctly, matter soluble in ether) was considerably greater than that in the food. Thus the "fat" in the dung amounted to 9·2 and 11 grams per day, while that in the food was only 4·1 and 4·7 grams per day.

Notwithstanding this source of error, digestion experiments yield results for fat which, though not absolutely accurate, are yet to a certain extent comparable and possess a definite value in estimating the worth of the different food-stuffs.

We will next consider the general digestive ratio of green and crude fodders, when they comprise the sole food of an animal. It will suffice if we only consider the more important results in this direction, which are prominently due to the experiments of Henneberg and Stohmann at Weende, and upon which the foundations of our knowledge of the subject are based.

1. *Digestibility of Crude Fibre.*

From 30 to 70 per cent. of the crude fibre is digestible, or at any rate escapes excretion in the animal's dung. Ruminants are peculiarly adapted for the digestion of crude fibre, and can assimilate a great deal more than horses. Pigs and Carnivora, as well as human beings, are only able to digest the tender fibre found in roots and in young and juicy green food.

Cellulose.—The digested portion, or that rendered soluble in the alimentary canal, is pure cellulose, which has the same composition as starch (44 per cent. of carbon). This has been proved by determining by chemical analysis the composition of (*a*) the fibre in the food and (*b*) that in the dung, and calculating the percentage composition of the digested fibre by the difference between (*a*) and (*b*) in weight and chemical composition.

Recent researches by Tappeiner make it very doubtful whether a feeding-value in proportion to its composition can be attributed to cellulose. Cellulose is rendered soluble in the first stomach and main intestine of ruminants and in the colon of horses by the fermentative action of Bacteria and similar micro-organisms. The greater portion is resolved into fluid acids (chiefly acetic, with a certain amount of butyric and propionic acids, &c.), while a smaller quantity is given off in the form of gas (marsh-gas and carbonic acid). From 100 parts of fermented cellulose 60 parts of fluid fatty acids result, and Weiske and Fleschig have shown that the action of these acids is not a favourable one to nutrition, and that acetic acid, for instance, does not behave as lactic acid or the carbohydrates in economizing albumen and increasing the production of flesh. It would thus seem that only a half or even less of the decomposed or digested cellulose actually contributes to the nourishment of the body.

In the presence of a food rich in albumen the fermentation of cellulose is increased, as was found by feeding goats and sheep on lupines. Experiments on horses at Hohenheim showed that the digested fibre—cellulose—in the food was absolutely useless for the production of work and force by these animals, or at any rate that in the experiments in question concordant results could only be obtained by deducting the fibre from the total organic matter digested, and considering the rest in the coarse and concentrated fodder as of equal value (see "Feeding of Horses").

Zuntz and C. Lehmann, as a result of exact investigations on horses at Berlin, have shown that the labour of chewing and the general effort involved in digestion by the horse often represented a considerable proportion of the nutritive effect of the food eaten. The effort of chewing hay represents 11·2 per cent. of the total energy derived from its digestion, that of oats only 2·8 per cent.; and the operations brought about in the stomach and intestines use up still larger quantities of this energy.

Similar observations were made by Zuntz and Magnus-Levy at Munich from the results of their experiments on men; for example:—

"The work of digestion involved with a diet of bread and butter represents 10 per cent. of its nutritive value, or more than 5 per cent. of the food requirement of a man in moderate work is used in supplying energy for the assimilation of the diet in question."

In more recent experiments, Magnus-Levy has found an increase of 10 to 15 per cent. in the gaseous products of the food as a result of the labour of digestion; when dogs were fed with bones difficult to digest, this increase of gaseous products was greater than when the dogs were fed on meat.

F. Lehmann at Göttingen found, in opposition to the results of Weiske and others, that the digested fibre had a distinct influence on the economy of albumen, and that it amounted to 61 per cent. of that of starch; while in further experiments carried out in co-operation with Vogel, it was found that a food relatively poor in fibre produced a greater increase in the live-weight of a fattening beast than one relatively rich in fibre, in the average proportion of 100 : 77.

Much still remains to be elucidated in this respect; but it can be accepted as a useful generalization that as ruminants can dissolve cellulose in the first stomach, and are not affected by the effort of digestion and the production of marsh-gas in the intestines to the same extent as other animals (such as horses), the fibre in food is of more service to ruminants than to any other animals.

2. *Nitrogen-free Extract.*

A certain amount of the so-called nitrogen-free extract remains undigested or is not resorbed from the digestive tract, and is discharged in the dung.

Compensation.—It is a noteworthy fact that a *compensation* takes place between the digested portion of the crude fibre and the undigested portion of the nitrogen-free extract, especially in the case of ruminants. That is to say, these two quantities are always nearly equal, so that the *amount of the nitrogen-free extract* found by analysis is *an approximate measure of the digestibility of the total non-nitrogenous matter in the food* (crude fibre and extract taken together).

This, however, is only true in a general way and on the average. In particular cases it is sometimes found that the quantity of non-nitrogenous substance digested varies from as much as 120 per cent. to as little as 80 per cent. of the amount of nitrogen-free extract found by analysis. This variable relationship in the case of the same green or dry fodder is dependent on the percentage digestibility of the crude fibre present, or is determined by the period of vegetation at which the food in question was cut and harvested.

The younger and more tender the fodder, the smaller, as a rule, its percentage of crude fibre and the greater the proportion between the non-nitrogenous food-constituents digested and the quantity of "extract" found by analysis.

This was illustrated by some experiments at Hohenheim in which sheep were fed with green clover cut at four different periods of growth; No. 3 was clover in full bloom. The first line (*a*) gives the percentage obtained by dividing the quantity of nitrogen-free extract actually digested by the amount of nitrogen-free extract found by analysis, and the second line (*b*) gives the percentage of crude fibre digested.

	No. 1.	No. 2.	No. 3.	No. 4.
(*a*)	111·9	105·5	101·8	88·5
(*b*)	60·0	53·0	49·6	38·8

From these results and others in agreement with them, it is evident that the digestibility of fibre decreases more rapidly than that of the nitrogen-free extract, as will be clearly seen if we substitute 100 for the figures in the first row, thus:—

	No. 1.	No. 2.	No. 3.	No. 4.
(*a*)	100	94	91	79
(*b*)	100	88	82	65

"Compensation," therefore, between the fibre digested and the "extract" undigested only occurs when the food-stuff is of medium quality and it is affected by the greater or less digestibility of the crude fibre.

3. *Composition of Nitrogen-free Extract digested.*

It has been shown, by essentially the same method as that applied to crude fibre, that the digestible portion of the nitrogen-free extract has very nearly the same composition as *Starch.* We may therefore assume that with the exception of fat, all the digestible non-nitrogenous materials in the fodder are converted, like starch itself, into sugar or sugary substances, and are resorbed and taken into the circulation in that form. An exception must be made in the case of the small quantities of organic acids, either contained ready-made in the food or produced during digestion from starch, sugar, and cellulose (see p. 111).

We are thus justified in regarding all the non-nitrogenous materials in the food of Herbivora which are not fat as *Carbohydrates*, and in concluding that they must produce the same effects on the digestive process of the animal body as those experimentally verified with Carnivora fed on starch and sugar, and which have been discussed in Part I. of this book. As far as Herbivora are concerned, the only important non-nitrogenous constituents of food are fat and carbohydrates.

4. *Undigested Nitrogen-free Extract.*

The undigested portion of the nitrogen-free extract is a mixture of various substances rich in carbon, and having on the whole the same percentage composition as the so-called *Lignin* (55 to 56 per cent. of carbon as compared with 44 per cent. in starch and cellulose).

It is therefore a matter of comparative indifference, in determining the digestibility of food, whether the lignin dissolves in the acid and alkaline liquids employed in the process of chemical analysis, or whether it remains mixed with cellulose in the crude fibre as "lignification substance."

5. *The Water Extract.*

From numerous experiments executed at Weende on oxen and sheep, it has been deduced that the total quantity of solid matter that can be extracted from a fodder by boiling water—the "Water Extract"—is a measure of the digestible proportion of the Nitrogen-free extract. In single cases, however, considerable departures from this rule were observed on both sides of the average, amounting to as much as 14 per cent.

This method of judging the quality of coarse fodder has not found any general application, for the reason that no necessary connection exists between the digestible nitrogen-free extract and the substances soluble in water, since the latter includes not only non-nitrogenous matter but also larger or smaller quantities of albuminoids and ash.

The digestibility of a coarse or green fodder is generally greater the more solid matter can be extracted from it by continued boiling, and although no scientific importance can be attached to the method, it yet affords a rough and empirical guide for practical purposes.

6. *Crude Fat.*

It has already been explained (p. 103) that the crude fat, or "ether extract," of coarse fodder is a mixture of various substances, some of which are digestible and some quite indigestible. The chlorophyll or green colouring-matter of plants is soluble in ether, but seems to be quite indigestible, and the same holds good for the accompanying wax-like substances.

It is therefore to be expected that the digestibility of the crude fat will vary according to the kind and quality of the fodder. This is always greater with young and tender plants than with older ones, and it has been found that while 50 to 60 per cent. of the crude fat of clover-hay and of the straw of leguminous plants is digestible, only 30 to 50 per cent. of the crude fat of meadow-hay and of the straw of cereals is capable of digestion.

7. *Crude Albuminoids.*

The digestibility of crude albuminoids in the various kinds of coarse fodder is subject to greater variations than that of almost any other constituent. Of the albuminoids in clover and meadow-hay, a quantity varying from 35 to 80 per cent. of the total amount is digested according to circumstances.

The albuminoids are generally more easily and completely digested the greater the amount in the fodder or the closer the proportion between the albuminoids and non-nitrogenous nutrients. The quantity and quality of the crude fibre present also influences the digestibility of the albuminoids. From direct experiments on animals we know that the albuminoids in meadow-hay of average quality are about as digestible as those in average clover-hay, but that the albuminoids in the straw of summer cereals, and especially those in the straw of winter cereals, are not so digestible; while the albuminoids in the straw of leguminous plants are inferior to those in the straw of cereals in this respect.

The digestibility of crude albumen in the various coarse fodders may be further modified by the condition of the fodder as well as by the kind of animal and by the quantity of other nutrients in the fodder. I will give the results of researches bearing on these points below.

The possibility of the decay and loss of nutritive albumen in the intestines, comparable to the fermentation of cellulose (p. 111), has been recently suggested; and Tappeiner, basing his calculations on the amount of phenols (including skatol and indol), found in the urine of horses and cattle, assesses the loss of albumen from this cause at 10 per cent. of the albumen "used up," or that not reappearing in the dung. It is still open to question whether the phenols are solely produced from albumen, or whether they may not be also due to the fermentation of other complicated vegetable foods. According to Hirschler, the presence or addition of easily-digestible carbohydrates greatly reduces the decay of albumen in the intestines.

Method of Artificial Digestion.

It is of interest to know that one can obtain exact information as to the digestibility of the albuminoids of food by Stutzer's method of artificial digestion, in which the digestive process is artificially carried out by the aid of an acid-pepsin solution, obtained by adding a very small quantity of hydrochloric acid to the extract of the fresh stomach of a pig. The method was afterwards modified, the food being first treated with acid-pepsin solution and then with alkaline pancreatic extract, and the corresponding amount of fresh dung produced by the animal extracted with pepsin solution. Pfeiffer, of Göttingen, obtained results of natural and artificial digestion for sheep which agreed remarkably well. The food employed in five different experiments was as follows:—

1. Hay only;
2. Hay and Earthnut Cake;
3. Hay, Earthnut Cake, and dried chopped Turnips;
4. Lucerne Hay only;
5. Lucerne Hay, Earthnut Cake, and Turnips.

The percentage of the nitrogen of the crude albuminoids in the food remaining undigested or undissolved was as follows:—

Experiments	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Artificial Digestion	20·57	14·41	13·22	10·83	10·69
Natural Digestion	21·46	15·40	13·65	11·32	9·93
Calculated from Food *minus* Dung, without allowing for Nitrogen decomposition products in Dung	35 69	24·65	25·05	23·71	20·41

If the nitrogenous decomposition products in the dung be not recognized, the amount of undigested nitrogen in the food may appear double as much as when due allowance has been made. If we are to use figures obtained by artificial digestion in the calculation of the digestible albuminoids in food-stuffs, we must allow an additional equivalent for the products of nitrogenous decomposition which are daily discharged in the dung, and which must be made good to the body by an additional amount of nitrogenous food.

Kellner first suggested as the outcome of his experiments at Hohenheim that this allowance should be 0·4 parts of nitrogen for every 100 of dry matter digested. Although this figure has been accepted by many as a safe generalization, experiments at Hohenheim and also at Göttingen have shown that great variations may occur. For instance, it was found in the five experiments quoted above that the quantity of nitrogen in the dung soluble in pepsin expressed as a percentage of the dry matter digested was as follows:—

1.	2.	3.	4.	5.	Average.
0·505	0·455	0·445	0·720	0·450	0·515

The difference between 1 and 4 (meadow and lucerne hay) is very marked. In other researches at Göttingen on pigs, a closer agreement with the figure 0·4 was obtained, for the variations in 9 experiments were only 0·38 to 0·48. Meissl and Strohmer obtained very different results on pigs fed exclusively on boiled rice. In two cases 1704·8 grams and 1699·71 of dry matter in the food were digested, and the dung only contained 2·13 and 3·72 grams of nitrogen respectively, some of which was due to undigested food; while the nitrogen due to the decomposition products in the dung alone ought to have been 6·82 grams and 6·80 on the basis of Kellner's assumption. In a further research in which the pigs were fed on flesh-meal, rice and whey 1451·3 grams of dry matter were digested per day and only 1·66 grams of total nitrogen was found in the dung. With a diet poor in nitrogen, such as starch, sugar, or fat, the nitrogen in the dung is small. H. Reider found by feeding a dog on a diet containing 130·4 grams dry matter per day, that only 0·22 gram of nitrogen was found in the dung, and a man receiving 485 grams per day of dry matter only excreted 0·54 gram of nitrogen.

Since the bulk of the nitrogenous digestion products in the dung of Herbivora is due to Mucin (the slimy matter of the intestines), its amount is determined by the quantity and condition of the dung, and bears no definite relation to the digested dry matter of the food.

On account of these discrepancies and the doubt which exists as to whether the substances extracted from the dung by the acid-pepsin solution can really be regarded as digestion products, it would be very rash to substitute results obtained by the artificial method for those obtained by direct experiment on the animal, and to employ them for the calculation of digestion coefficients. According to the kind, individuality, and method of feeding of an animal, a certain amount of albuminoids which have escaped resorption, but which are yet soluble in pepsin, are always present in the dung.

Direct experiments on the animal are still essential for securing the influence of all those conditions which affect the practical utility of a food-stuff. From the fact that the digestibility of nitrogenous substances is not the only question at issue, but that the digestibility of the non-nitrogenous constituents is equally important, and as the determination of the digestibility of these latter substances by artificial digestion is impossible at present owing to the lack of passably satisfactory and accurate methods, the "direct" method still remains the only complete and satisfactory means of determining the digestibility of a food-stuff.

8. *Inorganic Substances.*

Phosphoric Acid.—When ruminants are fed exclusively on coarse fodder, only minute traces of phosphoric acid are contained in the urine. Only so much of the phosphoric acid seems to be resorbed as is necessary for the formation of new tissue or the production of milk, all the rest passes into the intestines. In reality, however, the Phosphoric Acid as well as other mineral substances of the food are largely resorbed from certain portions of the intestines and the excess circulates round the body in the blood and passes again into the intestines (Weiske, Wildt). On the other hand, the urine of both ruminants and carnivora is very rich in Phosphoric Acid (20–45 per cent. of the ash of the urine) if the animals are entirely fed on milk, or if they are forced by several days of hunger to exist on their own flesh and blood.

When calves and lambs are fed on a high diet of corn, their urine always contains more or less phosphoric acid. The proportion of phosphoric acid is dependent on the food-supply, and it seems to be also influenced by the amount of lime in the daily food.

The following results were obtained at Hohenheim and are in agreement for both hay and clover-hay, despite the great difference in the mineral constituents of these fodders :—

	Provided in food.	Discharged in urine.
Potash	100 parts.	95–97
Magnesia	100	20–30
Lime	100 „	(ruminants) 2–5
Sulphuric Acid...............	100 „	100
Chlorine	100 „	100
Silica	100 „	100

The other ash-constituents of food, so far as they are not retained for use in the body or employed in the production of milk, are discharged in the dung. These facts have an important bearing upon the comparison of the manurial value of the liquid and solid excreta.

While only 2 to 5 per cent. of the Lime in the food is excreted by ruminants in the urine, horses excrete 40 to 60 per cent. The amount of Potash excreted by the horse is less than that excreted by cattle, that of Phosphoric Acid about the same.

CHAPTER III.

§ 1. *Conditions affecting the Digestibility of Coarse Fodder.*

[Under this heading I will propound sundry questions of special and practical interest to which direct experiments have given a more or less clear and decided answer.]

1. *Effect of Quantity.*

The digestibility of the constituents of coarse fodder is not affected by the quantity supplied.

This has been arrived at by many experiments at Weende and Hohenheim on oxen, sheep, and horses fed on hay alone, and clover-hay or lucerne. Healthy animals under normal conditions only eat as much of a coarse fodder as they are able to properly digest. It cannot be presumed that the digestive juices act more powerfully on a small quantity of food than on a larger, as it was found at Hohenheim that the percentage digested by a sheep was just the same whether it received 1, 2, or 3 lbs. of clover-hay. Although these results have only been so far confirmed in the case of meadow- and clover-hay of good or average quality, still the same doubtless holds good for the less digestible food-stuffs such as straw, chaff, &c. This constant ratio is most important, and greatly facilitates calculations of digestible food-constituents or "nutrients," and renders possible the estimation of the actual quantity of food-stuff required for the various purposes for which farm animals are kept.

2. *Green* versus *Dry Fodder.*

The nutrients in dry fodder are as digestible as those in green fodder.

This result is apparently in contradiction to the general experience of farmers. It must be remembered, however, that this is only true provided the green fodder and hay are otherwise of exactly the same quality, that both were cut at the same time and from the same field, and that none of the leaves or other tender and especially nutritious parts were lost during the making of the hay. These conditions are never completely reached in practice, especially in the making of clover- or lucerne-hay; and as green fodder is generally used in an earlier stage of growth than that which is made into hay, a greater nutritive effect is generally observed with the former.

For the present we may leave undecided the question whether the large quantity of water which animals in milk receive in green fodder exerts any considerable influence on the amount of milk produced; and we will only conclude that the *digestibility* of the organic constituents of a fodder is in no way altered by simple drying in the air, provided no loss occurs during the process.

3. *Ordinary Hay.*

In the ordinary method of making hay, much of the tender part of the plant is lost and the reduced digestibility of the food is self-evident. The loss of dry matter often amounts to 10 per cent. or more, and Weiske and S. Kühne found that sainfoin and lucerne were reduced 4 to 5 per cent. in digestibility when made into hay *.

The loss is still greater if, as a consequence of bad weather at harvest, a repeated wetting and soaking of the fodder, and perhaps a form of fermentation, has taken place, resulting in a loss of flavour. Young plants cut before they have developed much hard fibre are most liable to this deterioration, the aftermath for instance more than the main hay-crop.

4. *Effect of Storage.*

The storing of fodder for a long time may decrease both its digestibility and flavour, even when all necessary precautions are observed, such as a dry and airy storage-place &c. This conclusion can be drawn from experiments carried out at Hohenheim, when it was found that the crude albuminoids of a sample of aftermath immediately after harvest were digestible to the extent of 62 per cent.; 3 months later 56 per cent., and in the following spring only 54 per cent. were digested by the same animal, while the digestive coefficient for the other nutrients remained practically constant. Hofmeister obtained similar results at Dresden with

* See Table II. in the Appendix, where the digestibility of coarse fodder under various conditions of growth and treatment is given.

clover-hay. The deterioration was not due so much to chemical changes in the dry matter as to the breaking off of small pieces of the more nitrogenous portions of the fodder. But whether the commonly observed deterioration of hay and straw which has been carefully stored for a season is caused by an actual alteration in chemical composition, or is due principally to mechanical loss and deterioration of flavour, can only be decided by further experiments. When the hay has not been quite dried, or has been wetted by rain, a possible reversion of Albuminoids into Amides may take place, and thus reduce the feeding-value of the food.

5. *Period of Growth.*

It is well-known that *the nutritive value and digestibility of plants varies considerably with the period of growth.*

The following results were obtained at Möckern with oxen fed on green clover:—

Time of cutting.	Percentage of crude albuminoids digested.	Percentage of crude fibre digested.
May 20th. Just before blooming	71	51
June 7th. Full bloom ...	65	47
June 20. Towards end of blooming	59	40

The variation in the digestibility of the nitrogen-free extract was insignificant.

At Hohenheim it was found with sheep that the digestibility of clover in four periods of growth decreased with maturity from 76 to 59 per cent. for crude albuminoids, and from 60 to 39 per cent. for crude fibre.

At Proskau the following results were obtained :—

	Percentage of crude albuminoids digested.	Percentage of crude fibre digested.
Young clover	78	67
Mature clover	61	49

The aftermath is always proportionately more digestible than the main crop of hay, provided both are harvested in equally favourable weather; but, as I have just pointed out, aftermath is more affected by bad harvesting and is apt to be less tasty and aromatic than good hay, and the animals are often unwilling to eat it unless auxiliary food-stuffs be added. The nutritive effect of young plants must be greater than that of more mature plants of the same kind, since they are not only more digestible but contain a higher percentage of crude albuminoids and amides than the latter. This difference often exerts a great influence on the albuminoids actually digested. The above experiments at Möckern showed that 13·9 per cent. of the dry matter of young clover consisted of digestible albuminoids, while at the end of the flowering period this was reduced to 7·8 per cent. At Proskau a value of 21·2 per cent. as compared with 8·2 per cent. was observed in a similar case. It is thus seen that the nutrition in a given crude fodder may be twice or three times greater under favourable conditions of growth and harvesting than in a bad season and wet harvest.

6. *Effect of Season, Soil, and Manuring.*

Differences in season, composition, and character of soil, as well as in the system of manuring, exert a marked influence on the nutritive value of a fodder.

The food from the same part of a field or meadow may vary greatly as to its nutritive value from year to to year. For instance, clover and hay grown on the fields of the experimental station at Hohenheim in three successive years and under equally favourable conditions was harvested and fed to sheep ("Württemberg Bastards"). The digestibility of the nitrogen-free extract was found to be 63, 67, and 75 per cent. respectively in the three years, while the albuminoids varied to a less extent, 60, 64, and 65 per cent. being digestible. In other cases the variations are still greater, and similar differences exist between food-stuffs grown in a sunny or a shaded place under otherwise similar conditions.

7. *Influence of Methods of Preparing.*

While the subdivision of grain by mashing, grinding, &c., *may further a more complete digestion of such foods by certain kinds of animals, the common methods of preparing coarse fodder,* such as scalding, steaming, fermenting, &c., appear to *have a less favourable influence than is commonly attributed to them in practice.*

Experiments on rye-straw by Hellriegel and Lucanus at Dahme, showed that when fed to sheep as silage, its digestibility was in no way increased, and similar results on a mixed ration for milch-cows were obtained by Funke at Proskau. A comparison between brown silage and ordinary hay from lucerne was made at Proskau by Weiske, which showed that while the crude fibre was 8 per cent. more digestible in the silage, the nitrogen-free extract had suffered loss to the extent of 11 per cent. and the albuminoids had also been drawn upon.

Experiments by Hornberger at Poppelsdorf showed that steaming hay, and still more turning it into sour or sweet silage, caused a loss of digestible albuminoids. In practice, however, the palatability of a food may often be very considerably increased by suitable preparation, and the animals thus induced to eat larger quantities of a fodder less to their liking in its raw state. Although the prepared food may not really contain more digestible matter, it may yet produce a greater feeding effect. The flavour of food, as many experiments and observations have shown, plays a most important part in the actual production of flesh, fat, and milk from the digestible matter in the food, and can probably modify the nutritive result. The accurate investigation of this subject by direct experiment is unfortunately fraught with difficulties.

As in the case of coarse fodder, the digestibility of concentrated food-stuffs is not increased by the method of preparation. This has been illustrated by the experiments of Kühn at Möckern on oxen fed with wheat-bran, in which he showed that boiling, scalding, fermenting by the addition of acid ferments, and treatment of the bran with acids and alkalies all reduced its digestibility to a greater or less extent. This loss principally affected the albuminoids, and to a less extent the non-nitrogenous constituents of the bran.

It was further found that various liquid preparations of the bran, given as an addition to hay in various proportions, had no influence on digestion. Stutzer showed that the digestible albuminoids in bran were reduced by scalding. It was found, however, that lactic acid and the acids of fruit, such as tartaric, malic, and citric acids, have a very favourable action on the digestibility of bran, while acetic and butyric acid were found absolutely without effect in this respect.

8. *Influence of Work.*

It has often been assumed that a keen appetite resulting from hard work enables an animal to make greater use of the food provided. That *this is not the case* has been shown by a large number of experiments upon horses at Hohenheim.

A horse weighing 10 cwt. received a constant daily ration of 11 lbs. hay, 13 lbs. oats, 3 lbs. wheat-chaff. The daily work was regulated by a capstan, and its amount during successive periods and the percentage of organic matter digested were as follows :—

Period	I.	II.	III.	IV.	V.
Work	4,200,000 foot-pounds	double.	treble.	double.	as at first.
Percentage of organic matter digested	58·7	58·6	58·7	56·4	54·8

The smaller figures for Periods IV. and V. were due to the reduced digestibility of the hay on keeping, and are not the direct result of the difference in the day's work. In a further research the same horse received $16\frac{1}{2}$ lbs. hay and 9 lbs. beans per day, and in three experimental periods the work done amounted to 5,670,000; 17,010,000; and, again, 5,670,000 foot-pounds per day. The organic matter digested amounted to 60 per cent., 58·5 per cent., and 57·5 per cent., respectively, of the total organic matter supplied in the constant ration during the three periods. These small differences evidently have nothing to do with the amount of work done. This was clearly proved in further experiments, in which each period was considerably extended, and as a longer period for collecting the excrement was made possible more reliable results were obtained. The daily ration was maintained at 13 lbs. hay, 8 lbs. barley, and 3 lbs. linseed cake; while the work in Period I. was 5,656,000 and in Period II. 10,829,000 work units. The figures given show that the amount digested during the two periods was perfectly constant.

	Organic matter.	Crude albumen.	Crude fat.	Crude fibre.	N.-free extract.
Period I.	60·9	72·6	41·6	33·9	70·5
Period II.	61·1	72·4	41·5	34·3	70·5

On the other hand, L. Grandeau and Leclerc in Paris found that the digestion of a horse was reduced by very hard work.

The reduction in the amount of the total food digested averaged 2–3 per cent., and when the same work was done at a trot instead of walking, the reduction was as much as 4–6 per cent.

This result, however, must not be considered of universal application, but only true within certain limits and under certain conditions. So long as the work done does not exceed a certain limit, and the animal is not overworked, the influence of work in increasing or decreasing the powers of digestion is so trifling as to be negligible in food calculations.

9. *Different kinds of Ruminants.*

Oxen, cows, sheep, and goats digest one and the same fodder to an equal extent. The average of a large number of various experiments on hay shows that cows and oxen can digest 2–3 per cent. more than sheep, while a still larger number of experiments on clover-hay and green clover show that it is digested 2–3 per cent. more effectually by sheep than by cattle. These small differences compensate one another. Digestion experiments with goats have given perfectly normal results.

10. *Horses.*

Of non-ruminant farm animals the horse holds the first place. Since 1876 a large number of comparative digestion experiments on horses and sheep have been conducted at Hohenheim. The results are given in a tabulated form in the Appendix (Table II.). Twelve samples of hay were fed in this way and the following results obtained :—

(*a*) *The horse digests* 11–12 *per cent. less of the dry matter of hay than the ruminants.*—This is true of the most varying samples of hay.

(*b*) *The crude albuminoids of hay are generally equally digested by both horse and sheep.*—This does not hold good with exceptionally tender and nitrogenous hay, which is better digested by sheep, while coarse, poor hay is often better digested by the horse.

(*c*) *The horse digests much less of the crude fat than the sheep.*—With easily digested kinds this difference amounts to 50 per cent., and with less digestible samples is only 25 per cent.

(*d*) *The nitrogen-free extract is slightly better digested* (7–10 *per cent.*) *by sheep than by horses.*

(*e*) Especially important is the difference in the digestibility of the crude fibre of hay by horses and sheep.—*The horse digests about* 20 *per cent. less of the crude fibre than the sheep,* or $\frac{1}{3}$ less than that digested by the sheep : this difference, moreover, so far as the albuminoid ratio is concerned, is fairly constant for all kinds of hay and is practically independent of the quality.

(*f*) It is very different if the *digestibility of individual nutrients* be calculated as a percentage of the dry matter of the hay. Of the total 12 per cent. of difference in the case of easily digestible kinds of hay [see (*a*)], crude fibre represents 5–6 per cent., the nitrogen-free extract about 4 per cent., and the crude fat 1–1·5 per cent., besides a very small amount on the score of albuminoids. In the case of difficultly digestible hay the difference is distributed as follows: crude fibre 7–8 per cent., nitrogen-free extract about 3·5 per cent., and crude fat 0·5 to 1 per cent.

(*g*) *For the horse, the "compensation" between the digestible crude fibre and the undigestible nitrogen-free extract* (p. 113) *does not hold good in the case of hay.*—As a general rule horses digest 20 to 25 per cent. less of the total nitrogen-free matter in the food (crude fibre and extract) than ruminants.

Both horses and sheep digest the crude albuminoids and nitrogen-free extract of clover and lucerne-hay to an equal extent; the difference in the case of the crude fibre in lucerne-hay is not so great as in that of hay.

On the other hand, great divergence exists in the digestibility of wheat-straw, but further experiments are required to determine its extent with sheep and horses. Concentrated food-stuffs, with the exception of the fat they contain, are almost equally digested by both animals. This has been already proved for oats, barley, maize, beans, peas, and lupines, by a large number of experiments at Hohenheim.

11. *Influence of Breed.*

As the various species of ruminants digest their food to an equal extent, we should still less expect any difference to exist between individual breeds of one and the same species. Experiments by Hofmeister at Dresden, and others at Hohenheim, have concordantly shown that Merino, Southdown, and the so-called "Württemberg Bastard" breeds of sheep digest the same food-stuffs equally well whether fed on a store diet of hay or a fattening ration. Weiske's experiments on Rambouillet and Southdown sheep at Proskau confirm this.

It is very necessary not to confuse the *digestibility* of a foddcr with its *nutritive effect*. The latter may vary greatly with different breeds, and is determined partly by the appetite and amount of food the animal can digest day by day, and partly by the whole organization of the animal, its respiration, temperament, and other hereditary peculiarities.

The actual percentage digestibility of a food-stuff has nothing to do with this; it is constant for a particular food with every breed, although it may be modified by individual digestive disturbances, which unfortunately often occur and spoil the comparison of experimental results.

12. *Age and Growth of Animal.*

Even at different ages or in different stages of growth the digestive power for any given food seems to be nearly the same, provided the animals are weaned from milk, and that the fodder is agreeable in taste and adequate in nutritive effect. This has been shown by experiments at Hohenheim on sheep of two different breeds and continued for nine months consecutively (from the fifth to the fourteenth year of their age). They received both an exclusive hay diet and a rich ration of hay and grain. Experiments at Proskau have shown that sheep from four months to two years old, or practically during the whole period of growth, digest hay to the same extent.

It is of course possible that this constant digestive power would be less marked in the case of a poor and difficultly digestible fodder. So long as young animals are capable of rapid growth they are unable to thrive on such a diet, and as they cannot eat a sufficient quantity for their proper nourishment, they must suffer from a continuance of such feeding.

13. *Individuality.*

Individual peculiarities have often a greater influence on digestion than the breed or even the species of the animal. Besides temporary disturbances of digestion and the weakness of digestion caused by old age, animals of the same species, breed, age, and live-weight often show constant differences in digestive power, though these seldom exceed 2–4 per cent. of the total dry matter of the fodder.

In single individuals striking differences of digestive power, far below those of other animals of the same age and weight, are sometimes observed.

For example, a difference of 75 per cent. in the digestibility of crude fibre, and of 7 per cent. in that of the total organic matter, was observed in one case at Proskau.

At the same time it was found that those animals of a herd which attained the greatest live-weight in a certain time on a given kind of fodder did not always possess the greatest digestive power nor produce the most live-weight from the same amount of food. The conditions of appetite and the quantity of food daily eaten are much more important factors in determining the increase of growing and fattening animals than the intensity of digestive power.

Stunted animals, or those which have been badly nourished when young (especially during suckling), generally possess a relatively weak digestive power in later stages of development. How far the latter can be improved by the mode of rearing still remains to be investigated.

§ 2. *Digestibility of Concentrated Foods and their Influence on the Digestibility of Coarse Fodder.*

From the foregoing paragraphs it is seen that the percentage digestibility of coarse fodder, so long as it is *exclusively* used, is entirely dependent on the natural properties of the dry matter it contains, and this again is determined by such conditions as maturity, weather, soil, and manuring. Other conditions, such as the quantity daily supplied, green or dry condition, the methods of preparing, as well as the kind, breed, and age of the animal, have but a slight influence on the powers of digestion of ruminants.

This is an important result and greatly facilitates the calculation of the daily ration of an animal.

It is still more important to find out to what extent the digestibility of the constituents of coarse fodder is altered by the addition of concentrated foods, and to determine the digestibility of the latter. This can be done by adding increasing amounts of auxiliary food-stuffs to a constant quantity of daily coarse fodder, and calculating, from the directly determined digestion of the mixed foods, the digestibility of the coarse fodder on the assumption of the absolute digestion of the auxiliary food; or by assuming that the digestibility of coarse fodder is quite unaltered by more or less addition of the auxiliary food, the digestion coefficient of the latter can be determined.

To condense and simplify my remarks on the latest results of feeding experiments, I have employed the term "Nutritive Ratio," or its popular equivalent "Albuminoid Ratio," for expressing the *proportion* between the *digestible Nitrogenous and non-Nitrogenous food-constituents, i. e.* between the digestible albuminoids and amides on the one hand, and the carbohydrates and the "carbohydrate equivalent" of the digestible crude fat (obtained by multiplying by the "respiration" or starch equivalent of fat [2·44]) on the other.

1. *Increase of Albuminoids.*—The addition of wheat gluten or a one-sided increase of the digestible albuminoids has absolutely no effect on the digestibility of coarse fodder. This was proved at Weende by E. Schulze and Märcker, who fed sheep with 4 ozs. and then 9 ozs. of a preparation of gluten of 78 per cent. purity, in addition to 2 lbs. of hay per head per day.

The small apparent reduction in the amount of the hay albuminoids digested (4–6 per cent.) may be accounted for by the fact that traces of gluten remained undigested. This reduction in digestibility was not observed in the case of any other constituents of coarse fodder.

2. *Nitrogenous Special Foods.*—It is a most important fact that the common "*special nitrogen foods*"

employed in agriculture (with an albuminoid ratio of 1 : 1 to 1 : 5) do not affect the normal digestibility of the coarse fodders they supplement. This has been proved by adding increasing amounts of such special foods to a constant supply of meadow or clover hay. Experiments have been carried out at Hohenheim, Möckern, and Halle, with linseed-cake, bean-meal, rape-cake, wheat-bran, and cotton-cake fed to sheep, goats, oxen, and horses. All the other special nitrogen foods, such as oil-cake, leguminous seeds, brewer's grains, brandy "slump," &c., behave similarly. It should be here observed that all concentrated food-stuffs are not *absolutely* digestible so far as the albuminoids or the other constituents are concerned, but that each constituent of every food possesses a definite *Digestion-coefficient*, which feeding experiments have shown to remain constant and independent of the quantity provided to an animal.

It appears, for instance, that the albuminoids of leguminous seeds are digested by ruminants to the extent of 89 per cent.; in linseed-cake 85 per cent. is digestible, in rape-cake and wheat-bran 80 per cent., and in cotton-cake (not decorticated) 74 per cent. The percentage of crude albuminoids digested from the coarse fodder remains the same, whether fed exclusively or with any such additions.

3. *Effect of feeding Corn.*—The effect of an addition of corn, *i. e.* the grain of cereals, which possess a medium albuminoid ratio (1 : 5 to 1 : 8), have not yet been so satisfactorily worked out.

In the case of *oats*, experiments at Dresden and

Hohenheim on sheep have shown that the addition of oats does not alter the digestibility of hay. At Hohenheim a ration of hay and oats, in the proportions 1 : 1·76, 1 : 3·09, and 1 : 3·30, gave results which, on the assumption of a constant digestibility for the hay, made it appear that 78, 78·4, and 78·5 per cent. of the albuminoids in the oats were digested. At Dresden with a ration of hay and oats in the proportions 1 : 0·18, 1 : 0·44, and 1 : 0·75, and in which the quantity of oats was less in proportion than in the Hohenheim experiments, the digestibility of the albuminoids of the oats appeared less, viz. 74, 74·1, and 67·3 per cent., in the three series of experiments. The slight differences observed are probably due to the fact that the oats used at Hohenheim had a higher albuminoid ratio (1 : 5·16) than the oats employed at Dresden (1 : 7·07). Very concordant results were obtained for all the other food constituents except for the crude fibre, which in all grain and grain-products is subject to great variations.

Similar experiments on horses at Hohenheim gave practically a constant digestive coefficient for oats fed in varying quantities. It can be safely concluded from these results *that no "depression" of the digestibility of hay is caused by the addition of grain with an albuminoid ratio of* 1 : 5 *or* 1 : 6, *and that the "depression" is first evident when the ratio falls as low as* 1 : 7 *or* 1 : 8.

4. *Carbohydrates.*—The addition of large quantities of carbohydrates, such as starch, reduces the digestibility of both the albuminoids and crude fibre of hay. This has been proved by experiments on sheep, goats, oxen,

cows, and pigs. The "depression" in the case of the albuminoids of hay is only evident when the added starch exceeds 10 per cent. of the total dry matter of the hay. It is small with 15 per cent., but considerable when the starch amounts to 25 or 30 per cent. For instance, in one of Schulze and Märcker's experiments at Weende sheep were fed on $1\frac{3}{4}$ lbs. of hay and 8 ounces of starch per head per day, and the digestion of the albuminoids was reduced from 54 to 32 per cent., or the "depression" amounted to 22 per cent. of the total albuminoids, or 41 per cent. of the digestible albuminoids. Generally the addition of $\frac{1}{6}$ part of the weight of the dry matter of the coarse fodder as starch produces a depression of digestible albuminoids amounting to 15 per cent.; $\frac{1}{4}$ of starch = 25 per cent. depression, and $\frac{1}{3}$ of starch = about 40 per cent. This depression is rather less with nitrogenous hay (clover-hay and vetches, for instance), and considerably greater with cereal straw poor in nitrogen.

The depression is reduced or completely suspended by a further addition of a highly nitrogenous food-stuff, such as linseed-cake, and to a smaller degree by bean-meal and similar leguminous products. The digestibility of the crude fibre is "depressed" to a less extent by the addition of starch, but not so seriously as to be worth consideration in food calculations.

Sugar behaves like starch, but the depression produced is generally smaller. The digestion of the "Nitrogen-free" extract and the fat of the coarse fodder is not apparently affected by an addition of starch or sugar, so long as the added food itself is completely digested. This is seldom the case, however, if the carbohydrates be given in large quantity and the fodder itself be poor in nitrogen.

5. *Roots and Tubers.*—It is not probable that any practical man would actually feed his stock with pure starch or sugar; but potatoes and many of the roots used for feeding are very largely composed of starch and sugar, and must act somewhat similarly to the pure carbohydrates when fed as an addition to coarse fodder; but as they also contain small quantities of albuminoids in addition, this action may be considerably modified.

To determine this directly, experiments were carried out at Hohenheim in which coarse fodder was supplemented in 23 cases with potatoes, and in 53 cases with roots (mangolds, sugar-beet, and turnips). If, from the data obtained in these experiments, we are to deduce figures of general and practical utility and convenience, we must bear in mind two things:—*First*, that as the object of feeding farm animals is that of *production*, this is best secured by a diet of which the albuminoid ratio is between 1 : 4 and 1 : 8. "Depression" values are therefore of prime importance in arranging such a diet.

Secondly, the depression produced by roots and potatoes affects all the rest of the food, or both coarse fodder and concentrated food-stuff, so that the latter must be generally supplied in greater or less quantity to secure a productive food-supply, *i. e.* a diet of moderate or fairly high albuminoid ratio. It is true that no such concentrated nitrogen-foods were employed in these experiments, but as the hay was of an unusually rich and digestible character, it might be well considered a mixture of coarse fodder and concentrated food-stuff. With a uniform increase of auxiliary food the depression values must also increase uniformly in proportion, and the actual experimental results can be slightly modified to correspond. In accordance with this assumption, and as a consequence of the two observations just recorded, I have compiled the following table of "depression" values for present use in practice. It should be noted that the auxiliary food is expressed in terms of the proportion of dry matter, while the "depression" values are given as percentages of the digestible constituents in both coarse fodder and the concentrated food given in addition.

	Depression Values.			
Proportion of Roots or Potatoes to Coarse Fodder.	Crude albumen.	N.-free extract.	Crude fibre.	Organic matter.
	per cent.	per cent.	per cent.	per cent.
1 : 6	5	3	4	4
1 : 4—1 : 3	10	5	7	6
1 : 2	15	7	10	9
1 : 3—1 : 1	25	10	14	12

These values are equally good for potatoes or roots. When potatoes are supplied in such quantity as to represent half as much dry matter as that in the coarse fodder, the depression values given are too high.

It should be also noted that within the limits of the rational "productive ratio" (1 : 4 to 1 : 8) for which the figures are calculated, they are rather excessive for roots with a high albuminoid ratio, and often too small for roots with a low albuminoid ratio.

It is possible to bear all this in mind in food calculations, without the necessity or even possibility of employing a special depression value for every albuminoid ratio.

It is still open to question whether definite digestion coefficients cannot be obtained for potatoes and roots as for the concentrated food-stuffs, by assuming that the digestibility of coarse fodder remains constant under all the conditions involved.

Figures obtained in this way from the results of experiments on ruminants and pigs are given in the form of a table (II.) in the Appendix, and perhaps they may be used instead of the "depression" table in calculating food ratios.

At the same time I believe that we are justified from the chemical composition of "roots" in regarding the food-constituents they contain as absolutely digestible, and on this score I give the "depression" table the preference.

From the large amount of amides which roots and potatoes contain they must be considered as exclusive purveyors of carbohydrate, or in effect non-nitrogenous foods.

Moreover, this class of food is extremely digestible, as feeding experiments with sheep have given digestion coefficients for roots and potatoes as high as 92–95 p. c., and as much as 98 p. c. of potatoes was found digestible for pigs.

Pigs possess an abnormal digestion for carbohydrates.

Experiments at Hohenheim, in which pigs were fed on barley-meal and pure starch (alb. ratio of total food 1 : 9 to 1 : 12) resulted in a complete digestion of this excessive amount of carbohydrates. No depression of the albuminoids of the barley-meal was observed with a ratio of 1 : 9, but when the ratio was as extreme as 1 : 12 a depression of 9·5 per cent. of the albuminoids of the barley-meal was found.

6. *Fat and Oil.*—No reliable and concordant results have yet been obtained as to the influence of a small addition of fat or oil on the digestibility of coarse fodder or of the total diet.

The fat in the food plays a most important part in promoting the nutritive effect of food, as evidenced by flesh, fat, milk, and power; but the old idea that an addition of linseed or rape-seed oil increased the percentage digestibility of the individual constituents of the food appears to be quite a mistake. It is very important not to give cattle a food too rich in fat, or else loss of appetite and digestive disturbances are bound to follow.

It is well to know that this undesirable result is less likely to occur when the fat is an actual constituent of the food (oil-cakes), than when the same amount of oil is separately mixed with the rest of the food. This was practically illustrated at Hohenheim by feeding sheep with a fairly nitrogenous diet to which increasing quantities of partially extracted palm-nuts and linseed were added, until the oil added had risen to 3 or 4 ounces a day per sheep, the amount of the other food constituents remaining practically unchanged.

The digestion of the food was quite unaltered by the added fat.

7. *Salt.*—I have already stated the important and essential part played by salt in the process of animal nutrition, and that salt is even more essential for Herbivora than Carnivora.

Experiments at Salzmünde, Dresden, and Proskau have shown that salt does not exercise any considerable influence on the *digestion* of coarse fodder: small variations in both directions have been observed, but under normal conditions, and with healthy animals of good digestion, salt may be taken as absolutely inactive in this respect. This has been recently decided by repeated experiments at Hohenheim on sheep and horses. As a result of the improved taste, an increase of consumption and generally improved nutrition is often produced by giving salt with food, but this must not be confounded with the percentage digestibility of the food. The latter, we have just seen, is generally a constant quantity, and is invariably so with coarse fodder.

8. *Lime and Phosphoric Acid.*—Under certain conditions (*cf.* p. 15) the addition of such mineral salts as phosphate of lime is of the highest importance for securing the best nutritive effect of the food for certain purposes, but at the same time the digestive coefficients remain practically unaltered. This is true of young cattle or mature beasts fed on a diet lacking in phosphates. Since direct experiments have shown that phosphate of lime is really resorbed from the digestive

tract, its addition must be of nutritive value if the animal body is experiencing a want of this substance.

Young cattle are often fed on potatoes, roots, grain, and grain products—foods rich in phosphate and lacking in lime, and in such cases common chalk may be more satisfactorily and economically substituted for the more expensive phosphate of lime. Weiske recommends the addition of a little chalk to a rich diet of corn, since the mineral ash of corn, oats for instance, has an acid reaction.

Except for pigs fed on American flesh-meal (the residue from the manufacture of meat extract), the practical man will rarely have occasion to specially provide potash salts or phosphates for his farm animals.

CHAPTER IV.

The Food-Stuffs.

§ 1. *Coarse and Green Fodders.*

Hay.—In the tables provided in the Appendix, giving the composition and digestibility of food-stuffs, various kinds or groups of meadow-hay are included which clearly show that the higher the percentage of nitrogen the lower the percentage of crude fibre, and while the fat and ash increase, the nitrogen-free extract remains practically constant. As with all coarse and green fodders, the greater the amount of crude albuminoids the more easy its digestion; a further characteristic of hay and similar gramineous food-stuffs is that the digestibility of the albuminoids and nitrogen-free extract varies simultaneously, while the crude fibre and fat do not exhibit such uniformity. Finally, it will be noted that the digestibility of crude fibre in all kinds of hay is proportionately high, while that of the crude fat is low.

The nitrogen in hay is not the only criterion of its digestibility and feeding value, but, as can be seen from the tabulated results, crude fibre is also an important consideration. Hay rich in nitrogen and lacking in fibre is clearly the best and most digestible, while that poor in nitrogen and rich in fibre has the least feeding value. Samples poor in both nitrogen and fibre are distinguished by difficultly digestible albuminoids and an easily digestible nitrogen-free extract, while others rich in nitrogen and fibre exhibit the opposite condition or possess a medium digestive coefficient.

The figures given in the table for the albuminoids of hay and the digestive coefficients by no means represent the extremes of variations; these can range from 6 to 20 per cent. of the dry matter, and the digestibility of the crude albuminoids as determined by feeding experiments with 38 samples of hay give a minimum of 42 per cent. and a maximum of 72 per cent. of the total amount in the hay. This admits the possibility of 2·5 to 14·4 per cent. of digestible albuminoids, an extreme variation that readily explains the commonly observed fact that different samples of hay vary enormously in practical feeding value. If consideration be given to O. Kellner's discovery of a large amount of amides in tender hay which is rich in nitrogen, these figures for digestible albuminoids must be reduced from 2·5 and 14·4 per cent. to 2 and 9·3 per cent., though the proportion between the two remains about as it was before.

We have seen that the digestibility of a food when exclusively fed to ruminants is determined by its natural or inherent properties and the chemical composition of the dry matter, and is practically independent of all other conditions, such as green or dry state, cutting up, scalding, steaming, kind and age of animal, &c.

The horse digests hay and green fodder differently from ruminants (see p. 134). The natural properties of the fodder are very different according to the conditions under which it was grown, cut, or harvested.

The first point to be considered is the *period of growth* (see p. 127). It is well known that young plants contain more nitrogen and less fibre in their dry matter, and this of a more digestible kind, than that in more mature plants during the flowering period.

Good *Pasture-Grass*, if provided in sufficient quantity, must therefore be considered a powerful and productive food-stuff, while ordinary hay harvested at the usual time must be placed in a very different category. At Weende it was found that the dry matter of pasture-grass cut while still young contained 17·5 per cent. of crude albuminoids, while hay from older plants contained only 11 per cent. Hay was harvested from a sunny pasturage at Hohenheim, one half in two cuttings, the other in one, and the percentage of albuminoids in the double cutting was half as much again (334 : 225) as in the hay from the single cutting. Similar results were obtained from a clover-meadow in Proskau :—

	Dry matter.	Crude albuminoids.
Hay in 3 cuttings gave	3927 lbs.	825 lbs.
Hay in 2 cuttings gave	3731 lbs.	534 lbs.

The results are given for a German acre (Morgen).

From these figures it is evident that hay should not be allowed to reach full maturity, but should be harvested early to secure the most digestible and useful fodder.

In the earlier periods of growth the amount of amides contained in the dry substance of a plant is generally actually and relatively greater than at the time of flowering, and in pasture-grass it is often twice or three times as much as in ordinary hay. At the same time the former nearly always contains more actually digestible albuminoids than the latter. This was shown by experiments at Hohenheim, in which fodder was cut from the same meadow during two seasons, and in each at three different times, representing an earlier and later period of growth. The fodder was carefully dried and its digestibility tested with sheep. The percentage calculated from the dry substance of the hay was as follows :—

	1874.			1877.		
	24 April.	13 May.	10 June.	14 May.	9 June.	26 June.
Crude albuminoids.	25·06	16·31	13·37	18·97	11·16	8·46
„ „ digested	19·83	11·60	9·24	13·90	8·07	4·70
Containing :—						
Amides	5·47	3·10	1·83	6·55	1·78	0·64
Crude albumen......	14·36	8·50	7·41	7·35	6·23	4·06

The amount of amides is here calculated in the same way as the crude albuminoids and albumen, that is by multiplying the directly determined amide-nitrogen with the factor 6·25. The hay harvested on the 14th of May, 1877, contained an unusually high amount of amides for its period of growth; but this must be considered exceptional and occasioned by cold and wet weather, and a previous heavy application of liquid manure.

Alpine Hay.—The best meadow-hay is harvested from sunny upland meadows, where the plants do not grow to any considerable height, but form a thick carpet of grasses mixed with nitritious and aromatic herbs. This is an especial characteristic of the real *Alpine Hay*, which produces such an extremely favourable effect, even when fed in comparatively small quantities, on young cattle and milch-cows. The amount of crude albuminoids contained in Alpine hay equals that in the best meadow-grass, and the crude albuminoids actually digested by the animals amount to 12 and 14 per cent. of the dry substance of the food eaten, with an albuminoid ratio of [1 : 4]. Such hay is in reality a concentrated food-stuff and acts as such. This valuable fodder is not always marked by an especially high amount of albuminoids, as was shown by the analysis of five different sorts of hay from the Tyrolese and Swiss Alps by Kramer and E. Schulze. The average and extreme variations calculated for the same percentage of moisture (14·59 per cent.) were as follows:—

	Albuminoids.	Crude fibre.	Crude fat.	N.-free extract.	Ash.
Average	10·94	18·37	3·81	45·30	6·99
Variations ...	10·3—11·8	16·7—20·2	3·3—4·9	43·5—46·6	4·8—8·6

The quality and digestibility of Alpine hay seem to be mainly due to the relatively small amount of crude fibre and the large amount of fatty substance. The amount of phosphoric acid in this sort of hay is very variable (3·71–9·03 per cent. of the total mineral matter). The value of a particular hay for practical purposes more often depends upon its tenderness and fineness of growth, and its aroma and flavour, than upon its chemical composition, as was clearly proved by A. Mayer's experiments with several kinds of Dutch hay. Attention must be paid to the amount of the so-called rank grasses which may be present amongst the sweet herbage, and a careful botanical examination is generally desirable to see if there are any grasses or herbs intermixed which are distasteful to the animals, or may even contain injurious substances. "Horse-tail," for instance, agrees with horses but has a disadvantageous effect upon cattle, and especially upon milch-cows.

Aftermath.—In composition and digestibility the aftermath may be ranked with first-class hay, especially when it has been dried and harvested under favourable weather conditions; but its feeding-value is somewhat diminished by its inferiority to hay in flavour and aroma. The quality of the aftermath is especially dependent upon the weather at the time of harvesting, and on this account it is more highly prized in the southern part of Germany, where the harvest falls earlier in the year, and the weather is more likely to be favourable, than in the north. The amount of depreciation which hay undergoes in a rainy harvest is proved by the fact that 20 per cent. by weight of its dry substance is lost by simple soaking in cold water. Stöckhardt examined two kinds of hay, both taken from the same meadow and mown at the same time: one sample had been dried in three days and was housed in its best condition; the other had to be left lying in the fields in alternately wet and dry weather for thirteen days before it could be gathered in. Analysis proved that the hay which had been left in the rain had lost 12·5 per cent. by weight of the total dry substance, representing at least a quarter of its original nutritive value, since the loss consisted entirely of the more easily soluble, and therefore especially valuable nutrients (2·1 parts of albuminoids and 10·4 parts of non-nitrogenous nutrients and mineral salts). After chemical examination in two instances, Märcker calculated the loss of meadow-hay through prolonged and heavy rain as 18·4 and 17·6 per cent. of the dry substance. Aftermath is far more exposed to depreciation from this cause than meadow-hay, because it contains a greater amount of easily soluble constituents, and on account of its tender and fine condition it is readily soaked, less easily dried, and more subject to fermentation and decay. Under these conditions it is not to be wondered at that the aftermath is sometimes completely spoiled, becoming mouldy and not only distasteful but even injurious to the animals. If quickly dried and harvested in favourable weather, it forms an excellent fodder.

Effects of Manuring.—It is well known that the natural properties of the soil and its manurial condition have a great influence upon the quality of the fodder produced. Hay grown on a rich soil is better, that is to say, richer in nitrogen, than that grown on a poor soil. According to observations made at Tharand, the hay from a manured meadow contained 12 per cent. of crude albuminoids, that from an unmanured meadow only 9 per cent.; and still greater differences are often noticed in the same field if the intensely green and luxuriant patches are compared with the occasional yellow-green patches of the same crop in a similar period of growth. This was shown by experiments carried out by Ritthausen at Möckern. The luxuriant growth of oats, barley, wheat, and rye contained 16·4 per cent. of crude albuminoids in the dry substance, the light patches only 10·4 per cent. An interesting analysis was carried out by Weiske at Proskau, with fodder grown upon a heavy clay soil, consisting of Timothy-grass with a slight mixture of red clover. One sample was taken from a part of the field which had been manured in the ordinary way, the other came from rank patches of the same field, where an especially luxuriant plant growth had been induced by the excrement of grazing animals. The percentage of the dry substance was found to be as follows:—

	Crude albuminoids.	Crude fibre.	Crude fat.	N.-free extract.	Ash.
Ordinary manuring.	11·0	22·5	4·2	56·3	6·0
Highly manured ...	20·3	26·6	4·8	41·3	7·0

Considerable differences will be noticed in the amounts of crude albuminoids and nitrogen-free extract; and it should be observed that with the increase of nitrogen in the well-manured plants the percentage of crude fibre is also increased, and this may perhaps slightly lessen the digestibility of the crude albuminoids. Practical experience has shown that very luxuriant fodder, grown on highly manured soil in shady places or during a very wet season, is not necessarily of high nutritive quality, though it may contain a large amount of crude albuminoids. The reason for this may be found in the relatively large bulk of the fodder, its coarseness of fibre, and inferiority of flavour; but the principal cause undoubtedly rests with the large amount of amides produced under such circumstances. Further digestion experiments are still needed on this point.

In conclusion, it will be as well to mention the changes which hay undergoes through "heating" when packed in a moist condition in a silo.

Silage.—Experiments on brown hay have been carried out by Mach and Portele (St. Michel in South Tyrol), in which the hay cut from June 19th until July 16th was placed in a large silo holding 1132 cubic yards. By the end of August such rapid decomposition had been set up that spontaneous combustion was feared; and on examination it was found that while the upper layer remained green and unaltered, lower down the hay was at first slightly, then strongly browned, and at the bottom of the silo was completely carbonized. The percentage of dry substance in the first three layers of hay was as follows :—

	Ash.	Crude albuminoids.	Crude fat.	Crude fibre.	N.-free extract.	Total organic matter.
1. Undecomposed...	5·69	12·05	3·67	27·77	50·82	94·31
2. Slightly browned	7·04	11·23	4·02	24·06	53·65	92·96
3. Strongly ,,	7·93	11·51	4·05	25·03	51·48	92·07

The percentage composition of the dry substance of green hay, calculated for the same amount of ash, gave the following figures :—

2........................	5·69	9·07	3·25	19·44	43·33	80·78
3........................	5·69	8·54	2·92	17·97	36·63	71·75

The percentage loss was therefore as follows :—

2........................	0	24·64	11·45	29·77	14·66	19·18
3........................	0	29·01	20·80	35·33	27·30	28·25

According to this, the crude fibre suffered most loss, the crude fat or ether-extract apparently the least, while the crude albuminoids and the nitrogen-free extract were reduced in about equal proportion.

§ 2. *Red Clover as Green Fodder and Hay.*

From the tables in the Appendix it is clearly seen that in clover and meadow-hay an increase in the amount of albuminoids causes a corresponding increase in the amount of crude fat and mineral matter ; and while the crude fibre diminishes, the percentage of nitrogen-free extract remains the same or is very slightly decreased.

With clover-hay the amount of albuminoids varies from 12 to 18 per cent.; that of crude fibre from 25 to 39 per cent. of the dry substance. An exception must be made in the case of very young clover, which may contain as much as 30 per cent. of albuminoids and as little as 18 per cent. of crude fibre.

The digestibility of the crude albuminoids in clover-hay increases with their quantity and the simultaneous decrease of crude fibre. The digestibility of the nitrogen-free extract in various kinds of red-clover hay is less subject to variation than that of the crude fibre, and is exactly contrary to the facts observed in the case of meadow-hay. It may also be noticed that in clover-hay the nitrogen-free extract and the fat are more, the crude fibre, on the contrary, less digestible than in meadow-hay. This is seen by mutual comparison of the digestive coefficients for inferior and average qualities of the two kinds of fodder. The variations in the digestive coefficient for crude albuminoids are as great for clover-hay as for meadow-hay, and range from 43 to 76 per cent. Crude fibre varies from 39 to 60, nitrogen-free extract from 58 to 83 per cent.

The red-clover hay which is used as winter fodder in general practice is represented by the samples in the tables marked "inferior" or "average," and often contains as small a percentage of digestible albuminoids as meadow-hay of average quality, while the amount of non-nitrogenous nutrients may be even less. An explanation of this is found in the fact that red-clover is generally cut in full bloom, and made into hay at a time when it is no longer fit for the exclusive diet of cattle on account of its small nutritive value.

The nutritive value of the fodder is still more diminished by the breaking off and loss of the leaves and other tender parts of the plant during drying and storage, so that the hay consists almost entirely of coarse bare stalks. This loss is the more important because the leaves of clover are especially nitrogenous, and the albuminoids they contain more digestible than those in the stalks. Ritthausen calculated that the leaves contained 22·3 per cent. of crude albuminoids in the dry substance, and the stalks only 12·0 per cent., so that the leaves alone represent more than half of the crude albuminoids in the whole plant.

The preparation of clover-hay in unfavourable weather is a frequent source of deterioration, for this fodder suffers from rain even more than meadow-hay, as from 25 to 40 per cent. of its dry substance can be dissolved in cold water. Clover also dries more slowly than grass, and is therefore more damaged by wet harvesting. Two samples of clover-hay were examined by Ritthausen at Möckern, which were both cut from the same field at the beginning of the flowering period: one sample had been quickly dried, the other was left to lie for a fortnight in the rain. This latter sample when completely dried was still of tolerable quality, and could be used as fodder, but examination showed that 3·8 per cent. of albuminoids, 20·6 per cent. of nitrogen-free extract, and 3·0 per cent. of mineral constituents had been lost through soaking and fermentation, making a total loss of 27·4 per cent. of the original dry matter. The percentage composition of the two sorts of clover, calculated as containing 16 per cent. of moisture, were as follows:—

	Water.	Crude albuminoids.	Crude fibre.	N.-free extract and fat.	Ash.
Not rained upon ...	16·0	14·6	25·3	36·1	8·0
Rained upon.........	16·0	15·8	37·4	23·4	7·5

The clover which had been rained upon apparently contained a higher percentage of crude albuminoids than the other; and further observations have led to the conclusion that more non-nitrogenous than nitrogenous nutrients are removed by soaking clover in water. This explains the fact so often noticed in practice, that a clover-hay apparently rich in crude albuminoids may be of little nutritive value, owing to the quantity of crude fibre and small amount of nitrogen-free extract contained, which make it extremely difficult of digestion. That an increase of crude albuminoids in red clover is by no means a necessary consequence of being soaked with rain, but that often a decrease takes place, was proved by the analyses of two samples by Baesler, one of which had been harvested without rain, while the other had been exposed to 4½ inches of rain during the space of four weeks. The percentage composition was as follows, calculating 16 per cent. of moisture :—

	Water.	Crude albuminoids.	Crude fibre.	Fat.	N.-free extract.	Ash.
Not rained upon ...	16·0	14·9	21·6	2·4	38·0	7·1
Rained upon.........	16·0	12·1	32·2	1·6	30·9	7·1

It is clear from the foregoing remarks that the plan of making the whole of the clover crop into hay, which has been recently recommended by several authorities, will never find acceptance and approval, at any rate on large farms. The risk and unavoidable loss which the hay undergoes outweighs the slight advantage which may be gained by economy of fodder and a more rational mixture of feeding-stuffs. Green clover, when fed quite young, has an excellent nutritive effect, and more than repays the loss sustained in bulk. At Hohenheim it was found that the percentage of albuminoids contained in the dry substance of red clover at different stages of growth was as follows :—

Beginning of May.	June 13th.	June 23rd.	July 20th.
23·3 per cent.	16·6	13·4	11·4

G. Kühn, at Möckern, found the following percentages :—

May 20th.	June 7th.	June 20th.
19·6	16·3	13·2

It has already been mentioned that with red clover the digestibility of the crude fibre, and of the whole of the organic matter, diminishes with the decrease in nitrogen. Even if no perceptible alteration takes place in the percentage composition of the dry matter of clover as it advances towards maturity, a considerable and rapid decrease in the digestibility of the fodder is noticeable, especially with regard to the crude albuminoids and crude fibre. Several experiments carried out at Hohenheim on sheep fed with green clover cut at different stages of growth have confirmed this view (see p. 128, and Table II. in the Appendix).

In the tables in the Appendix I have classified as "excellent clover-hay" the green fodder of red clover, fed at a time when the heads are just beginning to show. "Very good" clover-hay represents clover at the beginning of the flowering period. "Average" clover-hay is that which has been mown when in full bloom and harvested in favourable weather, while that usually saved for winter fodder comes under the head of "inferior." Such inferior samples often contain only 12–13 per cent. of crude albuminoids as opposed to 33 per cent. or more of crude fibre in the dry substance. In many places it is customary to cut clover quite early, *i. e.* as soon as it can be reaped with the scythe, whereby a percentage of 20 per cent. of crude albuminoids is ensured, having a digestive coefficient of about 75 per cent. with a corresponding value for the digestive coefficients of the other constituents.

Brown Hay and Silage, if prepared with all due precautions from red clover, lucerne, and other green fodders, forms a pleasant and agreeable food for cattle, but it is of importance to guard against overheating and the spread of mould.

To explain the changes which such fodder undergoes during its preparation, I give below the results of experiments carried out by Weiske at Proskau, as also those of an analysis of the silage of red clover (just in bloom) by Heiden. The percentages are calculated from the dry substance:—

[Dry Matter=100.]	Brown Hay.			Lucerne.	
	From the outside of the heap, almost unchanged.	Midway between outside and centre.	From the centre of the heap.	Hay.	Brown Hay.
Crude albuminoids	12·8	15·3	15·5	18·4	22·4
Crude fat	3·2	3·9	7·2	2·3	2·7
Crude fibre	26·2	27·0	28·9	34·0	37·0
Extract	47·6	42·6	37·2	38·0	28·6
Ash	10·2	10·2	11·2	7·3	8·3

[Dry Matter=100.]	Sainfoin.		Red Clover.	
	Hay.	Silage.	New hay.	Silage.
Crude albuminoids	18·6	20·4	20·0	22·1
Crude fat	2·9	6·0	5·3	9·8
Crude fibre	33·9	35·2	25·7	27·8
Extract	37·9	30·9	40·5	28·7
Ash	6·7	7·5	8·5	11·6

The changes which the hay undergoes in this process are similar to those which are caused by continued soaking with rain; that is to say, the percentage of crude albuminoids, crude fat, and crude fibre increases, while the amount of non-nitrogenous extract diminishes, although the quantitative proportions are essentially different in the two cases. It will be noticed that the amount of crude fat or ether-extract in brown hay, and still more that in silage, is materially increased; and as it is impossible that any considerable amount of additional fat can have been formed, this apparent increase must be put down to certain decomposition-products, such as lactic acid (mainly derived from the nitrogen-free extract), which are soluble in ether. The decrease of the nitrogen-free extract in brown hay and silage, moreover, is often as great as that in hay which has been much damaged by rain, but the percentage increase of crude fibre is comparatively less (see p. 158). Upon lengthened storage the crude fibre of brown hay and silage undergoes a partial change, becoming more easily *soluble*, and the whole fodder loses slightly in digestibility, but not to the same extent as hay damaged by rain. This change in the crude fibre of brown hay was shown by experiments upon sheep by Weiske. It is worth noticing that fodder which has lost much of its flavour through bad harvesting, can be made more agreeable to the animals by turning it into brown hay or silage, and it can then be used during the winter as an aromatic and digestible addition to less palatable food. This method of preparation is entirely independent of weather; and although the advantages of such fodders are undeniable, still an actual loss of substance certainly takes place, and the digestibility of the fodder is rather diminished than increased.

Silage has not been adequately tested by direct digestion experiments, but its chemical composition has been carefully determined at the experimental stations of Proskau and Breslau, in the case of silage from lupines, lucerne, and green maize; also at Bonn, for Swedish clover; and at Münster and Halle analyses of the silage of green maize, potatoes, and diffusion residue (see "Roots and tubers") have been carried out.

The changes which green fodder undergoes when made into silage are seen from the result of an experiment made upon Swedish clover by Stutzer at Bonn. The clover to the amount of 525 lbs. (containing 29·3 per cent. of dry matter) was firmly pressed down into a walled pit on June 28th, and after 128 days (November 8th) 495 lbs. of silage, containing 24·6 per cent. of dry matter, was taken out. The whole amount of dry substance and the proportion of the different constituents were as follows (table, p. 167). [It should be understood that Albumen represents the digestible, Nuclein the indigestible albuminoids.]

The total loss of crude albuminoids was 20·5 per cent., that of nitrogen-free extract, 37·3 per cent. It will be noticed that the digestible albumen and the more easily soluble non-nitrogenous nutrients, such as sugar, gum, &c., have suffered most loss; so that not only the total amount of dry substance, but also the digestibility and nutritive value of the silage has been diminished in comparison with the original green

	Dry substance.	Crude Albuminoids.		
		Albumen.	Nuclein.	Amides.
Fresh	lbs. 153·8	7·8	7·2	5·5
Silage	lbs. 121·9	4·2	6·8	5·2
Loss in lbs. ...	31·9	3·6	0·4	0·3
Loss per cent. .	20·8	45·8	5·7	5·3

	Crude fat.	Crude fibre.	N.-free Extract.	
			Easily soluble.	Difficultly soluble.
Fresh	lbs. 6·2	35·5	11·1	69·5
Silage	lbs. 9·0	33·3	—	50·6
Loss in lbs. ...	[gain] +2·8	2·2	11·1	18·9
Loss per cent. .	+46·0	6·2	100	27·2

fodder. This has been confirmed in several other cases. At Breslau, for instance, silage of lupines, lucerne, and green maize was prepared according to Goffart's method, and after 4 months a loss of 60 per cent. of true albuminoids was found, while the amides had decreased only 10 per cent. Other experiments at Münster showed that the amount of true albuminoids in green maize was 80·7 per cent. of the whole of the crude albuminoids, while in silage 7 months old the percentage was only 53·6 per cent.; and again at Halle it was observed that 71·3 per cent. of the crude albuminoids in the green plant consisted of true albuminoids, but only 50·6 per cent. in silage. From this it would seem that the amides in the silage of green fodder are more stable than the real albuminoids; but it must be remembered that the latter substance is easily changed back into the former, and much of the amides found in silage must be considered as due to this change. Further experiments have confirmed the fact that the amount of ether-extract or crude fat is often considerably increased in silage; for instance, Weiske and B. Schulze at Breslau found that the fat contained in lupine silage had increased from 4·5 to 13·5 per cent. of the dry matter, that of maize silage from 2·1 to 13·4 per cent., and that of lucerne silage from 4·4 to 8·8 per cent. This was principally caused by the formation of large quantities of lactic and butyric acids, which are soluble in ether. The quantity of these acids found in the maize silage amounted to 3·47 and 7·45 per cent. respectively, or taken together to 10·92 per cent. of the dry substance; in the lupine silage they amounted to 2·38 and 3·58, or together 5·96 per cent.

The absolute loss of organic substance varies according to the duration of the fermentation and the mode of preparation of the silage, and not according to the bulk or weight of the fodder. At Münster 7 cwt. of green maize lost 10 per cent. of the whole amount of its dry substance after being 4 to 7 months in silage; but at Breslau, where a smaller quantity (2 cwt.) was used, the loss amounted to 25·7–36·5 per cent. in four months, and at Halle experiments with a large amount (85 tons) of the same fodder showed a loss of 23·4 per cent. at the end of 6 or 7 months. It is of great importance that the green fodder should be sufficiently finely divided by chopping before being very firmly pressed down into the pit, and that air should be most carefully excluded; but even with every precaution we may conclude that the average loss in making ensilage amounts to 15–20 per cent. of the original dry substance during the six months from the middle of the summer to the end of the year. This loss is principally due to the decomposition of organic matter, especially of the more easily soluble carbohydrates and the digestible albuminoids.

This has been confirmed by further experiments carried out on a larger scale by B. Schulze at Breslau. A certain quantity of green maize, cut into pieces ½ inch long, was pressed down into a space boarded off in the centre of a silo, which was completely filled with fodder, and capable of containing 480 cubic yards. The fodder was analyzed at the beginning of October when first cut, and again at the end of five months, when the silage was found to be in good condition, of a pale straw colour, and possessing a pleasant acid aroma.

The results were as follows :—

	Percentage of dry substance.	Calculated as percentage of dry matter.				
		Albuminoids.		Crude fat.	Crude fibre.	N.-free extract.
		Albumen.	Not albumen.			
Green...........	16·83	5·13	2·62	1·85	35·95	46·22
Silage...........	15·63	3·69	3·76	7·68	32·05	43·39

Calculated from the weight in lbs. :—

	Dry substance.	As percentage of dry matter.				
		Albuminoids.		Crude fat.	Crude fibre.	N.-free extract.
		Albumen.	Not albumen.			
Green...........	1094·1	56·1	28·3	20·2	393·3	405·7
Silage...........	885·4	32·6	33·3	68·0	310·4	384·2
Loss in lbs. ...	208·7	24·5	5·0 (gain)	47·8 (gain)	82·9	121·5
Loss per cent....	19·1	41·8	17·7 (gain)	236·0 (gain)	21·1	24·0

The greatest loss therefore takes place during the first 2 to 6 months after the fodder is put into the silo, after which the decomposition of organic matter proceeds very slowly.

Latterly the preparation of so-called Sweet Silage by George Fry's method has been much recommended and widely practised. The green fodder is left to wither until the dry matter reaches 25–30 per cent.; it is then pressed into silos under a pressure of 100 lbs. per square foot, or put into presses above ground fitted with powerful screws. The heap rapidly gets hot, and to secure success the temperature should be allowed to quickly rise to 140°–160° F., and then, having been as quickly reduced to 120° by increasing the pressure, the silage should be maintained at this temperature for a considerable time and then be gradually allowed to cool.

This process results in the production of lactic acid, but no volatile fatty acids of offensive odour are formed, and the loss of organic matter by decomposition is less in the making of sweet than in that of sour silage. These two kinds of silage are otherwise very similar, and either can be obtained at will by regulating the temperature, as sweet silage is produced at a temperature of about 120°, and sour silage below that limit. If the temperature exceeds 160°, or is kept as high for too long a time, the silage becomes burnt and brown, and the albuminoids are rendered practically indigestible. This is very apt to occur if the fodder is allowed to wither to an extent represented by a percentage of dry matter as high as 30–40 per cent.

This was confirmed by experiments with sheep at

Hohenheim in 1891, in which it was found that the digestibility of the crude albuminoids in sweet silage from meadow-grass was only 27 per cent., while that of the original grass was 56 per cent.; and by deducting the amides, &c., it is seen that the digestible albuminoids had been absolutely destroyed.

Similar observations have been made by many practical men. For instance, Albert found as the result of several experiments that the digestibility of the crude albuminoids was not effected, or only to a very slight extent, when the silage had been made at a low temperature, as is often the case if the green fodder contains so much moisture that the dry substance only amounts to 12–18 per cent. But under these circumstances a change of albumen into amides and the formation of acids have taken place to a much greater extent than before and many volatile ammoniacal compounds are formed, which according to Albert can amount to 31 per cent. of the whole of the crude albuminoids.

At Bonn, Stutzer analyzed a sample of very well-prepared sweet silage together with a sample of ordinary clover-hay, harvested from the same field at the same time. He found the following percentage of dry matter, calculated for 70 per cent. of moisture (p. 173).

Even in the preparation of sweet silage a more or less marked loss of organic matter takes place, according to the way in which the operation is carried out. Independently of this, the nutritive value of the organic matter itself is diminished when a green fodder of good quality is turned into sour or sweet silage, owing to the unavoidable decomposition of the more digestible

	Crude albuminoids.	Crude fat.	Crude fibre.	N.-free extract.	Mineral matter.
Clover-hay	16·07	3·47	35·75	37·74	6·90
Sweet Silage	18·73	6·50	28·27	38·51	7·79

	In percentage of N.-free extract.	In percentage of Crude Albuminoids.		
			Albumen	
	Sugar.	Amides.	digestible.	not digestible.
Clover-hay	5·38	17·7	51·8	28·5
Sweet Silage	6·64	43·3	35·9	20·8

carbohydrates and the conversion of albumen into amides. The acidity has practically no influence on the digestibility of the food, according to experiments by Weiske at Breslau. It is not, however, advisable to feed these fodders in too large a quantity at once, and they should be supplemented by a food rich in digestible albumen. This is of especial importance in the feeding of dairy cows; but the experience of farmers all over the world has shown that oxen and fat beasts can eat large quantities at a time without injury. Lawes and Gilbert found that 65 lbs. of sour silage (red clover) with a suitable addition had about the same feeding value for fat beasts as 12 lbs. of clover-hay and 49 lbs. of roots.

In an experiment upon milch-cows carried out by L. Broekema and A. Mayer, it was found that a diet of sour grass silage, compared with the same grass fed as hay, did not diminish the amount of milk produced. If anything, it increased the amount of fat in the milk, but the live-weight of the animals decreased in a very marked manner, and they rapidly became thin. Kirchner, experimenting at Halle, found that the substitution of an equal amount of maize silage for 40 lbs. of mangolds caused no perceptible alteration in the amount of milk produced or the live-weight of the animal, but the taste of the milk was affected and the butter made from it lacked consistency and flavour and quickly became rancid. In other places, however, more favourable results have been obtained.

The preparation of silage in walled pits or silos, or, better still, in presses above ground, is to be recommended in a wet and unfavourable season, especially in the autumn, and for such fodders as green maize, &c., which dry slowly and with difficulty; but the practical experience of all farmers has been, that with moderately good weather it is more advantageous to make ordinary meadow fodder into hay.

§ 3. *Lucerne as Green Fodder and Hay.*

This plant is generally more nitrogenous than red clover, but it rapidly develops woody fibre after the beginning of the flowering period, as was seen by an experiment at Möckern, which gave the following results :—

Time of cutting.	Percentage of crude albuminoids.	Percentage of crude fibre.
April 24th.........	34·4	22·0
May 22nd	26·3	27·5
July 3rd	17·8	48·5

This is a strong argument for cutting lucerne as early as possible, and for making it into hay if it cannot be used as green fodder. In all digestion experiments hitherto made with lucerne fed to sheep and oxen as green fodder or hay, the sample used has been the very best of its kind, and the averages, as tabulated in the Appendix, are comparatively high. At the same time we may assume that the crude albuminoids of lucerne have a greater digestibility than those of red clover, even when both are equally rich in nitrogen, while on the contrary the crude fibre in the former is less digestible than that in the latter. Fairly uniform factors have been obtained for the nitrogen-free extract, and the crude fat is apparently as difficult of digestion as that in hay.

Lucerne is both absolutely and relatively rich in nitrogen, and in practice it is well to remember that when fed alone, especially when used as green fodder, there is greater danger of waste of valuable nitrogenous matter than with clover. Weiske, experimenting with sheep at Proskau, first gave direct proof of the fact that the digestibility of the solid constituents in lucerne is in no way altered by drying in the air at the ordinary temperature, *i. e.* by the simple loss of water. The possible and often unavoidable losses, however, which occur in the preparation of hay hold good for lucerne as well as red clover. If lucerne is left lying in the field for any length of time during a rainy harvest, the loss of valuable constituents is very great, as is seen by the following experiments carried out by Märcker at Halle. The first sample (*a*) was lucerne which had been harvested absolutely without loss; (*b*) and (*c*) were left in the field exposed to wind and weather for 17 and 25 days respectively. The percentages are calculated for 15 per cent. of moisture.

	Albuminoids.	Crude fibre.	N.-free extract.	Mineral matter.
(*a*)	14·2	25·5	37·1	8·2
(*b*)	13·6	28·8	35·4	7·2
(*c*)	11·3	34·0	32·6	7·1

On account of the increased percentage of crude fibre, the loss in dry matter amounted to 25 per cent. in sample (*c*); but if we take into consideration the fact that this loss principally concerned the more easily digestible constituents, and also that the flavour of the fodder had most distinctly deteriorated, we realize that the diminution of the actual value of the fodder was very great.

The high digestibility found by experiment for the crude albuminoids in lucerne-hay, as well as those in green vetches and lupine-hay, has some connexion with the relatively large amount of amides contained. In lucerne which had been cut just before flowering, and in lupine-hay cut at the end of the flowering period according to usual practice, it was found that the amides amounted to one-third of the whole nitrogenous matter, or twice as much as is usually found in ordinary hay. This is also the case with red clover, and is a general characteristic of all plants which are still in rapid growth and which put forth young leaves and shoots at the time of flowering or harvesting. Such organic nitrogenous compounds as the amides concentrate in the buds and young shoots of the plants.

§ 4. *Vetch-Hay.*

The digestibility of this fodder has been examined at Hohenheim, and the average results of six separate experiments with sheep are given in the Tables in the Appendix. The hay which was used in these experiments was of exceptional quality, having been cut as the plants were just beginning to flower and dried in favourable weather: it is therefore comprehensible that the digestive coefficients were found to be equal to those of the best clover-hay, while the percentage of albuminoids digestible amounted to 23·8 of the dry matter. Vetches rapidly develop woody fibre after the beginning of the time of flowering, and their composition changes as vegetation advances. Those which Weiske examined at Proskau must have been cut when in full bloom, as they contained 18·3 per cent. of crude albuminoids and 34·4 per cent. of crude fibre. In experiments at Waldau it was found that the crude albuminoids in the dry matter of vetches decreased from 25·4 to 13·8 per cent. between May 23rd and July 12th as the plants advanced in growth, while at the same time the crude fibre increased from 20·8 to 39·8 per cent. At the period of growth at which they are generally used as fodder, vetches have a higher percentage of nitrogen than red clover.

§ 5. *Lupine-Hay.*

The yellow flowering lupine, if cut immediately after the bloom appears, provides the most nitrogenous of all known green or dry fodders. The lupine-hay which was used in experiments with sheep at the experimental station at Köthen was cut when the pods were just beginning to form, and rather earlier than is usually the practice. The dry matter contained 27·8 per cent. of crude albuminoids, the digestibility of which was found to be 74 per cent., the same as that of vetch-hay and lucerne. The digestive coefficient for crude fibre in lupine-hay is remarkably high [74], while that of vetch-hay, which has nearly the same composition, is

[54], and that of lucerne lower still [only 38]. Lupine-hay forms an exception to the otherwise universal rule, that the amount of nitrogen-free extract in a fodder is equivalent to the amount of this substance and that of the crude fibre which is actually digested by ruminants, as the proportion of these two quantities for lupine-hay is found to be 100 : 134.

It is well known that, as a rule, lupine fodder or hay can be fed only to sheep, on account of the bitter substance it contains, to which other farm animals have a strong objection. Still, on account of the large amount of nitrogen contained, it is a very valuable fodder, and especially so as it will grow and thrive on a light sandy soil, while it considerably improves the latter. At the same time it must be fed with caution even to sheep, and should be mixed with some other kind of fodder poorer in nitrogen. Further analysis has proved that lupine-hay varies considerably in its composition, according to the conditions of soil and weather under which it is grown. The crude albuminoids contained can vary from 15 to 28 per cent., and the crude fibre from 28 to 40 per cent. The hurtful and even fatal results which sometimes follow a diet of lupine-hay, such for instance as jaundice in sheep, seem to be due to a peculiar product of fermentation (Lupinotoxin) which is formed in the plant under certain conditions of soil, manuring, weather, and storage. The evil effects of this fermentation can be neutralized by heating the lupine-hay in steam for 4 or 5 hours under a pressure of 1–2 atmospheres, or for 1 or 2 hours under a pressure of 4–6 atmospheres, and the fodder then becomes agreeable and wholesome for sheep.

6. *Other kinds of Green Fodder and Hay.*

Besides those plants which we have already considered, there are a number of others, some of which are used alone as green or dry fodder, and some of which occur as more or less important constituents of certain kinds of green fodder and hay. These plants have all been repeatedly analyzed, but, with a few exceptions, they have not yet been made the subject of direct feeding experiments, and their digestibility and nutritive value can only be approximately ascertained from their resemblance in chemical composition to other known fodders.

The so-called *Hybrid or Swedish Clover* (Alsike) is very similar in composition to red clover, but is more tender and nitrogenous, and can be cut with advantage at a later period of growth, when the plants are in full bloom. This is also the case, in a still higher degree, with *White Clover*, which however is seldom grown alone for feeding purposes, but is generally mixed with other kinds of clover and grasses.

Yellow Clover must also be considered as a valuable fodder on account of its physical and chemical constitution. *Crimson Clover*, however, rapidly develops woody fibre, and generally speaking has but little nutritive value. According to Stutzer this latter crop is best harvested at the end of May or the beginning of June, as after this time no increase of organic matter takes place. In one case the nitrogenous substances, not albumen, which on May 14th and May 24th amounted to 30·3 and 23·9 per cent. of the whole nitrogenous matter contained, had decreased to 5·0 per cent. by May 31st:

therefore at the latter period of growth more actual albuminoids were present. *Sainfoin,* so far as it has yet been analyzed, is at least as nitrogenous as red clover, and preserves its flavour and digestibility better during the time of flowering. The *Kidney Vetch* is useful for cultivation on dry and sandy soils. This plant is poorer in nitrogen than the preceding ones, but it also contains less crude fibre and does not so rapidly become hard and tough.

Another plant which is frequently cultivated on sandy soils, *Serradella,* yields a delicate and easily digestible fodder of pleasant flavour. It is distinguished from the other plants in that it preserves its nutritive value and high percentage of albuminoids up to the end of the flowering period. At the same time the crop is usually small, and as the leaves, which form the most valuable part of the fodder, are easily lost during the process of hay-making, it is not advisable to put off the cutting of serradella until too late a date, especially as a considerable second cutting may be obtained. The same may be said of *Spurrey,* which, though only used as green food, has an especially favourable influence upon the production of milk. Latterly, Sand-Lucerne (*Medicago media*) and Russian Vetches (*Vicia villosa*), as well as different varieties of the genus *Lathyrus,* such as the Wood-Vetchling (*Lathyrus sylvestris*), have been much recommended for cultivation on certain very poor and stony soils.

The tall and late flowering kinds of *Green Maize,* which yield a large grass produce when grown on a strong soil, are watery and poor in nitrogen, but the fodder is agreeable to cows on account of its richness in sugar. When fed alone, green maize is apt to have an unfavourable influence on the quality of the milk produced, on account of its low albuminoid ratio, but when supplemented with more nitrogenous green fodders it produces excellent results. Green maize is especially suited for the preparation of sour and sweet silage (see p. 170).

The early kinds of maize are richer in nitrogen and more adapted for general fodder, but they do not thrive except in warm climates, and do not yield so large a crop as the later kinds. The cultivation and use of the *Sorghum* plant as green fodder is still more confined to southern countries. *Buckwheat*, on the contrary, if grown on a light soil and sown in conjunction with some summer cereal, yields a valuable green fodder even until late in the autumn. An excellent fodder for horses is provided by the young plants of the common *Thistle*. These weeds, so injurious to the good cultivation of the land, if fed to the animals in the spring-time, are said to purify the blood.

The *leaves of Mangolds and Sugar-Beet* are moderately rich in nitrogen, but contain a large amount of water. They must be used with care, for, on account of the large amount of salts and of organic acids, such as oxalic acid, which they contain, these leaves exert a strong purgative action. On this account it is best to use them in the form of silage as an addition to other winter fodder. It was found by direct experiments at Kuschen, that a sheep digested 57 per cent. of the organic matter of silage made from mangold leaves. According to experiments at Hohenheim by O. Kellner, the amount of oxalic acid contained in mangold leaves is not so great as has hitherto been supposed. It amounted to 3·51 per cent. of the dry substance, of which 1·44 per cent was soluble in water, and this was reduced to less than a third when the leaves were made into silage. It was further found that often more than half of the soluble mineral salts escaped in the fluids which are pressed out from the silage in course of preparation, so that by this means the leaves lose their injurious action, and the quality of the fodder is improved. On the other hand, the loss in bulk is very considerable, from 20 to 50 per cent. of the original dry matter being lost in the Hohenheim experiments, and from 28 to 60 per cent. of the original nitrogenous substance. This loss is the more important because it affects the albuminoids (52 to 68 per cent.) to a greater extent than the other nitrogenous compounds. In 100 parts of nitrogen contained in the green leaves, 72 parts were represented by albumen, 25 parts by other organic compounds, and 3 parts by nitrates; while in silage 4½ months old the nitrogenous substance which remained consisted of from 48 to 57 per cent. of albuminoids and peptones, and from 43 to 52 per cent. of other organic substances which were principally amides. In other experiments silage was found to have lost 31 per cent. of organic substance in five months, and 36 to 39 per cent. of crude albuminoids and nitrogen-free extract. The care with which the preparation of silage from any sort of fodder is carried out determines to a great extent the quantity and quality of the fodder obtained, especially with regard to the crude albuminoids.

The following experiment was carried out by means of artificial digestion :—(*a*) represents the green turnip-tops as analyzed in the autumn, (*b*) silage prepared in a well-lined and covered pit, (*c*) silage badly preserved in an earth-pit; both these last were analyzed in March. The percentage of crude albuminoids in the dry substance was as follows:—

	Digestible.	Indigestible.
	per cent.	per cent.
(*a*) Leaves.........................	15·18	6·13
(*b*) Silage well made	11·62	8·00
(*c*) Silage made in earth-pit ...	2·93	12·00

According to these figures the original amount of indigestible albuminoids alone remained absolutely unaltered; in (*c*) half of the original dry matter had disappeared, therefore the percentage of indigestible albumen had been doubled. The digestible albumen, including the amides, had been gradually destroyed through decay, and the nitrogen had evaporated in the form of ammonia, &c.

Carrot-tops and *Swede-tops* have not the same injurious effect as mangold leaves or only to an insignificant extent, and practical experience has shown that *Cabbages* form excellent food for milch-cows. *Potato-haulm* hardly comes into consideration as fodder, and experiment has proved that it is highly indigestible. The leaves and tender parts of *Artichoke* stems, on the contrary, are readily eaten, and with good results, by sheep. The same may be said of the *leaves of trees,* which contain an average amount of nitrogen and very little crude fibre, this last amounting hardly to 10 or 12 per cent. of the dry matter, while the fatty substance (ether extract) has been calculated as 10 per cent. The leaves most generally used as fodder are those of the poplar, lime, ash, willow, and elder, also vine leaves, and, in Italy, mulberry leaves in the autumn; birch and beech leaves are supposed to be less wholesome, and green pine needles have often a distinctly injurious effect. The leaves of the yew-tree are so poisonous that it has been calculated that 5 to 6 ozs. would quickly kill a strong horse. Those leaves have the greatest nutritive value which have been gathered from the trees in July and August, but poplar foliage has been proved to be fairly easy of digestion even as late as the beginning of October. According to experiments by Wildt at Kuschen, 58 per cent. of the whole organic matter, and 56 per cent. of the crude albuminoids contained in poplar leaves were digested by sheep.

The value of *Brushwood* fodder has been recently insisted upon *. According to Ramann's analyses, young twigs about ½ inch in diameter are richer in nutritive substance in the winter than in the spring, especially as regards the crude albuminoids and starch, the former varying in beech twigs from 5·6 to 3·1 per cent., in birch twigs from 6·1 to 4·1 per cent. of the dry substance.

The brushwood, containing about 62 per cent. of dry matter, was first pounded and chopped to pieces, mixed with 1 per cent. of malt, and then hot slump or bran-mash was poured over it and left to ferment. The

* See Dr. Ramann and Jena-Köthen, 'Holzfütterung und Reisigfütterung,' Berlin (Springer), 1890.

temperature may rise to 140–160° in two or three days, but it is better if it only rises to 130–140°. It was fed to horses to the amount of 6 lbs., oxen received 16 lbs., and sheep 1 lb. each per day. In experiments carried out by Ramm at Poppelsdorf, milch-cows received as much as 39 per cent. of the dry matter of their whole ration in the form of brushwood fodder, prepared from beech brushwood. 123 pounds of this fodder was found capable of producing as much milk as a mixed feed of 18 lbs. of hay, 33 lbs. of chaff, and 88 lbs. of mangolds, if the small amount of digestible albuminoids contained in the brushwood was made good by an addition of 4 lbs. of earthnut cake.

At the same time, no great future can be predicted for brushwood as fodder, for it would only prove remunerative in those cases where it can be obtained cheaply, as in the neighbourhood of forests, and in a season when fodder and litter are scarce. Young shoots of trees cut with the leaves and fed to cattle in July or August have an excellent nutritive effect.

Brushwood fodder varies considerably in nutritive value and effect, according to the diameter of the wood, the kind of tree, and the time of cutting, as has been proved by digestion experiments with sheep, carried out by Lehmann at Göttingen. Older branches of beech brushwood and young acacia branches were both cut in the winter-time. The former contained 4·7 and the latter 11·3 per cent. of crude albuminoids in the dry substance, and the amounts digested were 11·5 and 36·0 per cent. respectively of the whole dry substance, 16·2 and 55·8 per cent. of crude albuminoids, and 16·4 and 47·4 per cent. of nitrogen-free extract. Poplar brushwood and foliage, cut in July, was digestible to the extent of 42 per cent. of the dry substance.

The digestibility of the fodder is rather injured than improved by pounding and fermenting, though its flavour may be improved in the process. According to experiments with artificial digestion by Stutzer, the crude albuminoids in the beech brushwood fodder prepared by Ramann are far less digestible than those in fodder from acacia brushwood, being respectively 28 and 64 per cent., while those in pine and elder brushwood are digested to 41 and 50 per cent.

Meadow-Grasses, such as rye-grass, timothy grass, and cocksfoot, all yield a nutritious fodder when young, and cereals when cut before the flowering period are only inferior to pasture-grass in point of flavour. The choice of grasses for cultivation is naturally determined by the quality of the soil, climate, hardiness of the plants, amount of produce expected at harvest, and other practical conditions and considerations. Grasses cultivated in the fields, and especially those grown in a strongly-manured soil, seem to be richer in amides than ordinary meadow-grass at the same period of growth.

§ 7. *Straw of the Cereals.*

The straw of the summer cereals is, on the average, poorer in crude fibre but somewhat richer in crude albuminoids than that of the winter cereals. Among the former, the straw of oats has been most satisfactorily investigated with regard to digestibility. According to experiments by Henneberg and Stohmann in Weende with oxen fed with oat-straw alone, the digestive coefficients for the crude albuminoids were found to be 44 and 39; but experiments upon sheep at Hohenheim gave a much lower number, 24: though the oat-straw contained very nearly the same amount of crude albuminoids. In the latter experiments the straw was hard of stem and had been grown in drills. The average digestive coefficient of the crude albuminoids in oat-straw can hardly be higher than 35: the crude fibre is quite as easily digested as that in good meadow-hay, but the nitrogen-free extract and the crude fat are decidedly less digestible. Few experiments have as yet been tried upon the digestibility of barley-straw. Wildt found that the digestive coefficient of the crude albuminoids was exceptionally low, but the straw which he used for the experiment was fully ripened, containing 4·8 per cent. of crude albuminoids in its dry substance. Nevertheless, 54 per cent. of the nitrogen-free extract and 56 per cent. of the crude fibre contained were digestible, and it is likely that the percentage digestion of the crude albuminoids may often be higher. This straw may prove to be a valuable fodder, especially as it is usually mixed in considerable quantity with young clover or other green fodder.

Similar digestive conditions obtain for the straw of winter cereals, though the digestive coefficient, and especially that of the crude albuminoids, is generally lower. The crude fibre is nearly as digestible as that in the straw of summer cereals.

§ 8. *Straw of Leguminous Plants.*

The digestive coefficients given in the Appendix for the straw of *field beans* are taken from experiments made at Weende and at Proskau. In this straw, as in clover-hay, the crude fibre is relatively indigestible, but the nitrogen-free extract is comparatively digestible. Further experiments were carried out at Hohenheim upon *pea-straw* (luxuriant haulm) containing 11·4 per cent. of crude albuminoids and 44·2 per cent. of crude fibre in its dry substance. The haulm was fed to sheep, and the substance actually digested had the composition of good clover-hay, containing 14·0 per cent. of crude albuminoids and 31·9 per cent. of crude fibre. It is thus comprehensible that the digestive coefficients were correspondingly high (60 per cent.) for crude albuminoids, 52 for crude fibre, and 64 for the nitrogen-free extract.

That the ripe straw of *Soja beans* is similar in composition and digestibility to bean-straw has been proved by experiments at Proskau. Generally speaking, the crude fibre is more difficult to digest in the hay and straw of leguminous plants than in those of the cereals, the nitrogen-free extract easier; but, as we have seen, an exception must be made in the case of lupine hay and straw.

In an experiment at Köthen, the lupine-straw used contained 7·0 per cent. of crude albuminoids and 48·6 per cent. of crude fibre in its dry substance, and was apparently well ripened; the digestive coefficients obtained were 51 and 65 for crude fibre and nitrogen-free extract respectively, and 37 for the crude albuminoids. The amount of nitrogen-free substance digested considerably exceeded the amount of nitrogen-free extract determined by analysis, in the proportion of 127 : 100 (compare p. 179).

§ 9. *Chaff and Husks of the Cereals and Leguminous Plants.*

Wheat-chaff usually contains a higher percentage of crude albuminoids than wheat-straw, but the chaff of such summer cereals as barley and oats is, on the average, poorer in nitrogen than the straw of these plants. The chaff and husks of such leguminous plants as peas, vetches, and beans are at least as rich in crude albuminoids as the straw. Chaff of all kinds is generally poorer in crude fibre than straw, and the digestive co-efficients for the different constituents will probably be correspondingly high, but no direct experiments have yet been made on this point. At the same time the mechanical composition of chaff makes it a more pleasant and agreeable fodder to the animals than straw, when fed in fair quantity. Rape husks are comparatively poor in nitrogen, but rich in nitrogen-free extract. It has been found that the crude fibre and the nitrogen-free extract in the pods of Soja beans are more easily digested, and the crude albuminoids less so, than those in the straw of the same plant.

CHAPTER V.

CONCENTRATED FOOD-STUFFS.

This term is applied to those food-stuffs containing a relatively large amount of digestible substance in a small bulk, and which are mostly purchased from outside the farm. The nitrogen-free extract of such foods is largely composed of carbohydrates, and the percentage of fat and albuminoids is often a high one.

§ 1. *Cereal Grain.*

In the first place, grain varies as much in composition as the coarse and green fodders we have just considered, and particularly is this evidenced by the amount of crude albuminoids, which varies between wide limits and is influenced by the general conditions of growth and harvesting [*i. e.* soil, manuring, climate, season, variety, maturity, &c.].

Wheat and oats seem to be more influenced by these conditions than either rye or barley. The dry matter of wheat contains albuminoids which have been found to vary from 10 to 24 per cent. Preussler obtained the following results as to the albuminoids in a highly nitrogenous variety of wheat under varying manurial conditions.

Manures applied.	Crude albuminoids in Corn, per cent.	Crude albuminoids in Straw, per cent.
Unmanured	16·3	3·4
Superphosphate	17·6	3·7
Nitrate and Ammonia Salts...	21·4	—
Phosphates and Nitrogen manures.....................	22·4	5·2

Other experiments have failed to give such decided evidence of the effect of manuring on the composition of cereal crops, because such factors as the nature of soil or weather have intervened and veiled the true influence of the manurial treatment.

It is safe to conclude that cereal crops grown on a rich soil will be richer in nitrogen than those grown on moderate or poor land indifferently manured.

Wheat and *Rye* have not yet been investigated by direct digestion experiments, but there is little risk of error in assuming for them the factors already established for other cereals. It would thus appear that 95 per cent. of the nitrogen-free extract and 85–90 per cent. of the albuminoids in wheat and rye are digested by farm animals, if fed under favourable conditions and properly prepared. The results obtained for *Oats* by digestion experiments gave an average digestibility of 77 per cent. for crude albuminoids and 73 per cent. for the nitrogen-free extract; the same determinations in the case of *Barley* gave 77 to 87 per cent.; and values of 79 to 91 per cent. were obtained for *Maize*. Experiments on maize at Hohenheim and elsewhere have given higher values (85 and 95 per cent.) for its digestibility in the case of pigs. Sheep fed on *Wheat and Spelt bran* digested 78 per cent. of the albuminoids and 82 per cent. of the "extract." By feeding oxen on dry wheat-bran, Kühn obtained values for the albuminoids varying from 71 to 89 per cent., and from 70 to 82 per cent. for the "extract," and found that various methods of preparing the bran rather reduced than increased its digestibility (*cf.* page 129).

Experiments at the Dairy Station at Kiel showed that wheat-bran was an excellent food for milch-cows, and yielded far better results in milk and butter than a diet of rye-bran, and was even superior to a diet of rye-, oat-, and barley-meal in equal proportions. The effect of bran on pigs is quite different, for, like human beings, the pig finds bran difficult of digestion.

Samples of wheat-bran or "middlings" are often sold which contain considerable quantities of *Corn-cockles.* As corn-cockles have a bitter taste, animals generally refuse a food which contains them in quantity. It has been shown that they are not poisonous, as generally supposed, at any rate for pigs, as these animals ate them eagerly and with good results. Even when barley-meal contained 40 and 70 per cent. of corn-cockles, no evil effect was observed with the pigs.

A "digestion" experiment on pigs showed that for the production of 100 lbs. of live-weight little more food was requisite with this mixture than with barley-meal in a state of purity, and the flesh produced by the diet containing corn-cockles was of perfectly normal composition and quality. A diet containing 40 per cent. of corn-cockles was found to have no visible bad effect on young pigs. At the same time we can hardly assume that, apart from their bitter taste, corn-cockles are absolutely harmless for other animals, such as milch-cows for instance.

Rice-meal is obtained in large quantity as a by-product from rice-mills. A good sample contains 12 per cent. of albuminoids, 12 per cent. of fat, and 50 per cent. of starch, and serves as an excellent and easily digestible food for pigs, or favours the production of first-rate milk and butter when fed to cows. Great care must be exercised in buying rice-meal, as it is frequently adulterated to a very large extent with gypsum and chalk. Samples sold as "Rice-meal" or "Rice Middlings" often contain such a large amount of hard, indigestible rice husks (even less digestible than ordinary cereal straw or chaff) that they are not really concentrated food-stuffs at all, but ought to rank and be sold as coarse fodder.

Oats are comparable to wheat in the marked variation in the percentage of nitrogen they contain. This variation depends on the thickness of the husk and the proportion of husk to grain. The latter is generally rich in nitrogen, and especially so in fat (4–7 per cent.). The quality of a sample of oats cannot be simply estimated by the weight per bushel, and it would always be advisable in buying any quantity of so valuable a food-stuff to have it analyzed first. It is still an open question whether the excellent feeding-effect of oats on horses is due to a stimulation of the nervous system by a peculiar substance contained in oats which has been called "Avenin;" and it is still more uncertain whether the increased milk-production of cows fed on oatmeal is due to the same cause. After grinding or pulverizing, the stimulating effect of oats is somewhat reduced.

Barley is not so rich in nitrogen as the other common cereals, and the more uniform and developed the grains the poorer they are in nitrogen.

Buckwheat and *Maize* contain still less nitrogen, and the amount is subject to considerable variation. The high percentage of fat in maize (5–8 per cent.) may partially account for its excellent fattening qualities, especially for pigs. It has also proved a good food for horses, and if supplemented with bean-meal a desirable, *i. e.* medium, albuminoid ratio can be obtained. The great Paris Omnibus Company has tried replacing half the oats usually provided for the horses by crushed maize (including the cobs), with most excellent results. The cobs provide the cellulose lacking in the maize, and the two together are equivalent in composition and feeding-value to oats. The New York Omnibus Company give each of their horses 14 lbs. of maize a day; while the Berlin Tramways Company supplement 3 lbs. of oats with 15 lbs. of maize per horse per day, with most satisfactory results. Maize has proved an excellent food for horses doing hard and regular work at a moderate pace, but is less suited for hunters or light hacks.

Brewers' grains only contain 20–24 per cent. of dry matter. As the albuminoid ratio is high and the animals appreciate the aromatic flavour, they are a most valuable food for fattening and especially good for producing milk. Brewers' grains have been recently placed on the market in a *dry* condition, and on account of their concentration, convenience for transit, good keeping qualities, and low price, are to be highly recommended as a food-stuff. Experiments at Halle have shown that dried grains are as good as fresh grains for feeding purposes, and that as much as 12 lbs. per day per 1000 lbs. live-weight can be given to cows, with a decided increase in milk-production. Other investigations have shown that if the "grains" are heated above 90° C., or the juice be previously expressed, valuable food material is lost and the amount of digestible albuminoids reduced.

Gluten obtained as a by-product in the manufacture of wheat starch is an excellent food for pigs. It is also to be met with in the market as a dry, brittle mass, in which form it is eagerly eaten by sheep, and for fattening purposes serves as a valuable addition to a food lacking nitrogen.

Malt-sprouts is a favourite food for young cattle, cows, and fat beasts. Its nitrogenous composition places it in the same category as leguminous seeds and oil-cakes. Considerable quantities of amides, however, varying from 23 to 36 per cent. of the total nitrogenous substance or amounting to about 4 per cent. of the dry matter of malt-sprouts, have been observed. When supplied in quantity not exceeding 4 to 6 lbs. per 1000 lbs. live-weight, malt-sprouts acts as an excellent milk-producing food; quantities exceeding 10 lbs. per day are very apt to cause a cow to slip calf.

The good feeding-effect of this food-stuff is often considerably reduced by the presence of dust and dirty sweepings, and care is necessary to avoid such impure samples of an otherwise valuable food.

§ 2. *Leguminous Seeds.*

The variation in the amount of albuminoids is less marked with leguminous seeds than with the cereals, as it lies between 22 and 30 per cent. of the dry matter. Beans and vetches are usually richer in nitrogen than peas. *Lupines* contain an exceptionally high percentage of albuminoids (from 32 to 48 per cent. of the dry matter), and the seeds of yellow lupines are richer in nitrogen than those of the blue and white species. Lupines are possessed of a peculiar bitter taste, and are disliked by all farm animals except sheep. As lupines will grow vigorously on an arid sandy soil and can be bought extremely cheaply despite their richness in nitrogen, it is not surprising that many attempts have been made to remove the objectionable bitter taste and to make lupines a possible food for other animals than sheep and goats.

This can be achieved by steaming the lupines for an hour and then repeatedly soaking them in water. O. Kellner has tested this method at Hohenheim by scientific experiments with sheep, horses, and cows, and found that the "sweetened" lupines had an excellent effect and largely increased the production of milk. A comparative test with beans resulted in favour of the lupines. At Halle, they found that all farm animals ate the sweetened lupines with relish and the best results. Many other methods for sweetening lupines have been brought forward and carefully tested. All processes involve a considerable loss of dry matter from the plants, which Gabriel found to amount to 15 or 20 per cent. The nitrogen-free extract and mineral constituents suffer to the extent of 45 to 65 per cent., while the loss of albuminoids in the process only amounts to 5 or 10 per cent. of that originally present in the lupines. The residue, especially if Kellner's process be employed, is, if anything, more digestible than before. This process has proved the best not only because it involves least loss, but on account of its simplicity. Whether it is possible, *i. e.* practicable, to further reduce loss by omitting the steaming and simply soaking for 3 or 4 days in cold water, as has been suggested, requires further experiments for decision.

RESULTS OF DIGESTION EXPERIMENTS.

No. of Experiments.	Percentage of Albuminoids digestible.	Percentage of N.-free extract digestible.
Bean-Meal:		
18 (on Ruminants)	81–95	88–95
Average....................	88	92
On Horses..................	86	93
Peas-Meal:		
Pigs (fed exclusively) ...	85	95
Lupine Seeds:		
Sheep (fed with rye-straw as well)	97	81
Sheep (fed with hay as well)	92–94	84–89
Goats	90	—

Schulze found in one experiment that the loss of dry matter by soaking lupines in cold water without a preliminary steaming amounted to only 5 to 11 per cent., while only 1 to 5 per cent. of the albuminoids, 15 to 20 per cent. of the nitrogen-free extract, and 4 to 7 per cent. of the mineral constituents had been lost. At the same time the bitter alkaloid had been reduced from 0·36 per cent. to 0·078 and 0·04 per cent. Gabriel found that steaming lupines in an autoclave at 140° C. reduced the digestibility of the organic matter from 81 to 68 per cent., and that of the albuminoids from 87 to 67 per cent.

Stohmann found that lupines increased the digestion of the non-nitrogenous constituents of hay, and the same result was observed for crude fibre in some experiments with sheep at Hohenheim.

The generalization deducible from these figures is, that about 90 per cent. of the albuminoids of leguminous seeds is digestible, while that of the nitrogen-free extract is rather lower.

Soja Beans (Chinese oil-beans), which have been recently cultivated in many parts of Germany, are distinguished by a high percentage of albuminoids (33·4 per cent.) and of fat (17·6 per cent.). Experiments at Vienna in which pigs were fed with potatoes and 2½ to 3 lbs. of Soja beans per day gave highly satisfactory fattening results. Sheep, oxen, and cows have been found to flourish when Soja beans were added to a diet otherwise poor in fat and nitrogen.

Acorns and *Horse-Chestnuts* are poor in fat and nitrogen, but rich in easily digestible starch (especially acorns), and 88 per cent. of the total organic matter was found digestible for sheep. Pigs are well known to eat acorns greedily, and even sheep and oxen will willingly eat acorns and horse-chestnuts in the form of meal.

§ 3. *Oil Seeds and Cakes.*

Oil-seeds, such as Linseed and Rape seed, containing 30–45 per cent. of fat are not often fed as such, though the smaller kinds of linseed are sometimes used as an addition to a food lacking fat with excellent results, provided the amount of fat is not so excessive as to disturb the animal's digestion.

In the first place, few direct determinations of the digestibility of oil-seeds have been made.

Results obtained at Hohenheim indicated that the digestibility of linseed was as nearly as possible the same as that of the cake obtained from it. Many digestion determinations have been made on *Oil-cakes,* such as Linseed cake, Rape cake, Cotton cake, Palm-nut cake (extracted Palm-nut meal), Coconut cake, as well as Earth-nut, Sesame, and Sunflower-seed cakes. The results given in the table (see Appendix) for *Linseed cake* are the average of experiments on sheep, goats, and oxen at Hohenheim, Halle, and Möckern, and the individual results are very uniform.

Results for Rape cake by Hofmeister on sheep and by Kühn on cows gave 80 per cent. as the digestibility of both albuminoids and nitrogen-free extract; while more recent experiments by Kühn on oxen gave values of 86 and 75 per cent. for the digestibility of the two constituents.

Rape cake is apt to contain mustard oil. Some Indian cakes containing as much as 0·5 per cent. of this substance have been found to affect the flavour of milk and butter when largely fed to dairy cows.

Cotton cake has been tested as to digestibility at Hohenheim and Breslau. The cake from the undecorticated seeds (containing 20–25 per cent. of crude fibre) proved difficult of digestion, while decorticated cotton cake (with only 4 to 6 per cent. of crude fibre) was found very digestible and was much appreciated by sheep. Similar results for the other oil-cakes were obtained and will be found tabulated in the Appendix (Table II.).

The digestion coefficient of *Coconut cake* was determined at Hohenheim by feeding pigs on a mixture of one part of cake to two parts of barley-meal. The pigs ate the coconut cake greedily, while they absolutely refused to touch *Candle-nut cake* (the richest oil-cake, containing 58 per cent. of crude albuminoids in the dry matter), and starved for three days rather than touch barley-meal containing a small quantity of this cake. Sheep also refused to touch it, though it has been found elsewhere that cattle will eat it readily. *Palm-nut cake* was found at Hohenheim and Möckern to be highly digestible, and not only palatable but productive of the best results with milch-cows and fat beasts.

Oil-cakes from foreign seeds, especially the highly nitrogenous *Earth-nut* and *Sesame cakes*, the cake from *decorticated Cotton-seeds* and to a less extent *Sunflower-seed cake*, are in universal use in Germany. From the large amount of albuminoids they contain and their moderate price, they are especially suitable as an addition to a food otherwise poor in nitrogen; they have proved of great value for dairy cows, but the daily quantity must not exceed 2 to 3 lbs. per cow, or else the milk and butter are apt to suffer in flavour. Earth-nut cake has also been employed as a partial substitute for oats in feeding horses: thus 12 lbs. of oats may be replaced by 8 lbs. of oats and 2 lbs. of earth-nut cake. Great care should be taken to avoid samples of earth-nut cake which are impure or adulterated with sand, woolly masses and stiff hairs, which are bad for the animals and may even cause their death. Fraudulent adulteration with powdered earth-nut shells (possessing no feeding value) is sometimes practised.

Cotton cakes are also frequently adulterated in a similar way, though it must be admitted that of recent years greater care has been exercised in cake factories to exclude impurities.

All cakes and oil-seeds obtained from hot climates are very apt to be impregnated with bacteria and mould spores, and to readily undergo decomposition or become mouldy. Such cakes are not only distasteful to the cattle, but if eaten are apt to cause them injury. It is highly desirable in the examination of such cakes not to limit it to a mere chemical analysis, but to supplement it with a microscopic examination and a test for moulds &c. as well. The frequently observed ill-effects of cotton and other oil-cakes when fed in a wet or sodden condition is probably due to the action of moulds. The fat in Earth-nut and Sesame cakes as well as in rice- and flesh-meal is very apt to become rancid and unwholesome, and Ulbricht regards it as due to the liberation of greater or less quantities of the free acids of the fat.

Beside the American cakes from *decorticated* cotton-seed, another class of cake made from *undecorticated* Egyptian cotton-seed is placed on the market, and as this contains finely-pulverized husks of a leathery consistency, it is less digestible and nutritious and has been found of little value for dairy purposes. Owing to its cheapness, it has proved much more satisfactory for sheep and draught oxen, and in England it is often used in preference to decorticated cotton cake and found to exert an excellent feeding-effect.

Poppy-seed cake is now obtained in quantity from Oriental poppy-seed and in South Germany is used largely by farmers, as it can be bought at a very moderate price. It is usually fed to the extent of 2 to 3 lbs. per head per day, but if continued for any length of time or given in larger quantity, the milk is very apt to become watery and insipid. The dark-coloured or "blue" poppy cakes appear less liable to produce this undesirable result than the "white" cakes.

Hemp cake must not be fed in too large a quantity, as it is very apt to disagree with sheep and horses, though to a less extent with cattle. The same thing is true in a more marked manner of *Beech-nut cake*, which can be largely fed to cattle, but is so poisonous to horses that merely a pound or two may suffice to kill any horse eating it.

§ 4. *Animal Products.*

Flesh-meal. — For richness in nitrogen and high digestibility, the American flesh-meal of commerce holds first place among farm foods. It consists of the dried and powdered residue from the manufacture of "extract of meat," and contains 10 to 13 per cent. of moisture when air-dried, and in a completely dehydrated condition contains 82–83 per cent. of albuminoids and 13 to 14 per cent. of fat. Digestion experiments at Hohenheim on pigs fed with potatoes to which from 8 ozs. to a pound of flesh-meal per day was added, gave results for the digestibility of the albuminoids in the flesh-meal amounting to 97 per cent., while 87 per cent. of the fat and 95 per cent. of the total organic matter was digested.

It is evident from the high digestibility of flesh-meal, that it must be an extremely valuable addition to a food poor in nitrogen, when it is desirable to increase the albuminoid ratio of the diet. It possesses a further value as a means of persuading animals to eat larger quantities of such a food as potatoes.

These Hohenheim experiments also showed that the albuminoids of flesh possessed a feeding-value which was practically the same as that of the vegetable albuminoids in such foods as peas.

Flesh-meal has been found a most satisfactory food for cows and oxen, and if at first supplied in very small quantity, and gradually increased to 2 or 3 lbs. a day, the animals soon overcome their initial prejudice against it, and eventually get to like it immensely. Sheep are the most obstinate in accepting this food, but that they can become reconciled to it has been shown by experiments at Dresden, in which lambs six months old were fed for 186 days on a food containing considerable quantities of flesh-meal. The result in this case was certainly little better than that attained with barley-meal; but in some experiments at Kuschen it was found that sheep fed on barley-straw and flesh-meal, with an albuminoid ratio for the combination of [1 : 3·5], increased considerably in weight in a comparatively short time. It was found that flesh-meal was as easily and completely digested by sheep as by pigs. Experiments on cows at Kiel showed that when 2 lbs. of flesh-meal was substituted for 2 lbs. of rape cake and 1 lb. of bran in the daily ration of a cow, 2 lbs. more milk per day was obtained, and the percentage of fat in the milk was not reduced.

Norwegian Fish-Guano, at first employed solely as a manure, was tried as a substitute for flesh-meal by Weiske and Kellner, and found to be even preferable, as all animals, sheep included, will eat it eagerly. Fish-guano only contains about 2 per cent. of fat, and the nitrogenous constituents are of a gelatinous nature and generally inferior to albuminoids in nutritive value. In the Proskau experiments on sheep, however, it was found that the nitrogenous constituents of fish-guano, owing to their high digestibility, produced a better feeding-effect than an equivalent amount of nitrogen provided in good hay and oatmeal.

Experiments at Hohenheim in which sheep were fed with fish-guano, showed that 90 per cent. of the nitrogenous matter was digested, and that the large amount of phosphates contained in the guano was excreted in the dung in a more soluble form, and proved a quick-acting manure. These results set at rest all doubts of the value of fish-guano as a concentrated food-stuff, but whether it can hold its own against the present relatively cheaper price of flesh-meal in the market is questionable.

Dried Blood contains 91·9 per cent. of albuminoids in the dry matter. From digestion experiments on dried blood given as an addition to a diet of potatoes and barley-straw, it was found that pigs digested 72 per cent. and sheep only 62 per cent. of the albuminoids present. Dried blood as usually sold is very hard and dry, and probably if it were softened by soaking or boiling, it would prove more completely digestible. The albuminoids actually digested by pigs appeared exactly equivalent to the same quantity of vegetable albuminoids (peas).

Cockchafers are similar to dried blood in composition, and are used on the continent as cattle-food.

Dairy Products.—Whey obtained from milk in the process of making cheese is a much-valued food for pigs, and contains about

1	per cent. of	albuminoids;
4·6	„	milk-sugar;
0·3–0·6	„	fat.

Its albuminoid ratio is not exceptionally high and varies greatly with the extent to which the albuminoids have been separated from the milk as cheese. Pigs eat whey eagerly, and if the excessive amount of water it contains be counteracted by the addition of corn-meal of some sort, they flourish exceedingly. Even bran and oatmeal, which are considered somewhat unsatisfactory foods for pigs, appear to produce good results when mixed with whey.

"Skim" and "sour" milk are much more nitrogenous and nutritious than whey, and are invaluable for supplementing such a starchy food as potatoes. All the constituents of milk may be considered completely digestible, though Soxhlet found that when the sole food of calves was restricted to milk, a certain small proportion of it escaped digestion.

§ 5. *Tubers and Roots.*

All roots and tubers produce a general depression and debility of digestion if fed continuously in excessive quantity. If supplemented with highly nitrogenous foods to a normal albuminoid ratio, pigs are peculiarly adapted for their digestion, and sheep, oxen, and cows eat and flourish on them when given as an addition to hay or other fodder. If the amount of roots or tubers does not exceed a quarter of the rest of the ration (calculated as dry matter in each case), excellent results with young cattle, fat beasts, and milch-cows can be obtained. Under such conditions potatoes and turnips are to all intents and purposes completely digestible, and the "depression" exerted on the digestibility of the coarse fodder is not of any consequence (see p. 144).

1. *Potatoes.*—The variety and conditions of soil, manuring, and weather cause great variations in the composition of potatoes, and the dry matter varies from 18–30 per cent., the albuminoids from 1·3–4·5 per cent., and the starch from 12–27 per cent.

The more starch there is in a potato, the less, as a rule, the amount of albuminoids, while a watery potato contains less starch and comparatively more albuminoids and mineral matter than one of a more concentrated character. This is at once evident by calculating the percentage composition of the total dry matter.

A potato of average quality contains 25 per cent. of dry matter, and its albuminoid ratio (neglecting amides) is 1 : 10 to 12.

A very rich or moist clay soil produces potatoes richer in nitrogen but poorer in starch than those grown and well-ripened in a sandy soil or sandy loam. A clay soil rich in humus often grows much larger potatoes than a sandy soil, but despite their size these often contain less starch than smaller tubers grown on the same soil.

In a soil of sandy nature this reduction of starch with increase of the size of the tubers disappears, and potatoes grown on a typical sandy soil often contain more starch the bigger they are, especially if the smaller ones have not properly ripened through bad weather.

The effect of manuring on the composition of the potato crop is considerable: thus, in one case, potatoes manured with potash and lime contained 2·27 per cent. of albuminoids, while the same kind, heavily manured with ammonia salts, contained 4·44 per cent.

With potatoes, as with all other crops, the effect of a manure is largely influenced by the varying condition of the soil, method of cultivation, and season; and the nature and extent of the effect produced by any particular manure may be accentuated or entirely suppressed by the varying influence of these important factors.

It should be noted that potatoes are rich in potash, fairly so in phosphoric acid, but contain very little soda and lime, and this needs especial attention in feeding milch-cows or young animals in rapid growth.

Forty per cent. of the crude albuminoids of potatoes generally consists of amides; watery potatoes contain even a larger proportion than this, and at least $\frac{1}{4}$ of the nitrogen of potatoes rich in starch is due to the presence of amides.

These latter compounds are principally represented by asparagine and glutamine. Nitrates and salts of ammonia are rarely found in tubers, although Kreussler detected 5 per cent. of nitrates in the stalks and leaves of young plants.

If potatoes be allowed to become frozen they suffer a loss of fermentable material, which was found by experiment to amount to 3–8 per cent. of the starch-value of the dry matter, or 0·57 to 2·13 per cent. of the tubers in their natural condition. A conversion of albuminoids into amides is produced by frost, and frost-bitten potatoes contain an abnormal amount of these compounds. Such potatoes do not keep well unless turned into a sour ensilage. German experiments have shown that it is necessary to steam the frost-bitten potatoes before they are allowed to ferment, otherwise great loss of albuminoids takes place by the escape of the juices, and as the normal production of lactic acid is then retarded, the resulting silage is apt to assume a flavour disliked by the animals.

Milch-cows should never be given more than one half, young cattle not more than one third of their food-requirement in the form of potatoes (either raw or cooked).

Potatoes that have germinated should be avoided for milch-cows, as the *solanin* contained in the sprouts is very apt to make them slip calf.

2. *Artichokes* are only occasionally employed as a farm food. The tubers contain more water and more albuminoids than potatoes. Sheep eagerly eat the leaves and tender parts of the luxuriant upper-growth. Artichokes appear to contain as large a proportion of amides to albuminoids as turnips, and some determinations of amide nitrogen at Hohenheim gave results amounting to more than 40 per cent. of that of the albuminoids.

3. *Roots* are characterized by the preponderance of sugar in the nitrogen-free extract and the *pectin* which they also contain. Starch also occurs in some "roots," such as carrots. Numerous experiments have proved the high digestibility of pectin, and it was found that as much as 98 per cent. of it was digested by sheep and cows even when fed in quantity. It also appears that the nutrient action of pectin is precisely equivalent to that of starch and sugar.

It has been generally observed of all roots that the larger and finer they are, the more watery their consistency and the less the percentage of dry matter.

The amount of nitrogenous substances in the dry matter is increased by heavy manuring with dung, &c., though the different kinds of "roots" vary in this respect. Sugar-beets, as grown for the purposes of sugar manufacture, contain the greatest amount of solid substance, and the lowest percentage of nitrogen found in any roots. If heavily manured or cultivated at wider intervals, so that beets exceeding 2 lbs. are obtained, they are practically equivalent to ordinary mangolds.

The albuminoids calculated from the determinations of nitrogen in roots are invariably in excess of the truth unless allowance be made for the amides and nitrates which actually represent part of the nitrogen. This is especially noticeable with coarse mangolds grown with a powerful nitrogenous manure, in which hardly a third of the contained nitrogen really exists as true albuminoids. This may also explain the observed fact that the actual feeding-effect of turnips is less than that deduced from the percentage of nitrogen and the equivalent amount of albuminoids they contain.

According to Kellner, carrots, turnips, and especially swedes, contain less amides and nitrates than mangolds, since these latter contain about 60 per cent. of amides and nitrates (in terms of the total nitrogen), while the other roots contain about the same amount as potatoes, or only 40 per cent.

The custom, in some districts, of removing the leaves of a root-crop reduces both the crop and quality of such roots as mangolds, and a loss of half the crop has been observed as the result of this practice. Removing the leaves from a growing root-crop was found to reduce the amount of sugar 3·8 per cent., while the roots were not only watery but did not ripen properly.

Practical men are well aware that the different kinds of roots differ not only in flavour but also in digestibility and feeding-value. Carrots are most highly esteemed for promoting a vigorous and full-blooded condition, and on this account are often given in small quantity to horses and young animals. Swedes are a more concentrated and nourishing food than mangolds.

4. *Potato-Slump.*—The manufacture of potato-spirit has been considerably extended on the Continent in conjunction with the growing of the potatoes themselves on soils especially adapted for the purpose. By employing the residue or "slump" (left after the spirit has been made and separated by distillation) as a farm food, better feeding-results are obtained than are possible with untreated potatoes.

To use potatoes to any purpose as a food-stuff, they must be supplemented with a highly nitrogenous food, and on light sandy potato soil this would have to be bought, as the soil would not produce an adequate supply. Even if lupines were largely grown they could only be used for sheep. The potato-slump contains everything in the original potatoes except the excessive quantity of starch which has been turned into spirit; and as it possesses a high albuminoid ratio it serves as a highly productive food-supply, and may even enable animals to eat large quantities of straw and chaff to advantage. Without buying anything, the potato-grower can thus adopt an economical and rational method of feeding his stock.

Nothing is lost to the farm, as all the nitrogen and mineral matter which the potatoes have extracted from the soil, together with that in the malt added to the "mash," are contained in the "slump."

It is thus evident that a combination of potato-growing and distilling on some poor sandy soils is the only means whereby the land can be farmed highly and to good profit.

The loss of starch in the potatoes is readily made good in practice by the addition of any of the non-nitrogenous food-stuffs which are always readily available. "Slump," like the potatoes and malt used for its production, contains amides, but Morgen and Behrend have observed the interesting fact that in the process of fermentation a considerable amount of the amides is converted into albuminoids.

Their results in two cases were as follows :—

	Percentage of total Nitrogen as Albuminoids and Peptones:—	
	In sweet mash.	In mash after fermentation.
A . .	55·06	71·27
B . .	54·46	71·93

This amounts to an increase of about 17 per cent., so that instead of containing 40 per cent. of the nitrogenous matter as amides, which is the amount found in potatoes, the "slump" must contain as little as 25 per cent. This throws light on the wonderful feeding-value of potato-slump.

Formerly, potato-slump contained 7 to 8 per cent. of dry matter with an albuminoid ratio (by the usual calculation) of [1 : 3] to [1 : 4], dependent on the strength of the "mash." Improved methods, which secure economy of material and a more uniform and energetic fermentation, have lately been introduced, and the slump so obtained, though more watery (5 to 6 per cent. of dry matter), possesses a higher albuminoid ratio, viz. [1 : 2·5] to [1 : 3].

A further point about slump is the comparatively high proportion of mineral matter (0·5–0·8 per cent.) and crude fibre (0·6–0·9 per cent.) which it contains.

Potato-slump can be fed with excellent results to all farm animals, and is peculiarly suitable for oxen, cows, and fat beasts, but should be used with judgment and in smaller quantity for young animals, pigs, and horses. It need hardly be stated that so watery a substance requires a considerable addition of dry and solid fodder when used as a cattle food. Overfeeding with slump produces general debility and is apt to engender disease; the so-called "slump-malanders" seems to be due to a micrococcus that readily flourishes in slump, and it is very important the slump should be used fresh and hot, and never be left to get quite cold.

A judicious supply of slump increases the quantity without reducing the quality of milk; too much, *i. e.* more than 50 lbs. per 1000 lbs. live-weight of the cow, causes watery milk and bad butter, which latter not only does not keep but is very apt to develop a bitter taste. Dutch cows seem to take very kindly to slump, and were found to produce as much good milk on 10 gallons of slump per day as on a diet of clover, maize, and buckwheat.

5. *Rye and Maize Slump.*—These by-products of the distillery are even more valuable food-stuffs than potato-slump, because they do not undergo so complete a fermentation, and are consequently richer in dry matter.

On the other hand, the "slump" from *Beet molasses* is a very indifferent food-stuff, and can only be used when supplemented by at least twice as much potato-slump.

This is not due to lack of dry matter, but to the excessive quantity of mineral salts (2 per cent.), which appear to have a bad effect on the animals. At the same time the nitrogenous constituents appear of doubtful feeding-value.

"Evaporated slump" has recently been placed on the market, and this, if obtained from rye and maize, is an excellent food-stuff, and exceeds even dried brewers' grains in feeding-value, owing to the higher percentage of fat and albuminoids and the smaller amount of crude fibre which it contains.

6. *Sugar-Beet Residues.*—Wherever obtainable, these residues are used for feeding purposes, but their composition and value vary a good deal with the extraction-process from which they have resulted.

The pulp obtained from the old-fashioned presses contains 30 per cent. of dry matter with an albuminoid ratio as low as [1 : 10] or even less. That obtained by the centrifugal process possesses the same albuminoid ratio, but contains only 15 to 20 per cent. of dry matter. The residues obtained by the modern "diffusion" process are of quite a different character, as the beets instead of being treated in a pulp are cut up into little pieces and treated with warm water; in this way the sugar is extracted from the beet by diffusion, while the non-diffusible albuminoids are left behind. The residue thus obtained has a high albuminoid ratio, and is the more valuable for feeding-purposes in that the amides, which are easily soluble, are separated from the beet-chips and pass over to a great extent into the extract. A serious drawback to the value of fresh "diffusion chips" is their watery nature, and the small amount of dry matter (6 per cent.) which they contain. By moderate compression the dry matter can be increased to 10 per cent.; by powerful but expensive pressing a product containing 15 per cent. of dry matter is produced. The fermentation of "diffusion chips" in a pit or silo always results in loss and reduced digestibility. The following table gives the observed loss on making a sample of "diffusion chips" into sour silage:—

	Dry matter.	Crude fibre.	Crude albuminoids.	N.-free extract.
	per cent.	per cent.	per cent.	per cent.
Minimum	14	9	5	15
Maximum	46	52	40	57
Average	34·8	19·6	24·5	37·8

It is very important that the fermenting mass should be well stamped down to a compact and air-tight consistency; the addition of chaff is a bad practice, and was found to increase the loss of organic matter from 21·8 to 29 per cent.

By using extra precautions for keeping out air and maintaining a great pressure on the heap, Liebscher found he could reduce the loss to 6 or 8 per cent. Stutzer found that frozen "chips" became sour, and that the digestibility of the albuminoids was reduced from 86 to 70 per cent., while that of the crude fibre was improved.

Another method of preserving diffusion chips without fear of loss, is that of drying them by artificial heat. This has become much easier and cheaper since Märcker found that if the chips were mixed with about 0·5 per cent. of lime they could be compressed by machinery, and the greater part of the water expressed without appreciable loss. Such dried "chips" have proved excellent food for cows (6 to 10 lbs. a day) and for fat beasts (11 to 16 lbs. a day), despite the large amount of lime contained (4·5 per cent. of the dry matter). The results were also far better than those obtained from slump or fresh chips that had not been dried. No loss of calves or accidents in calving resulted, and the milk, butter, and meat produced were superior in every way. Dried chips serve as an excellent substitute for hay, and can replace bran or barley-meal in the proportion of 3 lbs. of chips to 2 of the latter. The inventor Märcker thought that the pressed chips containing lime would not make good silage owing to their rapid fermentation; but Müller succeeded in making excellent sweet silage from them.

Part III.

THE FEEDING OF FARM ANIMALS.

CHAPTER I.

FEEDING STANDARDS.

The growth and nutrition of all mammals are governed by essentially the same principles and laws, and hence a knowledge of the latter provides a firm and sound basis for the practical feeding of farm animals.

The various animals of the farm may eat different kinds of food, but with regard to the "nutrients" or true food-constituents of such foods, and their general effect on the body, no distinction can be drawn. It is true that the digestive system of Herbivora, and especially that of ruminating species, is able to assimilate cellulose and convert it into starch, while Carnivora are practically unable to accomplish this digestive feat; but any particular food-constituent once assimilated by either class of animal undergoes absolutely the same changes and exercises the same nutritive effect.

The quantitative result is admittedly often unequal on account of the great variations in the amount of the particular food-stuff eaten by different animals. It has been found that under certain conditions Carnivora can eat, digest, and resorb as much carbohydrates as Herbivora (see p. 39).

It is self-evident that only real, *i. e. digestible,* food-constituents can be taken into consideration in prescribing the daily ration of a farm animal, and that the amount of the various nutrients capable of digestion in a food-stuff represents its value as a Farm Food.

The old-fashioned method of reckoning from "crude constituents" without reference to their digestibility is no longer permissible. Calculations based on digestible constituents avoid the great errors involved in giving a different value to the same food-constituent whether existing in a coarse or a concentrated food-stuff.

The science of Farm Feeding involves the classification of organic food-constituents into two broad classes, ALBUMINOIDS and CARBOHYDRATES, or NITROGENOUS and NON-NITROGENOUS Nutrients.

All the non-nitrogenous nutrients can be represented in composition and nutritive effect by starch if the amount of digestible fat be multiplied by its "starch equivalent."

At the same time we shall quote Fat as such in all feeding standards, although the economical minimum of fat for particular feeding purposes cannot be yet very rigidly fixed owing to the conflicting results of the experiments hitherto made on this point. We only know for certain the general facts: that the fat of food is more easily stored up in the body than that produced by the decomposition of albumen; that the former, under certain conditions, is an invaluable and concentrated respiration-material, and that fat can be readily replaced by carbohydrates, so far as its influence on the decomposition and storage of albumen in the body is concerned. We are clearly justified in regarding fat as an essential constituent of the daily food of milch-cows, fat beasts, and working animals, and also in prescribing an addition of fat in those cases where a rich diet containing a high amount of nitrogen is necessary for the object in view.

A *feeding standard* should also specify and regulate the *total organic matter* in the ration of a farm animal, and should enable a practical man so to regulate the supply of bulky and concentrated food-stuffs, that not only the amount and ratio of the digestible constituents be that demanded by the "standard," but that the volume or bulk of the total ration may also be in correspondence. At the same time a farmer should not bind himself slavishly to the exact requirements of these feeding standards. Their practical value does not lie in half a turnip or a wisp of straw too much or too little, but in enabling a farmer to tell at a glance, or by a simple rough calculation, how to secure a proper albuminoid ratio with the food-stuffs at his disposal for the end he has in view. Used in this way, they will avoid the inevitable losses arising from rule-of-thumb methods and individual errors of judgment, and will enable the stock-keeper to feed his animals in the best and most remunerative way.

In food calculations the *Amides* have to be allowed for among the nitrogenous constituents. If we decide to employ only the digestible and real albuminoids as a basis for the calculation of our albuminoid ratios and feeding standards, very many of the commonly accepted data require considerable alteration.

Unfortunately we are not yet in a position to make this change, as not only the amount of amides in the various farm-foods, but even their specific value as food is still undecided (*cf.* p. 100). For the present we must rest satisfied in food calculations with an after-glance at such experimental results as have been so far obtained.

How this may be done by the help of Table III. in the Appendix, which gives the proportion of amides in various food-stuffs, will be explained in a subsequent chapter; for the present we will leave the Amides entirely out of consideration in our discussion of "albuminoid ratios" and "feeding standards."

We fully recognize as the most important mission of the Science of Farm Feeding, and, in this book, as our most cherished aim and object, the determination of the *productive minimum* and *best proportion* of food-constituents in the daily ration of an animal for the particular object in view. On that account our treatment of the subject in the following pages shall be limited to the working-out of this vital and practical issue.

The taste and general "specific" characters of food-stuffs for particular animals are matters that concern practice, and are dealt with in books on practical Agriculture.

In the present state of our knowledge we are bound to consider that *any* particular *nutrient* once digested and resorbed *exercises absolutely the same effect* on the animal organism *whatever its source* may have been. We cannot expect the true albuminoids in grass and hay to produce a different effect under comparable conditions from the albuminoids in the seeds of mature plants. Our present knowledge throws great doubt on the uniform value of the nitrogen-free nutrients, and especially on that of crude fibre (*cf.* p. 111), but further experiments are needed to explain and confirm the variation. The practical value of *flavour* and its effect on the general "condition" or capacity for work of an animal is a matter for the farmer to decide by practical experience and personal discretion; and as science cannot at present deal with this aspect of the practical feeding of farm animals, we are consistently bound to leave it out of consideration in this book.

Practical details as to the general treatment and rearing of stock, stall fittings, methods of preparing food, &c., are also out of place here. We only insist that unless such practical details are attended to in the most perfect and efficient manner, it is quite impossible to realize the best results from any system of feeding. Although the method of preparation—cooking, for instance—does not increase the digestibility of the food itself, still it may, under certain conditions, improve the flavour of the food and tempt the animals to eat it more freely and with better results than if it had been left raw.

Productive Albuminoid Ratios.

A conventional distinction is often drawn between feeding for *maintenance* and feeding for *production.*

The distinction is simply a matter of *degree* and not of real difference, and no hard and fast line can be drawn between the two standards of feeding, as one merges imperceptibly into the other.

It is clearly evident that if an animal remains quietly in a stall, a minimum of albuminoids and a low albuminoid ratio will suffice to keep it in fair condition. On the other hand, any form of *production* in addition to this will require a higher albuminoid ratio in the food-supply to make it possible.

The albuminoids are directly active and essential for all forms of production (meat, fat, wool, milk, and work), and frequently provide the material directly employed; the albuminoid ratio of the food must not be too low, or else the albuminoids supplied will be insufficient for the end desired. We have also seen (see p. 141) that too low an albuminoid ratio invariably reduces and sometimes to a very serious extent depreciates the digestibility of the albuminoids contained in the food, and thereby militates against the "economic maximum" for the whole food.

On the other hand, the albuminoid ratio should not be too high, as the excess of albuminoids will increase the amount of circulatory albumen in the body, and thereby occasion an unnecessary waste and loss of this most valuable material. The result of an excessive albuminoid ratio is frequently worse than that of a lower one, that is a better end may often be attained with a less expensive diet.

It has been found that the albuminoid ratio of a rational or economic productive diet lies between very narrow limits.

The economic ratio for a productive diet for Farm Animals lies between the proportions [1 : 4] and [1 : 7].

If the ratio be *lower* than [1 : 7] a lack of albuminoids for quick and certain production is inevitable; and growth and production take place so slowly and with so little energy that the *financial profit* is both *delayed* and *greatly reduced,* even *though* the *food* itself be comparatively *cheap.* A *higher* ratio than [1 : 4] for farm animals involves unnecessary *waste* in the body of the animal and a comparatively greater waste of money than that involved by a ratio which is too low.

Between these limits the effect of a diet for farm animals will be greater with the same amount of food the higher the albuminoid ratio, but whether the result would be satisfactory and economical at this higher ratio is a matter that requires very careful consideration of the various conditions of the case for decision.

The medium albuminoid ratios [1 : 4] to [1 : 7] fairly represent the "natural" food of farm animals. Average *hay* is often assumed to be a *standard food* for ruminants, but as its albuminoid ratio is as low as [1 : 8] it can only be considered suitable for purposes of maintenance or a very slow production, and is quite unfit for the rapid and large production of meat, fat, or milk. The normal food of cattle is *grass* such as is found on a good pasture, and this possesses an albuminoid ratio of [1 : 4] to [1 : 6].

Cows can only be expected to produce a liberal yield of milk, calves a normal rate of growth, and fat beasts a satisfactory increase in live-weight, when the albuminoid ratio in their food is as high as that of pasture grass, and its mechanical condition such as to make possible the consumption of the necessary quantity of food required by the animal. Cattle, feeding at will on a pasturage, crop the young and tender grasses and sweet herbs, and avoid the long-stalked plants which have run to seed, and as hay includes these latter it cannot be considered a natural or possible substitute for good pasturage.

Clover-hay of average quality has an albuminoid ratio of [1:5] to [1:6], and would appear at first sight a better food than hay; but on account of its great bulk and toughness it does not supply sufficient digestible food-material for the animals, and must be supplemented with some easily digestible auxiliary food-stuff of high albuminoid ratio if actual production be desired. Young clover cut before flowering and fed green has an albuminoid ratio as high as [1:3] or [1:4]; exclusive feeding with this fodder, therefore, involves a waste of albuminoids, and a better result at less cost can be obtained by supplementing the young clover with straw, chaff, &c., and reducing the albuminoid ratio to [1:5].

Clover in full-bloom of course requires no such reduction, but may need the addition of a special nitrogenous food-stuff.

It is very remarkable that in cereal grain—the basis of all kinds of bread—the albuminoid ratio lies between [1:5] and [1:7]. Maize possesses a lower ratio than barley, and this again a lower one than oats, rye, and wheat.

Bran of all kinds has a ratio ranging between [1:4] and [1:5]; while leguminous seeds, brewers' grains, malt sprouts, and "slump" are highly nitrogenous, and have an albuminoid ratio of [1 : 2] to [1 : 3]; oil-cakes rank as high as [1 : 1] or [1 : 2].

These nitrogenous food-stuffs produce most excellent results, even when fed in small quantity as an addition to other food.

Milk is nature's obvious standard of food for young animals, and its albuminoid ratio is in agreement with the standard we have set up. Calculating the fat as its equivalent in starch, cow's milk has an albuminoid ratio of [1 : 4·5], as deduced from an average composition of 3 parts of albuminoids, 3·5 of fat, and 5 of sugar in a hundred. The milk of Carnivora has a higher ratio than cow's milk; human milk, on the contrary, a lower.

The normal diet of human beings, which one can certainly regard as "productive" feeding, has been made the subject of very many direct experiments day by day. C. Voit found that a man doing average work required

5 ozs. albumen	per day,
$12\frac{1}{2}$ ozs. carbohydrates	,,
4 ozs. fat	,,
[1 : 4·7] alb. ratio.	

Other calculations specify

$4\frac{1}{4}$ ozs. albumen	per day.
18 ozs. carbohydrates	,,
2 ozs. fat	,,
[1 : 5] alb. ratio.	

CHAPTER II.

FEEDING FOR MAINTENANCE.

Oxen.

In order to determine, as a basis for the rational feeding of ruminants, the minimum of food required to maintain a full-grown animal at rest in a stall in an average bodily condition, oxen were selected as peculiarly suitable for the purpose of the investigation. Oxen do not utilize any large quantity of their food-supply in producing hair or excessive bodily excretions, and the bulk of the food they eat is employed for the simple purpose of bodily maintenance. Henneberg and Stohmann, of Weende, conducted experiments on oxen of a German breed from 4 to 6 years old. They determined the digestibility of the food and the albumen consumed, but they were unable to control the fat consumption because the experiments were not conducted in a respiration apparatus.

It was found that the animals could be maintained in an apparently constant bodily condition without appreciable variation in live-weight by providing the following rations:—

Per day per 1000 lbs. live-weight.

	lbs.		lbs.		lbs.	
1.	3·7	Clover-hay,	13	Oat-straw, and	0·6	Rape cake.
2.	2·6	„	14·2	„ „	0·5	„
3.	3·8	„	13·3	Rye-straw, „	0·6	„
4.	25·6	Mangolds,	12·6	Oat-straw „	1·0	„
5.	19·5	Clover-hay.				

	Nutrients contained.	
	Albuminoids.	Nitrogen-free.
Maximum	0·84 lb.	7·77 lbs.
Minimum	0·41 „	7·04 „
Average	0·57 „	7·4 „
Albuminoid Ratio [1 : 13].		

It was also found that when the temperature of the stall was maintained at 62° to 69° F. a slight increase of flesh resulted, so that the food was fully sufficient to maintain the bodies of the animals at a normal condition. In one experiment in which the temperature of the stall was as low as 57°, although the diet was the highest quoted above, the animal slightly lost flesh, owing to the increased demands of respiration. The above standard diet contained 0·05 lb. phosphoric acid, 0·1 lb. lime, and 0·2 lb. potash and soda; and these amounts are therefore perfectly sufficient for the maintenance of an ox per day per 1000 lbs. live-weight. The water required per day varied from 52 to 64 lbs. per 1000 live-weight, or an average of 5½ gallons.

It is quite impossible to tell with certainty whether the fat, as well as the flesh, in the bodies of the oxen remained constant during the experiments. It could only be inferred from the general appearance and condition of the animals that no loss of fat had taken place.

With reference to the results of further experiments made at Weende, and of others elsewhere, in which no loss of bodily flesh took place, I suggest that as the temperature of the stall was rather high for winter (62° to 69° F.), the averages of the numbers obtained are too low for the minimum requirements of full-grown oxen at rest, and should be increased to 0·7 lb. albuminoids, 8·4 lbs. digestible carbohydrates, giving a total of 9·1 lbs. The albuminoid ratio is then [1 : 12]; and the total quantity of organic matter can be kept at 17½ lbs. per 1000 lbs. live-weight by providing straw as the main fodder, and supplying hay or small quantities of a special nitrogen-food with or without the addition of roots.

The amount of digestible fat required to maintain an ox is not great. In the Weende experiments it was found to vary between 0·15 to 0·20 per 1000 lbs. live-weight.

The results of practical experience agree with these experimental deductions. Henneberg records two instances, (*a*) at Weende and (*b*) elsewhere, of full-grown oxen fed during the winter months on a constant diet :—

(a). [lbs. per 1000 lbs. live-weight.]	(b). [do.]
12·9 Straw.	16·3 Barley-straw.
7·1 Sainfoin-hay.	0·4 Aftermath.
0·4 Bean-meal.	2·0 Clover-hay.
0·4 Rape cake.	1·3 Pea-straw.
	2·9 Mixed Barley- and Oat-meal.
Equivalent to :—	Equivalent to :—
1 lb. Albumen.	0·7 Albumen.
7·8 Carbohydrates.	8·8 Carbohydrates.
8·8 Total "real food."	9·5 Total "real food."

The animals fed on ration (*a*) increased 70 to 90 lbs. apiece; the oxen fed on ration (*b*) performed light draught-labour without losing in condition.

In the first part of this book we recognized as a general law of animal nutrition that an animal does not increase, but rather loses in bodily substance, if with a constant amount of food the proportion of the albuminoids is increased, as in the Weende experiments. If, for example, an ox receiving 9·1 lbs. of food, of which 0·7 consists of albuminoids, receives instead 1·5 lbs. of albuminoids and 7·6 lbs. of carbohydrates, the excess of albuminoids will be decomposed and hardly any of it be stored up as flesh. It is highly important to guard against too high an albuminoid ratio in feeding cattle for maintenance, as not only is the food itself more expensive than necessary, but it is also wasted. Still less satisfactory results will follow if the amount of the albuminoids be reduced and the carbohydrates be increased to the same extent. An undue increase of albuminoids will not effect a large production of flesh, nor will an excessive proportion of carbohydrates conduce to an increase of the live-weight of an animal, if the necessary amount of albuminoids be lacking.

When we desire to do more than merely *maintain* the animal and bring about an actual *production* of any kind, we must at the same time increase both the supply of albuminoids and carbohydrates in the food, but in variable proportion as suited to the particular end in view. In deciding on this proportion, we must bear in mind the bodily condition of the animal. If the latter is rich in flesh but poor in fat, a rather lower albuminoid ratio is calculated to bring about a further increase of flesh, than if the animal be proportionately rich in fat and lacking in flesh. In this latter case a high albuminoid ratio will be required for the quickest and most satisfactory production of flesh. Fat produced from the albumen or other materials in the food is more easily retained and stored up in the body of a fleshy than that of a fat animal. A high albuminoid ratio often induces a very rapid fattening, although the albumen may not be actually stored up as such.

These facts and observations make it abundantly evident that it is impossible to fix an albuminoid ratio at constant value for any particular object in feeding—variations always occur in individual instances, and the values given, and in fact all feeding data, must be regarded as only general averages and approximately correct in individual cases.

CHAPTER III.

THE PRODUCTION OF WOOL.

We have already seen that the food required to maintain a sheep is proportionately greater than that required by an ox. A certain amount of the albuminoids in the food of sheep is involved in the production of wool. Owing to their lively and active habits and their comparative restlessness even in a pen, sheep necessarily require a high amount of material for respiration, and the more so as they give up a greater proportion of heat by radiation from their bodies than larger animals (see p. 70).

It is really remarkable, all things considered, that the food required to maintain a sheep as compared with an ox is so small as it really is. This is doubtless due to the thick covering of wool which reduces the radiation and conduction of heat from their bodies, and thus economizes the food required for respiration. Under equal conditions, a goat of the same live-weight as a sheep requires more food for its maintenance than the sheep.

Henneberg has conducted elaborate experiments on the feeding of sheep at Weende, in which not only were the visible excretions determined and analyzed, but by the additional assistance of a respiration apparatus a complete account of the "*consumption*" and "*production*" was rendered possible (*cf.* p. 32).

The sheep experimented upon were of a coarse-woolled Göttingen breed, 4½ years old and weighing 106 lbs. apiece (including wool). They were fed entirely on hay of average quality and received 26 lbs. (containing 21·4 lbs. of dry matter) per day per 1000 lbs. live-weight (excluding wool). They digested 1·32 lbs. of albuminoids, 10·21 lbs. of carbohydrates, and 0·32 lb. of fat, or, if the fat be calculated as carbohydrates, 11·38 lbs. of total non-nitrogenous matter.

A small bodily increase of 3 ozs. of albumen and 5 ozs. of fat per 1000 lbs. live-weight took place each day. The food supplied was therefore more than adequate for the maintenance of the animals; and if we deduct from the food supplied that stored up in the body, we shall have the exact amount of food required to maintain a sheep in a constant condition. This amounts to about 2 ounces of albumen and 17 ounces of non-nitrogenous nutrients (calculated as carbohydrates) per head per day; or, expressed as "per 1000 lbs. live-weight per day," is equal to

1·14 lbs. of albumen.
10·63 lbs. of total carbohydrates.

11·77 lbs. Total digestible food.
Albuminoid ratio = [1 : 9·3].

Further experiments were made at Weende on the same sheep, and the following data (each obtained from the average of 5 single experiments) may be taken as a summary of the results:—

WEENDE SHEEP EXPERIMENTS.

[lbs. per 1000 lbs. live-weight.]

	Digested Albuminoids.	Digested Carbohydrates and Fat.	Total digested food.	Albuminoid Ratio.	Gain (+) or Loss (−) of Albuminoids.
(*a*)......	1·04	9·49	10·53	[1 : 9·1]	−0·042
(*b*)......	1·56	9·54	11·10	[1 : 6·1]	−0·006
(*c*)......	1·11	11·70	12·81	[1 : 10·5]	+0·124
Average.	1·24	10·24	11·48	[1 : 8·5]	+0·025

The average of the 15 experiments shows an insignificant increase of albumen (0·025 lb., or $\frac{2}{5}$ of an ounce). We thus see that with sheep, as with oxen, a high albuminoid ratio is to be avoided if they are only to be kept in condition and not to be actually fattened.

The following results on sheep were obtained at Hohenheim, the figures being given as lbs. per 1000 lbs. live-weight (exclusive of wool) :—

	Albuminoids digested.	Carbohydrates and Fat digested.	Total food digested.
Series I.	1·37	8·92	10·29
Series II.	1·23	9·93	11·16

These figures are in substantial agreement with those obtained at Weende. The food used at Hohenheim contained less carbohydrates and was smaller in quantity than that employed at Weende, and the animals slightly lost in weight. The loss of weight was more marked with sheep of the "Electoral" breed than with "Southdowns" or "Württembergs." Sheep with a fine fleece are always smaller than coarse-woolled breeds, and on this account require a greater amount of food in proportion to their weight.

The results of these careful investigations show that full-grown sheep kept solely for wool can be maintained on a diet consisting of the following :—

	Per 1000 lbs. live-weight per diem.			
	Digestible Albuminoids. lbs.	Digestible Carbohydrates and Fats. lbs.	Total Organic matter digested.	Albuminoid Ratio.
(*a*) Larger Breeds.	1·2	10·8	12	[1 : 9]
(*b*) Smaller Breeds.	1·5	12·0	13·5	[1 : 8]

The digestible fat in the food amounted in (*a*) to 0·20 lb., in (*b*) to 0·25 lb., and the total crude organic matter of the food varied from 20 to 22 lbs. The daily production of "washed" wool varied from 0·12 to 0·2 lb. per day. These results are referred to 1000 lbs. "shorn" weight; and they might also be used without alteration for unshorn sheep, as any error involved would be on the right side.

Feeding for Wool.

Diet has a distinct influence (within certain limits) on the production of wool. A fattening diet produces no more wool than a ration which is adequate for maintenance. Henneberg found at Weende that sheep produced 0·141 lb. of wool (per day per 100 lbs. live-weight), equal to 0·273 per cent. of their shorn-weight, when fed on a maintenance diet, and 0·141 lb. of wool, equivalent to 0·286 per cent. of the shorn-weight, when fed on a fattening diet. Similar results were obtained at Hohenheim on young sheep when fed on a rich diet for 9 months; the live-weight rose from 56 lbs. to 102 lbs., while others fed on hay only increased from 56 to 80 lbs. Although there was so great a difference in live-weight, the quantity of *wool* was absolutely *the same.* The wool of the fat sheep which had been fed on corn was beautifully white, while that of the sheep fed on hay was of the usual dirty colour, and even after washing appeared grey in comparison to the other wool.

	Wool per head. lbs.	Washed wool. lbs.	Washed wool (after extraction. of fat).
Sheep fed on corn.	4¾	3¼	2 lbs. 6 ozs.
Sheep fed on hay.	5¾	3½	2 lbs. 6 ozs.

Results quite the opposite of these have been obtained from experiments on Rambouillet sheep, by Weiske at Proskau, in which he found an increase of 12·5 per cent. in the wool produced by a fattening diet as compared with ordinary maintenance. These experiments also contradict the popular idea that the production of wool is most rapid in the winter, as it was found that the production of wool throughout the year was as follows :—

Season.	Wool produced.
Winter	26·1 per cent.
Spring	37·0 „ „
Summer	36·0 „ „
Total	100

Experiment showed that *repeated* shearing yielded more wool than a *single* shearing. When a sheep was shorn 6 times a year, 20 per cent. more wool was obtained than by a single shearing at the end of 12 months; at the same time the animal, having been fed on the same diet throughout, lost weight when frequently shorn on account of the increased loss of heat from its body. The growth of wool is slowest in November and December, and most rapid in March and April, and is more influenced by the season than by the temperature of the air.

If the food supplied is not sufficient for the maintenance of a sheep in fair condition, the production of wool suffers in consequence. The Weende experiments have shown that a slight loss in weight does not necessarily cause a decrease in the amount of wool produced. If, however, the animal loses more than a certain amount in weight, a very marked decrease in the production of wool is inevitable. The wool produced in three instances was as follows :—

Method of feeding.	Wool per day as percentage of "shorn-weight."
(*a*) Insufficient nourishment.	0·237 per cent.
(*b*) Moderate ,,	0·292 ,, ,,
(*c*) Good ,,	0·306 ,, ,,

It was further found that a diet insufficient for normal maintenance does not seriously affect the yield of wool if the food be rich in nitrogen, and that, under otherwise equal conditions, albuminoids favour the production of wool. Roberts and Wing (U.S.A.) have confirmed this by experiments on lambs.

Our experiments at Hohenheim are completely in agreement with these conclusions.

Hohenheim Experiments on Wool-production.

Two lots of 6 sheep each were fed on a rich nitrogenous diet of hay and bean-meal just sufficient to keep them at a constant weight (102 lbs.), and in 121 days each lot had produced 10 lbs. of washed wool. Two other divisions were fed on straw and mangolds, and as they lost over 2 lbs. a head in weight, the diet was obviously insufficient; the wool produced was only 7½ lbs. A fifth division (6 sheep) had a poorer diet still, consisting of 2 parts of hay and 1 of oat-straw, and the animals lost 12 lbs. each in weight. The wool produced was 8 lbs., or rather more than that produced by lots 3 and 4.

TABLE OF RESULTS.

Lots.	Diet.	Loss in live-weight.	Wool produced per head.	Do. as percentage of shorn-weight.
I. } II. }	Hay and Bean-meal.	*nil.*	10 lbs.	31·9
III. } IV. }	Straw and Mangolds	2 lbs. per head.	7½ lbs.	26·5
V.	Hay and Straw.	12 lbs. per head.	8 lbs.	27·3

This shows that even with a sparing diet of hay there is still a considerable production of wool, but that the maximum is at once attained by a diet rich enough to keep the sheep in good condition. The results of feeding mangolds and straw clearly show that this is not an economical diet; not only was the wool less in quantity, but the animals lost considerably in weight.

CHAPTER IV.

THE PRODUCTION OF WORK.

§ 1. *Work and Rest.*

We have already learnt that thoroughly developed muscles in good practice are the first essentials for hard and continuous physical exercise, and that a high proportion of organized and circulatory albumen is requisite for the production of the necessary energy.

In order to maintain an animal in strong working condition, more food with a higher albuminoid ratio is necessary than that required for keeping an animal at rest in a stall in fair bodily condition.

Work itself does not involve the decomposition of more albumen than *rest* (*cf.* p. 76), but a continuous and severe form of work can only be satisfactorily performed if abundance of albumen be supplied in the food and the general activity of digestion kept at a high pitch.

Although the digestion of albumen is directly determined by the supply and the bodily condition of the animal, the oxidation of fat is considerably increased by muscular exercise. Fat or carbohydrates in the food can prevent loss of fat from the animal's body.

Fat is so concentrated a food for the purposes of respiration, that under certain conditions it should be added to the food of working animals. It is very obvious that an increased supply of both albuminoids and non-nitrogenous nutrients should be provided in the food of animals doing hard work and in quantity proportional to the work done, as the animals would otherwise lose in condition.

§ 2. *Draught Oxen*

require little more food for moderate work than for complete rest in the stall (see p. 76). For hard work the albuminoids should be increased from 0·7 to 1·6 lb., and the carbohydrates from 8·4 to 12 lbs. per 1000 lbs. live-weight per day. The albuminoid ratio of this "working ration" is [1 : 7·5], while that of the maintenance diet is only [1 : 12].

The working diet might be given in the form of good hay with a small addition of a concentrated food-stuff, or this combination might be replaced by clover-hay and straw, or, again, by straw with a little roots and some special nitrogen-food.

The bulk of the organic matter in the daily ration specified above is about 52 lbs. The amount of fat required by oxen doing moderate work at a quiet pace is not very great, as they can make much use of carbohydrates owing to the size of their digestive organs. The average diet of such oxen only contains 5 ozs. of fat per day per 1000 lbs. live-weight. Oxen doing really hard work ought to have more fat than this, and the addition of oil-cake to increase the fat to 9 ozs. per day is to be recommended.

§ 3. *Horses.*

The general food of a farm horse is simply hay and oats, with a greater or less quantity of chaff. The most desirable quantity and proportion of these three articles of food are very variable. In fact the food requirements of horses are more subject to variation than those of any other farm animal. The temperament of a horse prohibits a high diet when it is doing no work and is resting in the stable, but directly it does hard work a high diet of oats is necessary to keep it in condition. For the average work of farm horses, the following diet is adequate :—

(Per day per 1000 lbs. live-weight.)

1 lb. 9 ozs. digestible albuminoids.
11 lbs. 3 ozs. digestible carbohydrates.
[1 : 7] albuminoid ratio.
21 lbs. total dry matter in food.
8 ozs. digestible fat (included in the carbohydrates).

The fat is mainly derived from oats, which contain more fat than any other cereal; and this fact must be borne in mind when oats are replaced by any other food-stuff in the diet of a horse. When horses are doing very hard work, the diet might well be increased as follows :—

Digestible albuminoids	2·5 lbs.
,, carbohydrates	13·8 lbs.
Total digestible food	16·3 lbs.

Albuminoid ratio [1 : 5·5].

An even higher diet than this is often given to dray and heavy cart-horses, as it is not an uncommon practice to feed such horses on oats and bean-meal.

For hunters, hacks, and carriage horses doing plenty of work, a diet of oats alone with an albuminoid ratio of [1 : 6] or [1 : 7] is found advantageous.

Feeding horses entirely on hay is not so satisfactory as with cows, because horses eat less of it (not more than 56 lbs. a day), and cannot digest hay so well as the ruminants (*cf.* p. 134).

The diet of working oxen and horses is very similar on the whole, the only difference being that oxen can do with more hay and straw. Many experiments on the food-requirements of horses, extending over a number of years, have been carried out at Hohenheim, and recently interesting results have been obtained at Paris and at the Agricultural College at Berlin. Great variations were obtained in the amount of food-constituents digested by horses, dependent on the proportion of hay and straw to the oats or other concentrated food-stuff used. Uniform results could only be obtained by leaving the *crude fibre* entirely out of consideration, and simply regarding the other food-constituents as actually concerned in digestion (*cf.* p. 111).

The following results have been obtained by various experimenters :—

Food required to maintain a horse at rest.
(lbs. per 1000 lbs. live-weight.)

	Total digestible matter.	Crude fibre.	Digestible matter *minus* crude fibre.
1.	9 lbs. 6 ozs.	1 lb. 13 ozs.	7 lbs. 9 ozs.
2.	8 lbs. 6 ozs.	13 ozs.	7 lbs. 9 ozs.
3.	9 lbs. 6 ozs.	1 lb. 15 ozs.	7 lbs. 7 ozs.
4.	8 lbs. 1 oz.	$8\frac{1}{2}$ ozs.	7 lbs. $8\frac{1}{2}$ ozs.
5.	7 lbs. 12 ozs.	$5\frac{1}{2}$ ozs.	7 lbs. $6\frac{1}{2}$ ozs.

1 & 2. Hohenheim experiments.
3. Average of 38 experiments at Hohenheim.
4. Average of 6 experiments by Grandeau and Leclerc at Paris. (Diet: 1 part hay and 3 parts of a mixture of oats, maize, beans, and oil-cake.)
5. Results obtained by Lehmann at Berlin.

The following deductions can be drawn from these and other experiments as to the *rational feeding of horses*:—

1. *The crude fibre* digested by the horse from any source appears absolutely *useless* for the nourishment and maintenance of the animal.
2. If the crude fibre be deducted from the food, the *remaining nutrients* in both coarse and concentrated fodder possess the *same value* in every form of food.

3. To maintain a horse in stable, about $7\frac{1}{2}$ lbs. of food composed of digestible albuminoids and carbohydrates (including fat multiplied by the factor 2·4) are necessary.
4. For every additional pound of this nourishment a horse will be enabled to produce 1,736,000 foot-pounds of work (see p. 89).

The following results were obtained from direct experiments :—

	Digestible organic matter. (Per cent. of dry matter.) Total.	Fibre.	Without Fibre.	Equivalent of Work. Per lb. of dry matter.* (Foot-lbs.)
Hay	40·6	11·4	29·2	481,800
Clover-hay	41·1	12·0	29·1	480,150
Lucerne-hay	46·2	11·0	35·2	580,800
Oats	60·2	2·0	58·2	960,300
Barley	70·7	4·1	66·6	1,098,900
Maize	80·0	1·5	78·5	1,295,250
Beans	72·4	4·5	67·9	1,120,350
Peas	66·7	0·5	66·2	1,092,300
Lupines	63·4	8·7	54·7	302,550
Linseed cake	63·4	—	63·4	1,221,000

With regard to the leguminous fodders, it must be remembered that the cellulose they contain is of a more digestible kind than that in hay, and on this account their feeding-value is rather greater than that apparent

* In the original table the "work" is expressed as "kilogrammetres per kilo of dry matter;" 3 "foot-pounds per lb." are approximately equal to "1 kgm. per kilo," and the figures in this column have been obtained by multiplying by 3.

from the foregoing table. Foods rich in fat are desirable when the horses are doing very hard work. Nitrogenous foods like beans and lupines do not render possible a greater production of work than foods of medium albuminoid ratio, provided of course that a sufficiency of albuminoids be provided in the latter.

This minimum amounts to $2\frac{1}{2}$ or 3 ozs. of nitrogen per day per 1000 lbs. live-weight, but is still more for unusually strong and muscular horses, or for those doing heavy work, or for fast-trotting hacks and hunters.

Maize has recently been introduced as a substitute for oats; 4 lbs. of maize being equivalent to 5 lbs. of oats.

C. Lehmann makes the following statement:—"Maize contains a high proportion of digestible carbohydrates and tends to make the animals fat and very liable to sweat; while it improves their appearance, it somewhat detracts from their physical energy."

The horses of the Berlin Tramways Co. are fed to a considerable extent on maize, and for all animals in *regular* work such food does not tend to produce a fat and lazy condition. Horses which are occasionally idle and occasionally undergoing great exertion require a high nitrogenous diet. We recommend the following to practical men:—

To replace 11 *lbs. of oats*:

Give the horse 5 lbs. oats,
3 lbs. maize,
$\left\{\begin{array}{l}1\frac{1}{2} \text{ lbs. beans, or} \\ 1 \text{ lb. oil-cake.}\end{array}\right.$

Dried Brewers' Grains and dried "Slump" may be given in the following quantities:—

Hard work	$7\frac{1}{2}$ lbs. oats,	*per day.*
	9 lbs. "grains,"	
	$16\frac{1}{2}$ lbs. hay,	
	$\frac{1}{2}$ oz. salt.	
Light work	$5\frac{1}{2}$ lbs. oats,	*per day.*
	$6\frac{1}{2}$ lbs. "grains,"	
	$16\frac{1}{2}$ lbs. hay,	
	$\frac{1}{2}$ oz. salt.	

The effect of dried grains has been found to be very uncertain, and on that account the use of "grains" has been given up by the German War Department. In any case, care should be taken not to give too much at a time, and to make an addition of such palatable foods as oats, maize, or wheat-bran. Brewers' grains are very apt to undergo fermentation and to be impregnated with the foul and unpleasant products of bacteria. This is due to the fact that they cannot be dried at a high temperature as their digestibility would be seriously affected, and there is thus no adequate check on the growth of micro-organisms.

The flavour of food is most important for horses, as they are extremely sensitive and easily upset by anything unusual or unpleasant.

CHAPTER V.

THE PRODUCTION OF MILK.

It is highly important that we should have a clear understanding of the way in which milk is formed in the body before we consider the effect of feeding on the quantity and quality of the milk produced.

§ 1. *Formation of Milk in the Body.*

Milk is *not a simple secretion* and is not separated from the blood in the same sort of way as the urine filters through the kidneys, but is first formed in the *milk-glands,* and is principally the result of the breaking up of the gland-cells, and is in reality, to quote Voit, a "*liquefied organ.*" This fact is indicated by the composition of the ash of milk, which contains a considerable amount of lime and phosphoric acid—a characteristic of all animal *tissues* as distinguished from the plasma and the various liquids separated from the blood. These latter contain a considerable quantity of common salt.

The ash of milk contains 3 to 5 times as much potash as soda, while that of blood is 3 to 5 times richer in soda than potash. If milk were a transudation product of the blood, it could not possibly serve as a perfect and complete food as it would obviously lack some of the materials necessary for the growth of cells. Since milk is the direct product of liquefied cells, it provides the young with the food required for growth in the most suitable form and proportion.

The formation of milk is also indicated by the composition of the so-called *Colostrum,* which is the name given to the first milk produced after the birth of the calf. Colostrum contains small rounded gland-cells, but after a few days the growth and liquefaction of the cells proceed at such a rate in the milk-glands, that whole cells cease to appear in the milk and are resolved into the usual "milk-globules."

Milk is an organ that has been liquefied by fatty degeneration. The original cells from which the milk has been produced are composed of albumen which is changed into the constituents of the milk as soon as the cells commence activity.

Casein is not found in the blood, but results from the decomposition of cells, and this explains the fact that colostrum contains no casein but only ordinary albumen, and the amount of casein slowly increases with the growing activity of the milk-glands. Even the "*sugar of milk*" it appears, is not supplied as such to the milk-glands, but is formed in the glands themselves by the decomposition of albumen or fat. It is possible that the grape-sugar produced from albumen and contained in the blood and liver may also undergo a change into milk-sugar.

The milk-glands possess a very independent existence. They absorb material from the blood-capillaries and lymphatics, and by the disruption of the epithelial cells which line the interior of the milk-glands, milk is produced.

These self-contained functions find further confirmation in the fact that in the udder no nerves connected with the central nervous system have been found which could possibly affect the secretion of milk. Because the capacity of the udder and the dry matter of the glands appear too small in proportion to the milk produced, some have assumed that the act of milking stimulated the flow of milk. It is difficult to harmonize this view with the fact that the composition of milk is practically constant and with the wonderful elasticity of the organs. C. Lehmann has shown that the supposed increased rate of production of milk during milking cannot be appreciable, if it take place at all. Just before milking, a deep blue dye was injected into the blood of a goat. No immediate effect was produced on the colour of the milk during milking, but only after an hour or two, while the urine and skin of the animal were almost immediately dyed a deep blue.

§ 2. *Quantity and Quality of Milk.*

It is very evident that both the quantity and quality of the milk must be primarily determined by the *size* and general *growth* of the *milk-glands.*

It is a matter of common knowledge, that two cows fed in exactly the same way often yield very different quantities of milk, and that some breeds produce more butter than others. After the first calf, a cow produces less milk than after the third or fourth. The age of the animal and the duration of the period of lactation often have a greater influence on the amount of milk produced than the method of feeding, while the growth of the milk-glands reaches its maximum at or soon after the birth of the calf, and the glands gradually decrease in activity from this time.

Badly developed glands can never produce large quantities of milk, even with a most nutritious food. It is very evident that for the successful production of milk, *cows of suitable breed and of individual merits* are the *first essential.*

Mere size of udder is no safe guide, as profitable production depends rather on the rapid breaking-up and rebuilding of the cells and the quality of the milk, than on the mere size of the glands.

§ 3. *Effect of Feeding.*

It is evident from the foregoing description of the way in which milk is produced, that *diet* is only a *secondary* consideration in milk-production; but at the same time the manner and extent of the feeding have a very marked effect on the *quantity* of milk produced.

Before everything else, a liberal supply of albumen favours the production of milk, because it induces a continued and rapid building of gland-cells, which latter are principally built up with and charged from albumen. The albumen in the food, however, must pass into the plasma, for the most part as circulatory albumen, and thus rapidly reinforces the milk-glands.

The albuminoid ratio must not be too low, or else the liberal secretion of milk will be reduced on account of the storing up of flesh and fat in the body. On the other hand, too high an albuminoid ratio is to be avoided, as it involves the risk of a considerable proportion of the albumen in the food undergoing decomposition, and thus becoming useless for the production of milk.

Too high a ratio is still more undesirable, because the albumen digested from the food will not pass on to the milk-glands as such, but will first be largely decomposed into fat, and this latter will come in contact with the gland-cells. We can, however, provide milch-cows with a diet of higher albuminoid ratio than fat beasts, since with the former the excess of albumen is rapidly excreted in the milk, and has not so direct a tendency to increase the decomposition and waste of the albumen in the tissues of the body.

A sufficient quantity of "circulatory albumen" is especially necessary for obtaining and maintaining a high yield of milk, and everything calculated to increase the stream of albumen in the body must be considered, within certain limits, as equally conducive to an increased flow of milk (see p. 39 *et seq.*).

A large supply of water often increases the yield of milk without reducing its quality.

All practical observations and experiments have shown that not only should the diet of a milch-cow be adequate in quantity but that it should also be exceptionally rich in nitrogen. Such a diet maintains a high production of milk for a much longer period than a food relatively poor in nitrogen. This is a very important point, even if the daily difference between the yield of milk on the rich and poor diets be not a very large one. The poor average yield of milk resulting from a diet of ordinary hay can only be attributed to a lack of albuminoids in the food.

A good daily yield of milk can only be maintained on hay of exceptional quality, on good pasturage, or by supplementing hay with a richer food-stuff. The reduction in the yield of milk is generally very marked and rapid, as soon as the albuminoids in the food are reduced, although the carbohydrates and fats may still be supplied in abundance.

The following experimental results have been obtained :—

Where observed.	Yield of Milk.	
	With Food rich in Albumen. (Per Cow per day.)	With Food lacking Albumen. (Per Cow per day.)
(*a*) Möckern	21 lbs. 5 ozs.	16 lbs. 13 ozs.
(*b*) Hohenheim...............	29 lbs. 8 ozs.	18 lbs. 6 ozs.

The cows lost in weight on the insufficient diet, and still more lost in general appearance and condition.

It is true that a food which is not rich in nitrogen, but is nevertheless appreciated by the cows, often produces a large yield of milk. The intensity of milk-production is such with good milch-cows, that a high rate of milk-production is often maintained for a long time despite a poor and inadequate diet. This is effected at the expense of the flesh and fat of the body, and the cow becomes more or less thin.

It is highly important not to allow cows to lose condition, as not only are the quality and quantity of the milk affected, but it is often a very difficult and tedious matter to get such a cow into good condition again and restore a high standard of milk even by most liberal feeding.

The albumen in the food provides directly or indirectly the *casein* of the milk as well as the material from which the milk-fat (*butter*) is produced.

Experiments at Möckern and others at Hohenheim have shown that when cows had been fed on such a poor diet that the yield of milk had been considerably reduced, and the animals eventually brought to a condition of "nitrogen equilibrium" between the food supplied and the matter excreted,—that even under these extreme conditions the albumen and fat resorbed from the food fully accounted for the fat (butter) found in the milk (see p. 59). With a very rich and nitrogenous diet, even the milk-sugar found in the milk can be traced to the fat produced from the albuminoids.

In the case of Carnivora, the sugar in the milk must have been formed from albumen; while with Herbivora it is highly probable that the carbohydrates in their food contribute to the production of milk-sugar.

From a careful study and consideration of the large number of recent investigations on the production of milk, I conclude that the following represents

The Feeding Standard of a Milch-Cow.

(Pounds per 1000 lbs. live-weight per day.)

Digestible	albuminoids	2 lbs. 8 ozs.
,,	carbohydrates	13 lbs. 8 ozs.
,,	fats............	7 ozs.
Total bulk of dry fodder		24 lbs.
Albuminoid ratio [1 : 5·4].		

The above standard fairly represents the food provided by a good pasturage. It is true that a diet rather poorer than this, containing 2 lbs. of albuminoids instead of $2\frac{1}{2}$ lbs. per day, may produce a satisfactory yield of milk, but at the same time the latter is not the maximum possible, nor can it be expected to last any length of time, especially if the cow loses in condition. In my opinion *a standard of* $2\frac{1}{2}$ lbs. *of digestible albuminoids* should be aimed at under all circumstances.

We will assume that a cow yields 20 lbs. of milk per 1000 lbs. live-weight over a period of several months. The casein and albumen in 20 lbs. of milk amount to 10 ozs., the fat to 11 ozs.; and as two parts of albumen are required for the production of one part of fat (100 : 51·4), the albumen required by 20 lbs. of milk would be $(10+22)$ ozs. $=2$ lbs.

Even if we assume that all the fat resorbed from the food of the cow is employed in the production of milk, a standard of less than $2\frac{1}{2}$ lbs. of digestible albumen would leave little or no reserve of albumen for maintaining the energy of digestion, for the production of the gastric juices, the calf, &c. The effect of an increased supply of food up to or even beyond the standard we have laid down will be greatest with the best milch-cows, and will be greater with a small cow than with a larger animal yielding the same amount of milk. It is highly advisable to classify the different cows in a stall according to their individual milking capacity, and to feed each group on a diet best calculated to promote a maximum yield, lasting over a considerable period, without involving any waste of food.

§ 4. *Quantity of Milk.*

Both the digestible albuminoids and fat of the food contribute towards milk-production, and both ought to be taken into consideration, as they undoubtedly have a very great influence not only on the *Quantity* but on the *Quality* of the milk. All the experiments made on the feeding of cows have shown that we are quite safe in concluding, at any rate for cows, that

(*a*) Additional fat in the food increases the yield of milk;
(*b*) Under these conditions, the proportion of the constituents of milk is absolutely unaltered.

We can easily understand that additional fat in the food would save some of the albumen from undergoing decomposition, and thus render it available for the production of milk. Fat thus increases the total *quantity* of milk constituents without affecting their proportion to one another.

The fat in the food can only assist in the *direct* increase of milk-fat to an extent limited by its power of passing through the membranes of the body by *Endosmosis.*

In some experiments at Hohenheim, cows were first fed on such a poor diet that a rapid decrease in the production of milk resulted. Fat (rape- and linseed-oil) was then provided at the rate of 1 lb. per cow per day, and it was found that neither the quantity of the milk nor its percentage of fat were increased thereby. If anything, the milk contained less fat and more water than before.

G. Kühn and Fleischer found in some experiments at Möckern that the addition of 1 pound of rape-oil to a rich diet increased the yield of milk 1 pound a day, while the percentage composition of the milk remained unaltered. In some other experiments it was found that the addition of a pound of rape-oil to a diet of hay increased the yield of milk 8 ounces, while the percentage of fat in the milk-solids was distinctly *reduced.*

Stohmann experimented with goats, and found that the addition of oil to a *rich* nitrogenous diet of hay and oil-cake decidedly *increased* the amount of fat in the milk, but that the addition of oil to a *poor* diet of plain hay *reduced* the percentage of butter-fat.

At the same time it is quite open to question whether these results observed with *goats* would hold good for *cows.* The former are in many respects very different from the latter. In Stohmann's experiments, for instance, $6\frac{1}{4}$ to $6\frac{3}{4}$ lbs. of albuminoids per 1000 lbs. live-weight were required by the goats for a maximum production of milk. This is more than twice that required by a cow. It is highly probable, therefore, that the limits to the direct contribution of the fat in the food to that in the milk may be much wider for goats than for cows.

Weiske has carried out similar experiments on ewes. A certain ewe which had been fed on the following diet:—

(Per day)
1 lb. Hay,
1 lb. Barley-meal,
2 lbs. Turnips,

was then fed on :—

Green food [*ad lib.*].
1 lb. Barley-meal.
½ lb. Linsee dcake.

The yield of milk was not improved by the change of diet, though the percentage of fat in the milk was increased 5 or 6 per cent. When fed on green fodder alone, the yield of milk was considerably reduced, while its composition proved identical with that produced on the original diet.

(*a*) A diet of 3 lbs. of hay per day rapidly reduced the yield of milk from 25 ozs. to 21 ozs. per day, while the percentage of milk-solids and butter-fat increased.

(*b*) The addition of 5 ozs. of oil to the green fodder did not improve the yield of milk, though the fat and total solids were considerably increased.

Experiment.	Yield of Milk.		Total Solids.	Fat.
	Before.	After.		
(*a*)	25 ozs.	21 ozs.	18·60 per cent.	7·15 per cent.
(*b*)	21 ozs.	21 ozs.	19·64 „ „	8·68 „ „

Fleischmann has investigated the yield of milk from Dutch cows in various periods of lactation.

Period of Lactation.	*Yield of Milk.*	*Yield of Butter.*
1–5	7277 lbs.	277 lbs.
5–11	6208 lbs.	211 lbs.

He also found that the smaller the weight of a cow the greater the yield of milk in proportion :—

Weight of Cow.	*Yield of Milk per* 1000 *lbs. live-weight.*
1162 lbs.	5748 lbs.
1028 lbs.	6244 lbs.
978 lbs.	6670 lbs.

§ 5. *Quality of Milk.*

We must always bear in mind when discussing the production of milk, that its *quality* is even more dependent than the quantity on the breed and individuality of the cow and is further influenced by the special properties of the milk-glands.

No amount of feeding could possibly change the milk of an inferior German cow into the rich milk of an Alderney. Such a radical improvement as this could only be effected by careful breeding and a gradual development in the desired direction. The prevalent idea with some practical men that this improvement may be attained by food alone, is based entirely on a misconception of the way in which milk is produced.

A sudden change of food often causes a considerable alteration in both the quantity and the composition of the milk ; but it is always found that if the new food be continued long enough the milk returns to its original condition again. This has been well illustrated by experiments at Hohenheim, Möckern, and elsewhere, in which daily analyses of milk have been made for months in succession, rendering possible the calculation of the average of very numerous results.

Isolated analyses or short periods of investigation arc quite valueless and only lead to errors and false conclusions.

Fjord and Friis have carried out a systematic investigation in Denmark for 5 years, 1888–1892, on the milk produced by 1152 cows divided into 112 groups and belonging to 9 different dairies. They found that the *composition* of the milk was just the same whether the cows received barley-meal or an equal quantity of oil-cake as an addition to their ordinary diet. Oil-cake, however, decidedly increased the *yield* of milk, and also improved the condition of the cows to a small extent.

The quality of milk has another and very important connection with the manner of feeding. The appearance, consistency, colour, keeping qualities, aroma, and flavour of butter, as well as the ease or difficulty of its separation from the milk, depend very much on the food of the cow. With a food poor in nitrogen and not much relished by the animals, the butter obtained is generally hard like tallow and of poor flavour. Such butter contains an excess of solid fat (stearin), while the soft and oily fats (palmitin and olein) are in less quantity.

It is well known that butter is not so good in the winter as in the spring and autumn. The influence of food in this respect is practically very great, though the actual amount of fat in the milk may not be affected by rich feeding. At the same time the amount of *water* in the milk may fluctuate; and although the *composition* of the milk-solids remains the same, yet their total quantity may undergo considerable variation.

The milk produced by feeding a cow continuously on a poor diet is always more *watery* than that resulting from a rich diet. In summer cows fed on plenty of nitrogenous green fodder yield a richer and more concentrated milk than on an ordinary diet in winter, though the difference is not really so great as is commonly supposed. A difference of only ½ or 1 per cent. in the amount of the milk-solids, however, means a considerable variation in the yield of butter obtained from the milk.

In certain cases, perhaps dependent on the individual characteristics of the cows, a direct increase of the percentage of fat in the solid matter of the milk has been found to be produced by an improved diet. G. Kühn has obtained such results at Möckern with palm-nut cake and malt-sprouts. Bean-meal was found to have no effect on the amount of fats in milk, while rape cake sensibly reduced the percentage of the latter.

Recent researches by Schrodt at Kiel showed that very favourable results could be obtained by feeding with earth-nut and cotton cakes, provided the cakes were fresh and perfectly sound (see p. 271).

In practice the particular effect of any food is shown by its influence on the quality of milk and butter. The following table shows the effect of various typical food-stuffs:—

Food.	*Quality of Butter produced.*
Excess of Potatoes.	Hard, poor flavour.
Excess of Turnips or Mangolds.	Bitter taste.
Meal from Barley, Spelt, or Wheat.	Moderate consistency.
Peas and Vetches.	Harder consistency.
Oats, Wheat bran.	Softer consistency.

Oats are peculiarly favourable for the production of milk, and all starchy foods, such as grain, bran, rice-meal, &c., improve the flavour of the milk and butter produced, while oil-cakes are very apt to taint both milk and butter, and should be used with great care and not in too large a quantity. This precaution is most necessary with rape cake and poppy-seed cake.

A. Mayer classifies food-stuffs according to their effect on the consistency of butter as follows :—

(The order given is that of the hardness of the butter produced, No. 1 food-stuff yielding the hardest butter in each case.)

Coarse Fodders.	*Concentrated Foods.*
1. Straw.	1. Poppy cake.
2. Hay.	2. Linseed and Sesame cakes.
3. Summer hay and Maize fodder.	3. Earth-nut cake.
4. Mature grass.	4. Rye.
5. Young grass.	5. Cotton-seed cake.

The order would be inverted if the foods were classified according to their influence on the amount of fluid fatty-acids in the butter produced.

§ 6. *The Dry Substance of Milk.*

Many natural circumstances and conditions, quite apart from the manner of feeding, affect the proportion of dry matter in milk.

The milk of a cow yielding a large quantity is generally more dilute than that of another cow yielding a smaller amount of milk. The yield gradually diminishes from the birth of the calf, while the percentage of dry matter contained in the milk gradually increases. This increase is generally found to be due to *Casein,* while the fats somewhat decrease in quantity.

That the above is not always the case, however, was proved at Proskau by an investigation upon the milk from eleven cows at times varying from 3 days to 9 months after calving. It was found that there was no appreciable difference to be observed either in the percentage of dry matter or in that of fat between these limits of time.

Fleischmann, as a result of his researches, found that if cows be fed on a very high diet, the percentage of milk-solids and butter-fat steadily *increased throughout a lactation-period*; and he maintains that if suitable cows be fed on a diet far in excess of that usually recognized and employed, they will pay still better than if fed on an ordinary diet.

§ 7. *Effect of frequent Milking.*

The milk obtained from a cow at different times of the same day is seldom of identical composition. Long intervals between milking conduce to a more watery milk than if the cow be milked more often. If milking be performed three times a day, the milk at noon and in the evening is better than that obtained in the morning.

It was found at Proskau that the milk obtained by three milkings per day was superior both in quantity and quality to that produced by two milkings. Kaull proved that this increased yield was not due to the mechanical process of milking, but was caused by the frequent emptying of the milk-glands. Too frequent milking is quite as bad as leaving the milk-glands too long without relieving them of their contents.

The milk obtained at one milking also varies considerably during the process. The first portions are always poorer and more watery than the last portion. All these natural variations and sources of error must be most carefully guarded against in determining the specific influence of a certain mode of feeding on the milk produced.

§ 8. *Mineral requirements of Cows.*

Weiske has shown that lack of phosphoric acid and lime in food reduces the yield of milk. Henneberg and Stohmann found that an ox required per day per 1000 lbs. live-weight :—

Phosphoric acid...	0·8 oz.
Lime	1·6 ozs.
Potash	3·2 ozs.

If we assume that the milk produced by a good cow throughout a lactation-period averages 20 lbs. per 1000 lbs. live-weight, this would contain :—

Phosphoric acid...	0·64 oz.
Lime	0·48 oz.
Potash	0·58 oz.

By adding these quantities to the requirements of an ox as found by Stohmann, we obtain the following as the *Minimum Mineral requirements of a Cow* :—

Phosphoric acid...	1·44 ozs.
Lime	2·08 ozs.
Potash	3·78 ozs.

Lack of *potash* is not a probable contingency, as it always occurs largely in vegetable foods. The addition of *lime* and *phosphoric acid* to the diet of milch-cows is always worth consideration, but is not often necessary.

In 30 lbs. of average hay (the usual quantity fed per day per 1000 lbs. live-weight) are contained :—

2 ozs. Phosphoric acid.
4 ozs. Lime.
6¼ ozs. Potash.

Lime in the form of chalk is necessary when the cows are entirely fed on such foods as straw, chaff, roots, "slump" or sugar-beet residue. Phosphoric acid will only be lacking in exceptional cases.

§ 9. *Giving Salt to Cows.*

Salt is an essential addition to the food of milch-cows. *First*, because many foods are lacking in soda and rich in potash (see p. 17); and *secondly*, because salt stimulates the flow of the plasma, maintains the circulatory albumen in more active movement, and induces the cow to drink larger quantities of water, all of which tend to increase the production of milk.

Even if the addition of salt to the rich diet of a milch-cow should have no apparent effect on the quantity and quality of the milk, still it will generally be found that at any rate the cow herself looks the better for it, and that a high yield of milk is well maintained.

It is also a matter of common knowledge that salt improves the flavour of the food, increases the appetite of the cow and induces it to eat food that it would not otherwise relish.

Half an ounce of salt per day should be given to each cow; but care must be taken not to give more than this, or else the effects will be quite the opposite of those desired.

CHAPTER VI.

THE FEEDING OF YOUNG ANIMALS.

Calves.—Although numerous practical observations on the feeding of calves have been made, very many of them lack that scientific accuracy and general precision which are requisite for the foundation of general principles and laws.

The following results of experiments on calves by Crusius, though made a long time ago, are still interesting (p. 268).

The milk employed was fairly nitrogenous, but poor in fat, as it only contained 2·6 per cent. of butter-fat. If calves No. 1 and 3 had been fed on average milk, the albuminoid ratio would have been still lower.

We see that the increase in weight of the calves varied with the food in each case. The difference is not due to any *specific* effect of the fat in the food, but is the *direct* outcome of the difference in the amount of organic matter and variation in the albuminoid ratio in each case.

The albuminoid ratio of the food of calf No. 2 was too high, and a certain proportion of the albuminoids in the food must have been oxidized in the body of the animal. If the quantity of food had been increased, the albuminoid ratio remaining the same, it is doubtful whether any further increase of live-weight would have

Calf. No.	Live-weight. lbs.	Food per week.				Albuminoid Ratio *.	Increase in weight per week. lbs.	Organic matter in food for 1 lb. increase. lbs.
		Organic matter. lbs.	Albumen. lbs.	Sugar. lbs.	Fat. lbs.			
1.	106	14·8	3·4	8·2	3·2	[1 : 4·47]	12	2·46
2.	118	12·4	4·5	6·5	1·4	[1 : 2·05]	7·3	3·42
3.	104	18·9	4·6	6·5	7·8	[1 : 5·40]	21·5	1·76

No. 1 received 12 lbs. *new* milk per day,
No. 2 „ 20 lbs. skim milk „ „
No. 3 „ 16 lbs. new milk and 3½ lbs. of cream per day.

* The butter-fat and milk-sugar are calculated as an equivalent quantity of starch.

resulted. The addition of fat in the third case produced very favourable results.

Experiment No. 1, in which the calf was fed entirely on new milk, gave a very satisfactory rate of increase, although the amount of fat and albuminoids in the food was rather small. This illustrates the fact that carbohydrates (milk-sugar in this case) can partially replace fat in the food of young animals.

This last deduction from the experiments of Crusius is of considerable practical importance, since it shows that young calves can be successfully reared on a mixture of about equal quantities of milk and whey, or even on separated milk with the addition of sugar or starch in some digestible form.

It has also been found that calves can be successfully fattened on skimmed milk (20 to 24 lbs. per day). An increase at the rate of over 2 lbs. a day for several weeks can be obtained with a diet of skimmed milk, supplemented towards the end of the time with some other nourishing and digestible food.

I attribute the rapid increase in live-weight observed in experiments 1 and 3 to the comparatively low albuminoid ratio, and to the fact that the bodily increase consisted mostly of flesh. Fat cannot produce any very rapid increase in the weight of an animal, since for the most part it simply replaces water which is otherwise discharged from the body.

Ordinary flesh is three-fourths water, and one pound of albumen produces 4 lbs. of flesh. It should always be remembered, when estimating the growth of young animals, that the proportion of water in the body is much greater in a young than in an older one.

Fat.—If the fat of milk be *completely* replaced by carbohydrates, a disturbance of the nutritive effect results in the case of young animals. Fat is well known to be a concentrated combustible material and of greater value for respiration than any other food-stuff. Milk-fat is highly digestible and adds to the general flavour of the milk, and is thus a very valuable constituent of the food of very young animals. Calves should always be fed for the first fortnight on plain cow's milk. Average milk has an albuminoid ratio of [1 : 4·5], but owing to the very variable proportion of *fat* in milk (2 to 5 per cent.) the albuminoid ratio often varies from [1 : 3·3] to [1 : 5·5]. This explains why equal quantities of milk so often produce such different feeding effects.

A calf fed with 22 lbs. of new milk (containing 3 lbs. of dry matter) grows at the rate of $2\frac{1}{4}$ lbs. per day from the fourth to the sixth week of its existence. This result has been accurately deduced by Soxhlet from experiments with calves in a respiration apparatus (see p. 34). As we have already seen in our previous consideration of these accurate researches, a calf 2 or 3 weeks old practically increases 1 lb. in weight for every pound of solid food provided in the milk.

Colostrum.—Immediately after birth it is highly important to let the calf have milk from its own mother, as the first produce of the milk-glands after the birth of the calf—the so-called *Colostrum*—has a very different composition from the normal milk afterwards produced.

Colostrum contains more fat and sugar, and less casein and albumen, than ordinary milk, and the former therefore possesses a *lower* albuminoid ratio and at the same time is more digestible than the latter. These differences disappear after 8 days or so, and more rapidly with cows yielding a large than with others yielding a small amount of milk. A calf should receive one-sixth to one-eighth of its own weight of milk per day for 6 or 8 weeks.

Weaning.—When the diet of the calf is changed from the pure milk it has been receiving, great care is necessary in adjusting the new diet, or else the calf will lose in weight instead of maintaining its normal rate of increase. This can only be done when the change of diet is gradual and the same standard of digestibility, nutritive value, and flavour is fully maintained.

Crushed linseed mash and linseed cake are held in great favour, and other palatable oil-cakes, such as palm-nut, earth-nut, and coconut cakes, as well as such food-stuffs as oats, barley, malt-sprouts, pea-meal, &c., have been found excellent additions to the diet of young calves. It is also advisable to give calves a little of the very best hay, so that they may become accustomed to eating it; clover should be avoided.

If calves are weaned by being turned out on good pasturage, no difficulty arises; but if they are weaned in the stall, the food must be maintained as nearly as possible at the same albuminoid ratio as milk for some time, and can then be gradually lowered. It is possible to gradually replace the fat in the milk by digestible carbohydrates at a very early period with good results, if the calves are brought up on milk only. If the rules already laid down be observed, a calf will have been weaned when 9 or 10 weeks old, and will weigh, if of a medium-sized breed, from 150 to 220 lbs.

After the calf is weaned, it should receive a liberal diet with an albuminoid ratio of [1 : 5] or [1 : 6], corresponding to that of a good pasturage. Excellent results are sure to follow later on as a return for the good start the calf will thus be enabled to make. After the fourth or sixth month the diet should be gradually changed to one which is more bulky, less nitrogenous, and less concentrated than before. Roots are very suitable at this stage. To raise good milch-cows the calves ought not to be fed too long on a rich diet, as it has a tendency to make them fat and to eventually reduce their milking capacity.

This fact should be kept in mind when using the tables of feeding standards for calves given in the Appendix (Table IV.).

Lambs.—Great care must be exercised in feeding lambs. When quite young they grow even more rapidly than calves, and very readily lose ground if the diet provided is not suitable or sufficient for their needs. Great importance attaches to the selection of coarse fodder at and soon after the time of weaning. When the fodder is too coarse and hard or has been spoilt by bad harvesting, the lambs will not eat sufficient of it and gradually lose weight. Even good average hay needs an addition of a nitrogenous food, such as oats or other cereal.

Experiments have been carried out at Hohenheim on young Württemberg sheep from the fifth to the fourteenth month of their age. The diet varied considerably, and the actually digested constituents of the following diets were directly determined :—

(*a*) Corn alone.
(*b*) Excellent hay.
(*c*) Aftermath.

The figures given in Table IV. in the Appendix have been deduced from these researches, and are suitable for maintaining sheep of a moderately fine-woolled breed, and weighing from 100 to 110 lbs., in a good and constant condition.

Weiske has obtained very similar results by experiments with a herd of Merino Southdowns. The following table gives Weiske's results :—

WEISKE'S SHEEP EXPERIMENTS.

Age of Sheep.	Live-weight.	Organic matter in Food.	Digestible Food.			Albuminoid Ratio.
			Albumen.	Carbo-hydrates.	Fat.	
Months.	lbs.	ozs.	ozs.	ozs.	ozs.	
5–6	51	24	$2\frac{3}{4}$	$13\frac{1}{2}$	$\frac{1}{2}$	[1 : 5·3]
7–9	66	28	3	15	$\frac{1}{2}$	[1 : 5·5]
10–12	77	29	3	15	$\frac{2}{3}$	[1 : 5·8]
13–15	85	30	3	16	$\frac{3}{4}$	[1 : 6·2]
16–24	103	34	$2\frac{1}{2}$	$17\frac{1}{2}$	$\frac{6}{7}$	[1 : 7·6]

The Mineral Matter stored up in the bodies of the sheep was as follows :—

MINERAL MATTER.

Age of Sheep.	Live-weight.	Stored up per head per day.				
		Potash.	Soda.	Lime.	Magnesia.	Phosphoric Acid.
Months.	lbs.	grams.	grams.	grams.	grams.	grams.
5–6	51	2·04	0·84	1·56	0·12	1·09
7–9	66	2·89	1·05	2·00	0·32	1·65
10–12	77	3·05	0·81	1·81	0·38	2·50
13–15	85	2·65	0·72	2·07	0·35	3·14

It will be noticed that the amount of phosphoric acid stored up in the body of a sheep per day increases from the fifth to the fifteenth month, while that of the other mineral constituents remains practically constant throughout that period.

YOUNG PIGS.—No satisfactory researches have yet been made on the food-requirements of young pigs. It is customary to feed them generously from the very first so that they may rapidly become fat. The diet best suited to this end is discussed in the next chapter.

Mineral Requirements of young Animals.

In feeding young animals the greatest care is necessary with regard to the *Phosphoric acid* and *Lime* in the food supplied. The other mineral constituents, such as potash, magnesia, and iron, are always supplied in plenty and need no especial provision.

At the end of 12 months a calf weighing 770 lbs. (55 stone) has stored up in its body :—

{ 14 lbs. 13 ozs. of Phosphoric acid,
{ 16 lbs. 8 ozs. of Lime;

or { 277 grains of Phosphoric acid per day,
{ 307 grains of Lime per day.

The average food of such a calf for the first week would be represented by 2 gallons of milk containing

{ 303 grains of Phosphoric acid,
{ 250 grains of Lime.

A new-born calf is thus apparently able to store up the whole of the lime and phosphoric acid in milk, while the amount stored up during the later months of the first year must amount to 30 or 50 per cent. of that provided in the food (see p. 35).

The experiments of Weiske and Wildt on calves 5 to 6 months old showed a storage of

{ 324 grains Phosphoric acid per day,
{ 253 grains Lime per day.

The addition of Phosphate of Lime only results in assimilation when the calf is unable to get the necessary amount—viz.:

{ 325 grains Phosphoric acid per day,
{ 260 grains Lime per day—

from its food.

Although the mineral constituents of milk are to all intents and purposes perfectly digestible and capable of complete storage in the body, it is quite different with the mineral constituents of the other food-stuffs. In the artificial feeding of young animals, an appreciable excess of lime and phosphoric acid should always be provided, especially in the first months, when a rapid and sound development of the bony framework is most desirable and necessary. Young cattle are generally fed on hay and corn, and are not at all likely to lack mineral matter, as 1000 lbs. of oats, for instance, contain :—

6 lbs. 13 ozs. Phosphoric acid;
1 lb. Lime;

while 1000 lbs. of hay contain :—

4 lbs. 6 ozs. Phosphoric acid;
9 lbs. 13 ozs. Lime.

The two food-stuffs thus mutually adjust their individual deficiencies,—lack of lime in the case of oats and of phosphoric acid in the case of hay.

If more roots, corn, straw, or chaff be supplied and the amount of hay be reduced, a lack of lime may easily occur. For example :—

1000 lbs. potatoes contain:

1 lb. 10 ozs. Phosphoric acid;
5 ozs. Lime.

1000 lbs. cereal straw contain :

2 lbs. 6 ozs. Phosphoric acid;
3 lbs. 13 ozs. Lime.

The addition of a little chalk to the food in the form of powder or of "lick-stones" is evidently desirable under such conditions of feeding as the above. Phosphoric acid can be provided artificially in the form of phosphate of lime. Experiment has shown that this latter substance is capable of assimilation by calves and lambs, and it has been found of great benefit to foals.

The food of young animals reared artificially should always contain 2 to 3 times as much lime and phosphoric acid as that actually required by the animals.

If these important substances be lacking at all, the richest food will prove of little or no effect, and the young animals will lose ground and gradually decline in condition.

CHAPTER VII.

FATTENING.

The fattening of animals resolves itself principally into the storing up of *fat*. Lawes and Gilbert found from their experiments that in the process of fattening 10 times more fat than flesh is stored up in the body (p. 60). Recent researches by Kern and Wattenberg at Göttingen (see p. 62) also showed that in the fattening of full-grown sheep the increase was entirely due to fat and not at all to flesh.

In these researches, however, the animals were in excellent condition to start with. If this is not the case, the animals always make a good deal of flesh in the first stages of fattening. Young animals in rapid growth can make flesh at a quick rate, while the strictly "fattened" animal does not increase appreciably in this direction.

The general laws of Flesh- and Fat-formation have been already discussed in Part I. of this book, and I will only now refer to a few of the more important points involved.

Lean oxen, poor in flesh and fat, must first attain a good bodily condition before they can be fattened. It is impossible to make the body rich in flesh and fat if it does not already possess the necessary minimum of organized and circulatory albumen to render possible the digestion of large quantities of fat and albumen and to secure their resorption and storage in the body. To put lean oxen in good condition, the following diet would prove effectual :—

Clover-hay with a moderate addition of barley-meal and oil-cakes (or slump, brewers' grains, malt-sprouts, bean-meal, &c.) containing :—

(Per 1000 lbs. live-weight)
$2\frac{1}{2}$ lbs. digestible albuminoids;
$12\frac{1}{2}$ lbs. digestible carbohydrates;
[1 : 5] albuminoid ratio.

After a fortnight or 3 weeks the beasts will be in fit condition for fattening, and the diet must be modified by the further addition of 3 lbs. 12 ozs. of digestible non-nitrogenous food, whereby the albuminoid ratio would be reduced to [1 : 6·5]. The stream of circulatory albumen and its rapid destruction will then be reduced, and some of the albumen will be stored up in the organs.

At the same time the fat resorbed from the food and that produced from the albumen will escape combustion to a greater extent and will be stored up in the body. The laying-on of fat takes place more readily in the body of an animal already rich in flesh than in that of one which is relatively lean.

Pfeiffer and Kalb found that sheep fed first on a very rich nitrogenous diet, and then on an average fattening ration containing a fairly high proportion of digestible carbohydrates, increased in weight at a most extraordinary rate. After one-third of the fattening period is passed and the animals have laid on a good deal of fat, it is advisable to gradually increase the amount of digestible albuminoids in the food from $2\frac{1}{2}$ to 3 lbs., and thereby raise the albuminoid ratio of the whole diet to [1 : 5·5]. A rich supply of albumen for the production of fat will thus be provided, which is the more important as the laying-on of fat gradually increases in difficulty as the store in the body gets larger. There is no risk of increasing the stream of circulatory albumen, as already an abundance of fat will have been stored up in the body.

The standard just laid down should be now maintained for a considerable time.

Fattening Standard for Oxen.

(Per 1000 lbs. live-weight)

3 lbs. digestible albuminoids per day;
$16\frac{1}{4}$ lbs. digestible carbohydrates and fats per day;
[1 : 5·5] albuminoid ratio.

In practice it is usual to employ a rather less nitrogenous food just at the end of the fattening period, such, for instance, as the substitution of barley-meal for the oil-cake or other rich nitrogen-food previously supplied. Good results can thus be obtained if, as is often the case, the diet gains in palatability and the amount of digestible matter be increased. The diet of lower albuminoid ratio may permit of the laying-on of flesh without prejudicing the fat already stored up. It also appears that the final product of the fattening is thus sent to market in a more tender, juicy, and better flavoured condition, and is more suitable for the purposes of the butcher than if a higher albuminoid ratio be maintained to the very end. The final diet, however, must not be reduced to a lower albuminoid ratio than [1 : 6].

Effect of Fat in the Food.

The addition of fat to the diet of fattening animals, such, for instance, as 8 ozs. to 1 lb. of rape-oil per head per day for oxen, and 1 to 1½ ozs. for pigs, has often been found by direct experiment to produce excellent results, especially if the albuminoid ratio of the diet be a high one.

Such treatment favours the laying-on of both fat and flesh, and the addition of oil is especially appropriate in the second or main period of fattening, as the food would then be more concentrated than ever. At the same time, the addition of rape-oil or other fat has not yet found general acceptance in practice. This is obviously due to the fact that pure fat or oil commands a very high price, and if the oil be given in even slight excess or be administered for too long a time, the animals are very apt to suffer in appetite and digestive power. The proportion of fat in the diet of fattening beasts is well worthy of consideration, and may often be increased to advantage, especially with a high albuminoid ratio. This addition can be made most cheaply in the form of oil-cakes or in certain cases by small quantities of oil-seeds.

In fattening, it is very important to provide a diet which is not only easily digestible but which is also relished and liked by the animals, or else they will not eat it freely and in large quantity.

The *preparation* of the food and the addition of a certain amount of *salt* both tend to secure this end; for though the actual digestibility of the food may not be increased, still excellent results follow from the improved flavour of the food, and the larger amount which the animals are thereby tempted to eat (*cf.* p. 147).

Such food-stuffs as potatoes and sugar-beet residues are benefited by a fairly large addition of salt, but great care must be taken not to add an excess or unsatisfactory results will follow. Too much salt, as we have seen, causes the animals to drink to excess and retards their bodily growth (p. 43).

Excess of *water* in the food of fat beasts should be guarded against. The proportion of water to dry matter in the food of fat oxen should not exceed 4 or 5 to 1, and in the case of fat sheep a proportion of 2 or 3 to 1 should be maintained.

Fat Sheep.—All the experiments on the fattening of *sheep* point to the especial value of a high nitrogenous diet. Such a diet was found not only to produce a more rapid increase in live-weight than one of low albuminoid ratio, but after slaughtering the carcases were found to contain a greater proportion of fat (p. 61).

This fact finds confirmation in the ordinary experience of farmers. A diet of 2 lbs. of bean-meal a day in addition to hay is well known to rapidly fatten sheep.

The same general rules laid down for the feeding of fat oxen hold good in the case of sheep; but as they are usually in fair condition to begin with, the preliminary feeding can be dispensed with in the case of sheep. To start with, a diet with an albuminoid ratio of [1 : 5·5] should be given, and then this may rapidly be increased to [1 : 4·5] and maintained at that standard for a considerable time.

It cannot be denied, however, that a diet with a lower ratio than this [1 : 5 to 6] often succeeds well with fattening sheep. The principal considerations in fattening are, that the diet should be highly digestible and should be also relished by the animals. Watery food is even more hurtful for sheep than oxen, and excess of slump or roots should be avoided. On the other hand, the addition of potatoes permits of a favourable ratio of 1 : 2 or 1 : 3 between the dry matter and moisture in the food. The best results with sheep are obtained with good hay and an addition of corn or meal.

In proportion to their live-weight, sheep require food containing more dry matter, and that of a higher albuminoid ratio, than that suitable for oxen. As a general rule the best results will be attained both with fat sheep and oxen if the fattening diet contains 18 lbs. of digestible food per day per 1000 lbs. *original* live-weight. In the case of sheep, an average increase in live-weight amounting to 10 or 12 per cent. of the weight of the digested food ought to result, and rather more in the case of oxen.

The various breeds of sheep exhibit great differences with regard to the amount of food they will eat and its resulting nutritive effect. Sturdier breeds, such as English sheep in general and *Southdowns* in particular, are more easily fattened than the smaller breeds found on the Continent, such as the *Merinos* and *Negrettis*.

Sheep fatten most rapidly between the ages of 18 months and 3 years. It is true that, like all young animals in rapid growth, sheep will make a more rapid increase in live-weight during the first year with a rich diet than that attained by more mature animals of the same breed under similar conditions. The result is not so satisfactory, however, from the butcher's point of view, for not only is the dressed carcase more watery in itself, but it is also less in proportion to the live-weight and the amount of fat is smaller than with older sheep.

In an experiment at Hohenheim, lambs were fattened in 8 or 9 months to the same extent as older sheep in 3 months, and the cost of the former was far in excess of the latter. Two-year old sheep achieve the best fattening results both as to quality and quantity. Full-grown sheep (over 4 years old) rapidly develop fat in the region of the intestines and on the kidneys, but the meat is not of so fine a flavour as that of younger animals.

The results obtained by Kellner at Hohenheim by weighing the animals alive and the carcases when dressed, show that fat sheep can be maintained in prime condition without loss for a long time on an ordinary maintenance diet. He found that 12 fat sheep 1½ years old and 12 others 2 to 4 years old had been maintained in constant bodily condition for 2 months on a diet of 2¾ to 3 lbs. of ordinary hay per head per day.

Similar results were obtained with oxen. This is quite comprehensible when we recollect that *fat* is the chief product of fattening, and that this, when once produced, requires no further nourishment to maintain it and even acts as an economizer of albumen. If the animals be debarred from unnecessary movement and be kept in strict seclusion in a stall, a very moderate diet is all that is required to keep them in a constant condition.

Effect of Shearing.

Sheep generally fatten more quickly after than before being shorn.

Stohmann found by experiments that *before* shearing a high nitrogenous diet gave better results than one of lower albuminoid ratio, but *after* shearing both diets yielded the same increase of live-weight, and a difference was only found on comparing the dressed carcases in each case. The more rapid increase in live-weight after shearing is simply due to the improved appetite of the animal and the fact that it eats more food.

In one of Henneberg's experiments a greater increase of live-weight was obtained with the same amount of food after than before shearing.

The sheep in this experiment drank less water after being shorn, and thus was enabled to make better use of the food supplied, and to produce a greater increase of live-weight (see pp. 43 and 69). Kern and Wattenberg have shown, however, that the consumption of albumen is only reduced for the first few days after shearing, which is perhaps due to the fact that more nitrogen is employed in the production of wool.

Weiske found under similar conditions that sheep after being shorn drank less water than before, but he did not observe any appreciable increase of live-weight in consequence. The consumption of albumen had increased 5 per cent., and the rate of flesh-formation was thereby reduced, but this does not prohibit the possibility of an increased storage of fat in the bodies of the shorn sheep. The digestibility of the food was absolutely the same both before and after shearing, and the increased appetite of the shorn animals remains the only explanation of the facts observed.

Advice as to the Interpretation of Feeding Standards.

I would here urge farmers not to assume that the standards I have laid down for fattening oxen and sheep are suited to all conditions without modification. Some animals have a constitutional capacity for fattening, just as some cows are peculiarly adapted for giving milk, and in such cases food considerably in excess of our standard should be given at the discretion of the stock-keeper.

Märcker, as a result of a large number of practical experiments, has proved that a very highly nitrogenous diet caused a rapid increase of live-weight with fat sheep, although the improvement in the quality of the meat was doubtful.

The return made in the manurial value of the dung in the form of nitrogen and phosphates is an important item in the consideration of the financial outcome of this method of feeding. An increase in the carbohydrates and fats often gives excellent results; but in the case of sheep the quantity must not exceed 20 lbs. per 1000 lbs. original live-weight, whether the albuminoids be high or low in amount, as both the quality and quantity of the product would suffer. Up to this limit the increase of both groups of food-constituents is highly desirable.

The chief lesson to be learnt from all these experiments, as Märcker insists, is this :—

Only animals of the BEST quality will pay for fattening ; feeding inferior beasts on a high diet is simply waste of time and money.

The Fattening of Pigs.

The feeding-standard I lay down for fattening pigs is one in which the albuminoid ratio is gradually reduced with the progress of the fattening. I prescribe a lower albuminoid ratio towards the end of the fattening period, because bacon of a firmer and better quality is thus obtained and the pigs are less likely to become diseased than with a rich nitrogenous food. If lean swine of fair size be fattened, they will eat an enormous amount of food at first (exceeding 40 lbs. of dry matter per 1000 lbs. live-weight), and rapidly increase in weight, but the fatter they become the less they eat and eventually their appetite is hardly as great in proportion as that of fat beasts. This is still more noticeable if young pigs be fed on a fattening diet from the time they are weaned until they are a twelvemonth old, and have attained a weight of about 3 cwt. per head. With suitable food and pigs of a breed adapted for fattening, an average increase of 1 lb. for every 4 lbs. of dry matter in the food can be attained. At first an increase of 1 lb. results from 3 lbs. of food, but later on 4 or 5 lbs. of food are required to produce the same effect. Older pigs require more food in proportion to the increase produced than young ones. These facts have been confirmed by repeated experiments at Hohenheim and at other German as well as Danish experimental stations.

With regard to the tables in the Appendix (Table IV.) giving the feeding standard for fat pigs as deduced from the results of direct experiments, I should state that the high albuminoid ratio prescribed for the first few months after weaning the young pigs is open to objection because it may lead to the animals over-eating, and is more apt to engender diseases and lameness than a food less rich in nitrogen. It would be a wise precaution, therefore, to reduce the amount of the albuminoids in the food until an albuminoid ratio of [1 : 4·5] or [1 : 5] be obtained, and after the sixth month to gradually lower the ratio until it has reached [1 : 6·5]. With full-grown pigs, or at the end of the fattening period, the albuminoid ratio can be kept as low as [1 : 8] or even [1 : 10], provided the food be digestible and palatable. Good fattening results have been obtained on these lines at Hohenheim, where a diet of starch and barley-meal was employed, and also at Göttingen, where Henneberg found raw sugar produced excellent fattening results.

The addition of about $\frac{1}{4}$ oz. of powdered chalk per head per day undoubtedly contributes towards the health of fattening pigs. This addition of chalk should never be omitted with young pigs, as the food usually provided is rich in phosphates but invariably lacking in lime. A small amount of salt ($\frac{1}{4}$ oz. per head per day) should always be added to the food of pigs.

It is very evident that the feeder has at his disposal a large number of possible combinations of food-stuffs which conform to the feeding standard, and one of the most important questions for him to decide is, "What foods at my disposal will achieve the best result at the smallest expense?"

Experience has shown that barley-meal, maize-meal, and pea-meal, mixed with steamed potatoes, are excellent foods for fat swine, while oatmeal and bran have proved of little value in this respect. The addition of whey or sour milk is a great improvement to a food which the animals do not relish by itself. The waste-products of the dairy are of the greatest value for feeding pigs.

Henry, of the Wisconsin experimental station U.S.A., found that pigs fattened on a diet of corn (maize, pea-meal, &c.) required 552 lbs. of food for 100 lbs. increase in live-weight, but that results as good were obtainable if half or even two-thirds of the corn diet were replaced by whey (containing 6·1 per cent. dry matter. Albuminoid ratio [1 : 6·6]). Henry estimated that 760 lbs. of whey were equal to 100 lbs. of corn. Fjord states that he found 12 lbs. of whey were equal to 1 lb. of barley- or rye-meal.

Flesh-meal is a highly digestible nitrogenous food, and is an excellent addition to a general diet in which albuminoids are lacking (see p. 203).

Raw sugar acts like whey, which contains the sugar of milk (*lactose*), and is a capital food for fat pigs. German farmers would gladly use it for fattening pigs at a good profit were it freed from the tax placed upon it by a short-sighted government.

A large number of experiments on feeding pigs with sugar have been made in Hanover.

The addition of 3 lbs. of sugar to the food of fattening pigs resulted in the production of 1 lb. of pork, and the pigs were found capable of eating 1 to 1½ lbs. per head per day without waste or any disturbance of digestion. The rate of fattening was thus increased and the amount of food required to produce it decidedly reduced. Pigs eat sugar with relish; it increases their appetites, and they do not get tired of it. Calves and sheep do not take kindly to sugar. The bran of wheat and rye does not suit fattening pigs (p. 193).

Friis and Petersen found bran far inferior to barley-meal for pigs; not only was the pork of poor quality but there was 4 per cent. more loss in killing and dressing the carcases.

APPENDIX.

TABLE I.

The Composition and Feeding-value of Food-stuffs.

The figures given in this Table are AVERAGES, and must not be regarded as absolutely accurate for all cases or under all conditions. Their value lies in enabling a farmer to easily reckon up the *feeding-value* of his stock in hand, or to get a fairly accurate idea of the best and most economical *combination* of the food-stuffs at his disposal for any particular branch of stock-keeping.

It is highly necessary that such figures should be based as far as possible on the latest scientific results, and that all those errors and inconsistencies, which are so glaringly evident in former tables, in which the compilers have selected standard values suited to their own fancy or limited experience, should be rigidly excluded. Averages are most valuable as an index and guide to the intelligent and rational use of feeding-stuffs.

The following remarks are intended to throw further light on this table :—

1. I have set forth in the case of Hay, Clover, Straw,

and some other farm foods the composition of different *qualities* in each case. The values given are calculated from the average of direct experiments in each case, and with a little experience a practical man can easily decide in which class to place any particular sample with which he is concerned. To guide the farmer as to how to judge the probable quality of a sample of hay or straw or other food-stuff, I have fully discussed in Part II. the various conditions which determine or modify the feeding-value of the various farm foods in general use. I append a brief *résumé* of the conditions affecting the *quality* of a food-stuff.

(a) *Period of Vegetation.*—A young plant contains more albuminoids and less crude fibre than one in a later stage of growth. The alteration in the composition of grass is not so marked in its first vegetative growth as at the period of flowering and just after. Clovers develop excess of fibre more rapidly than grasses.

(b) *The leaves* often contain two or three times as much albuminoids as the stalks of a fodder-plant, while the latter contain more crude fibre. The more the growth of leaves is favoured and the less the loss of leaves in any method of preserving or storing, the more valuable the fodder.

(c) *The Soil* has a very great influence on the crop grown upon it. A rich soil encourages luxuriant growth and the production of shoots, stalks, and leaves. A light sandy soil usually yields corn, roots, and fodder-crops less rich in nitrogen than those grown on a heavy clay, although the product of the lighter soil is often possessed of better flavour and aroma. A wet sour peat always detracts from the high quality of a crop.

(d) *Manuring, Weather, and Climate.*—Chemical analysis has proved over and over again the marked influence of these agencies on the composition of a crop. By a liberal dressing of manures rich in nitrogen and phosphates a poor soil has been proved capable of yielding large crops. The season determines the quality and quantity of a crop producible under given conditions of soil and manuring. A favourable season which is both warm and moist can produce as good a crop on a poor soil as powerful manures under less favourable conditions of weather.

(e) *The weather during Hay-making* is well-known to have a most important influence on the quality of the Hay. If hay be soaked with rain, it not only loses in flavour but also in actual feeding-value. Aftermath is more easily spoilt than Hay, and Clover most of all. Clover-hay is often rich in nitrogen, but is found to contain an excess of crude fibre and to be greatly lacking in nitrogen-free extract, because the latter has been washed out by rain during hay-making.

Fodder is always the worse for being soaked, and is often actually hurtful if it has become mouldy in consequence.

(f) Many other causes contribute to variation in the quality of foods—for instance, the situation of the field with regard to sunshine, the closeness with which the plants grow together, the general methods of cultivation, harvesting, preservation, storage, &c. It is impossible to allow a definite and fixed value for all these variables in food calculations, and each must use his own judgment in deciding as to the comparative quality of any food-stuff.

More analyses of food-stuff are still much needed with special reference to the growth and general conditions under which the crops have been grown and harvested. Märcker has conducted this new branch of food-analysis with great zeal, and it is now possible to obtain data referred to the quality of many food-stuffs.

The monumental work of Dietrich and König, in which they have made a complete and systematic compilation of all the food-analyses on record, is an invaluable guide and an ideal work of reference.

2. This table contains the amount of actually digestible food supplied in the various food-stuffs, under the headings "Digestible albuminoids," "Digestible fats," and "Digestible carbohydrates." It was not possible to base these values on direct "digestion experiments" in all cases; but so many of the typical food-stuffs have been investigated in this way, that little risk of serious error is involved in calculating digestion values from a comparison with others based on direct experiments. The figures I have obtained by calculation may of course be modified in future to a certain extent when the results of direct experiments have been obtained. In the year 1874, when the first edition of this book appeared in German, it was necessary to start with such figures, as the employment of "digestible" values is the only way in which the general laws of animal nutrition and the rational feeding of farm animals can possibly be placed on a sound and firm basis. In framing my tables, I have brought just the same considerations to bear on the results obtained

by experiments on the digestibility of food-stuffs as an intelligent farmer would apply if he wished to determine correctly the feeding-value of any food of known composition.

Any food-stuff of practically the same composition as that given in the table may be safely concluded to possess the digestible value attached to it there. If, however, a sample exhibits a decided variation from the typical samples given in Table I., its digestibility will vary in proportion, and by consulting Table II. its probable extent can easily be found.

3. I have put in separate columns the digestible carbohydrates (nitrogen-free extract) and the digestible fibre (crude fibre). This is necessary on account of the recently established fact that much of the fibre which is apparently digested undergoes decomposition and passes off as gas from the intestines. Foods rich in fibre require greater efforts of digestion and rumination on the part of cattle than the easily digested roots and concentrated food-stuffs. I have decided that the crude fibre apparently digested (from the difference between food and dung) should be considered as only *half* that value for *cattle*, and of *no* feeding-value at all for horses.

4. The most striking results of scientific investigations on the feeding-value of farm foods is that *the digestible constituents* of foods—the so-called nutrients—measure the real feeding-value of a food.

Digestible albuminoids, fats, and carbohydrates are the only materials that represent the real value of any food-stuff, and it is highly desirable that some system of *money valuation* should be adopted so that a farmer may see at a glance what food-stuff at the current market price would be actually the cheapest for his purpose.

The customary scale for valuation has been that of:—

Crude albuminoids $= 5$
Crude fats $= 5$
Crude carbohydrates $= 1$
Carbohydrates $= \frac{3}{5}$ of a penny per pound.

The author proposes the following scale as more in accordance with current market prices:—

Digestible albuminoids $= 3$
Digestible fats $= 2$
Digestible carbohydrates $= 1$
Carbohydrates $= \frac{3}{5}$ of a penny per pound.

The values so obtained require a reduction of about a third in the case of such coarse fodders as chaff and straw. This is due to the fact that the returns made for digestible albuminoids in these food-stuffs include a certain proportion of amides or substances other than true albuminoids, while the ether-extract always contains waxy substances, and the nitrogen-free extract contains more fibre (cellulose) than is the case with concentrated food-stuffs.

The calculated values obtained in this way are frequently at variance with the market price, which fluctuates in obedience to supply and demand. Food-stuffs employed for human food are generally abnormally high (wheat, rice, and generally peas and potatoes), as is also the case with foods employed in manufactures, such as barley, sugar-beet, oily seeds, &c. Such foods as oats and linseed cake, which possess a reputation as excellent foods for special purposes, are generally at a premium, while foods that are apt to disagree with cattle or are not relished by the animals (lupines, poppy cakes, &c.) are usually sold at prices below their apparent value.

For the control of the sale and purchase of food-stuffs in Germany, the seller has to provide a guarantee; and in case the analysis should prove that the sample was not up to the standard guaranteed, the buyer is entitled to compensation based on a system of food units. The unit values recognized officially for

Crude albuminoids	= 5
Crude fats ...	= 5
Carbohydrates	= 1

To give an example of the working of this system, let us consider the unit feeding-values for rape cake. A sample of rape cake guaranteed to contain

31	per cent.	Albuminoids,
10	,,	Fats,
28	,,	Carbohydrates,

is sold at £6 per ton.

Here we are dealing with

$$31 \times 5 = 155$$
$$10 \times 5 = 50$$
$$28 \times 1 = 28$$
$$\text{Food units} = 233$$

Two hundred and thirty-three units are therefore sold for £6, so that a single unit is worth 6*d.* [6·17 pence]. From this the compensation due for a certain deficiency on analysis can easily be determined.

When it is necessary for a farmer to buy a special food-stuff as addition to his own supply on his farm, a comparison of "food-values" with the current market price will enable him to decide on the cheapest substance suited to his particular purpose.

All foods possess a certain *manurial value* quite apart from their direct *feeding-value*. The value of the manurial constituents in concentrated food-stuffs is, roughly, 6*d*. per lb. for nitrogen, 4*d*. for phosphoric acid, and 2*d*. for potash. Owing to the inevitable loss incurred in the manipulation of farmyard dung, these values require considerable modification. A reduction of 50 per cent. on these values in the case of nitrogen, and of 30 per cent. for potash and phosphoric acid, is necessary, so that the *practical* manurial value of these substances in food-stuffs is as follows:—

Nitrogen ...	3*d*.	per lb. :	*roughly*,	3*d*.
Phosphoric acid	2·8*d*.	"	"	2*d*.
Potash ...	1·14*d*.	"	"	1*d*.

It should be remembered that *feeding* and *manurial* values depend on quite different conditions, and the value of a food is primarily measured by its feeding-value, while that of its manurial efficiency is a secondary consideration.

It is a very difficult problem to adjust a valuation between these two considerations, and many food-values are calculated entirely without reference to the subsequent manurial value of the dung produced.

TABLE I.

Giving the average Percentage Composition and Percentage of Digestible Constituents of Food-stuffs [1].

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
I. Hay.										
(a) *Meadow-hay and Grasses.*										
Meadow-hay, poor	14·3	5·0	7·5	33·5	38·2	1·5	3·4	19·3	15·6	0·5
,, better	14·3	5·4	9·2	29·2	39·7	2·0	4·6	21·1	15·3	0·6
,, average	14·3	6·2	9·7	26·3	41·4	2·5	5·4	25·7	15·0	1·0
,, very good	15·0	7·0	11·7	21·9	41·6	2·8	7·4	27·9	13·8	1·3
,, extremely good	16·0	7·7	13·5	19·3	40·4	3·0	9·2	30·1	12·7	1·5
Alpine hay	14·3	6·2	13·5	22·7	39·4	3·9	9·2	27·0	13·9	2·3
Aftermath	14·3	6·6	11·7	22·0	42·3	3·1	7·4	29·1	13·2	1·4
Moorland hay	11·0	6·4	9·2	26·7	44·2	2·4	5·1	28·3	15·7	1·3
Salt meadow-hay	11·7	7·4	8·1	28·4	41·7	2·7	4·3	24·6	16·4	1·4
Sour hay	13·0	6·3	7·6	32·8	35·7	4·6	3·4	20·9	14·8	1·5
Woodland hay	15·0	5·0	8·7	26·0	43·2	2·1	5·0	27·6	15·3	1·1
Rye	14·3	5·1	10·4	23·1	44·5	2·8	6·6	28·9	15·4	1·3
Oats in ear	11·5	6·1	7·5	30·1	42·4	2·4	3·8	24·2	14·7	0·9
Hungarian Brome-grass	13·4	5·7	10·8	29·4	38·5	2·2	6·1	23·4	17·6	0·9
Rye-grass, English	14·3	6·5	10·2	30·2	36·1	2·7	5·1	19·9	15·4	0·8
,, French	14·3	9·9	11·2	29·4	32·6	2·7	5·6	17·5	15·6	0·8
,, Italian	14·3	7·8	11·2	22·9	40·6	3·2	7·1	26·6	14·9	1·4
Pasture-grass (average)	14·3	5·8	9·5	28·7	39·1	2·6	5·3	23·6	17·3	1·1
Timothy grass	14·3	4·5	9·7	22·7	45·8	3·0	5·8	29·8	13·6	1·4
Schrader's Brome-grass	14·3	9·4	9·7	22·8	41·6	2·2	5·4	25·7	13·3	0·9

[1] Refer to Explanation of Table on page 290.

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
(b) *Clover and Leguminous Crops.*										
Bokhara Clover, young	14·3	8·0	16·7	30·3	27·9	2·8	8·5	18·1	13·6	1·6
Sainfoin just in bloom	15·8	6·7	15·4	24·9	34·0	3·2	10·9	25·2	10·7	2·1
,, in bloom	16·7	6·2	13·3	27·1	34·2	2·5	9·3	25·3	9·8	1·6
Hop Trefoil	16·7	6·0	14·6	26·2	33·2	3·3	9·2	23·2	13·1	2·0
Bird's-foot Trefoil	12·5	6·8	13·5	22·5	41·7	3·0	7·4	27·1	11·2	1·5
Crimson Clover (*Tr. incarnatum*)	16·7	5·1	12·2	30·4	32·6	3·0	6·2	21·2	13·7	1·4
Lucerne, average	16·0	6·2	14·4	33·0	27·9	2·5	10·1	19·5	13·9	1·0
,, very good	16·5	6·8	16·0	26·6	31·6	2·5	12·3	22·1	11·4	1·2
Red Clover, inferior	15·0	5·1	11·1	28·9	37·7	2·1	5·7	24·6	11·6	1·0
,, ,, average	16·0	5·3	12·3	26·0	38·2	2·2	7·0	25·3	11·7	1·2
,, ,, very good	16·5	6·0	13·5	24·0	37·1	2·9	8·5	26·0	11·3	1·7
,, ,, excellent	16·5	7·0	15·3	22·2	35·8	3·2	10·7	26·8	11·0	2·1
,, ,, not rained upon	16·0	7·5	14·9	24·8	34·6	2·2	9·4	24·2	11·6	1·3
,, ,, rained upon	16·0	7·0	11·9	33·1	30·5	1·5	6·1	18·3	13·2	0·7
Sand Lucerne (*Medicago media*) just in bloom	16·7	6·1	15·2	30·1	28·9	3·0	11·7	20·2	12·9	1·2
Alsike	16·0	6·0	15·0	27·0	32·7	3·3	8·6	22·5	12·3	1·8
Serradella in bloom	16·0	8·1	16·2	25·6	30·3	3·1	11·1	18·2	11·5	2·5
White Clover, average	16·5	6·0	14·5	25·6	33·9	3·5	8·1	23·7	12·2	2·0
Kidney Vetch just in bloom	16·7	6·4	13·8	25·5	35·1	2·5	7·9	22·8	12·8	1·4
Peas just in bloom	16·0	7·3	21·8	23·3	28·8	2·8	16·7	18·6	12·8	1·7
,, in bloom	16·7	7·0	14·3	25·2	34·2	2·6	9·4	20·5	12·6	1·6
Vetch, average	16·7	8·3	14·2	25·5	32·8	2·5	9·4	19·7	12·8	1·5
,, very good	16·7	9·3	19·8	23·4	28·5	2·3	15·1	18·5	12·6	1·4
Wood Vetch	13·0	5·4	21·9	20·2	36·6	2·9	15·3	24·2	11·0	1·7
Lupine, average	16·7	4·6	17·1	28·5	30·9	2·2	11·3	17·8	19·5	0·7
,, very good	16·7	3·1	23·2	25·2	28·6	2·2	17·2	17·6	18·4	0·7
Meadow Vetch (*Lathyr. sylvestris*)	17·3	4·8	18·5	26·0	28·2	5·2	13·9	18·3	13·0	3·1
Sand Vetch in bloom	16·0	5·9	21·6	27·7	25·4	3·4	16·2	15·2	13·3	1·8
Soja Beans, end of bloom	16·0	5·8	14·2	35·5	26·3	2·2	9·1	16·0	20·5	0·4
Vicia dumetorum, bloom	16·0	5·2	21·2	19·6	35·2	2·8	15·4	26·8	10·8	1·9
Tufted Vetch (*Vicia cracca*) just in bloom	15·6	5·8	23·1	16·4	37·4	1·2	16·2	28·0	10·5	0·5
Tufted Vetch in bloom	16·5	4·3	17·3	25·3	34·6	2·0	12·1	25·2	13·2	1·3

TABLE I. (*continued*).

FOOD-STUFFS.	Total. Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Digestible. Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
Oat Vetches	16·7	7·2	12·6	28·0	33·2	2·3	7·2	19·6	15·4	1·1
Vicia monantha in bloom	16·0	8·8	20·3	17·5	35·0	2·4	14·2	28·0	8·8	1·5
Kidney Vetch in bloom	16·0	5·6	9·4	30·8	35·9	2·3	5·2	21·9	14·8	1·2
Wild Vetch (*Vicia sepium*)	16·0	6·0	19·2	27·5	28·9	2·4	14·6	20·3	14·1	1·5
(c) *Other Fodder-plants.*										
Spurry in bloom	16·7	9·5	12·0	22·0	36·6	3·2	7·6	23·7	13·1	1·9
Yellow Broom, tops	8·3	7·9	15·9	33·1	29·5	5·3	10·3	16·3	15·0	2·7
Mustard in full bloom	16·0	7·1	11·2	29·4	33·4	2·9	6·9	21·7	15·1	1·7
Gorse	15·0	3·5	9·0	41·8	28·7	2·0	3·6	17·2	16·7	0·9
Prickly Comfrey, before bloom	15·0	15·0	20·7	11·5	35·1	2·7	12·0	29·7	2·1	1·8
Water Thyme (*Elodea canadensis*)	17·0	10·4	15·3	13·9	35·5	1·9	9·0	24·5	6·6	0·7
(d) *Foliage, Herbs, Leaves.*										
Stinging-Nettle leaves	11·4	14·0	18·3	10·6	38·0	7·7	12·8	30·0	6·0	4·9
Hop bine	10·6	10·8	12·5	24·5	38·1	3·5	8·0	27·1	7·6	2·5
Spent Hops	15·0	4·0	15·8	18·7	40·5	6·0	5·0	20·3	2·8	3·9
Potato haulm	10·0	11·6	9·4	26·0	40·6	2·4	3·8	24·4	9·6	0·6
Leaves at the end of July	16·0	7·0	10·5	14·2	49·3	3·0	6·2	32·5	5·3	2·4
Poplar leaves in October	16·0	7·5	10·8	17·4	38·6	8·7	6·0	26·2	5·6	6·9
Artichoke tops	12·5	11·8	14·4	14·9	42·9	3·5	8·6	32·4	8·8	1·7
II. Green Foods.										
(a) *Grasses.*										
Oats	81·0	1·4	2·3	6·5	8·3	0·5	1·3	5·0	3·9	0·2
Rye	76·0	1·4	2·9	6·5	12·4	0·8	1·8	8·1	4·3	0·4
Grass, just before blooming	75·0	2·1	3·0	6·0	13·1	0·8	2·0	9·1	3·9	0·4
,, rich meadow	78·2	2·2	4·5	4·0	10·1	1·0	3·4	8·1	2·8	0·6
,, meadow	80·0	2·0	3·5	4·0	9·7	0·8	2·5	7·3	2·6	0·4
,, water-meadow	80·8	1·7	3·5	4·9	8·4	0·7	2·4	6·3	3·2	0·4
Maize, American	82·8	1·5	1·4	5·0	8·9	0·4	0·7	5·5	2·7	0·2
,, earlier	80·6	1·2	1·7	5·6	10·4	0·5	1·0	6·7	3·1	0·3
Hungarian Brome-grass in flower	75·0	1·8	3·1	8·5	10·9	0·7	1·8	6·8	5·0	0·3

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
Rye-grass, English	70·0	2·0	3·6	10·6	12·8	1·0	1·8	6·9	5·3	0·4
,, Italian	73·4	2·8	3·6	7·1	12·1	1·0	2·3	8·0	4·6	0·4
Sorghum (Indian Millet)	77·3	1·1	2·5	6·7	11·7	0·7	1·6	7·9	4·0	0·3
Stubble catch crop	70·0	6·4	3·7	7·4	11·0	1·5	2·5	7·5	4·5	0·8
Pasture-grasses (average)	70·0	2·1	3·4	10·1	13·4	1·0	1·9	8·1	6·1	0·5
Timothy grass	70·0	2·2	3·4	8·0	16·3	1·1	2·1	11·2	4·8	0·6
(b) *Clover and Leguminosæ.*										
Bokhara Clover, young	87·5	2·1	2·9	3·6	3·5	0·4	1·6	2·0	1·6	0·2
Sainfoin just in bloom	81·4	1·2	4·2	5·2	7·3	0·7	3·0	5·7	2·2	0·5
Hop Trefoil	80·0	1·5	3·5	6·0	8·2	0·8	2·2	5·7	3·0	0·5
Crimson Clover	81·5	1·6	2·7	6·2	7·3	0·7	1·5	4·8	2·7	0·3
Lucerne, quite young	81·0	1·7	4·5	5·0	7·2	0·6	3·5	5·1	2·2	0·3
,, just in bloom	74·0	2·0	4·5	9·5	9·2	0·8	3·2	5·4	3·7	0·3
Red Clover before blooming	83·0	1·5	3·3	4·5	7·0	0·7	2·3	4·9	2·5	0·5
,, ,, full bloom	80·4	1·3	3·0	5·8	8·9	0·6	1·7	5·8	2·9	0·4
Sand Lucerne (*Medic. media*)	78·0	1·9	4·0	8·0	7·3	0·8	3·1	4·3	3·2	0·3
Alsike just in bloom	85·0	1·5	3·3	4·5	5·1	0·6	2·1	3·6	2·2	0·4
,, full bloom	82·0	1·8	3·3	6·0	6·3	0·6	1·8	4·5	2·4	0·3
Serradella in bloom	81·0	1·8	3·7	5·8	6·9	0·8	2·5	3·7	2·6	0·5
Bokhara Clover in bloom	79·7	2·3	4·1	5·7	7·3	0·8	2·6	5·0	2·8	0·4
Red Clover in stubble	83·4	1·5	4·3	2·9	7·0	0·9	3·2	5·2	1·5	0·5
White Clover in bloom	80·5	2·0	3·5	6·0	7·2	0·8	2·2	5·0	2·9	0·5
Kidney Vetch	83·0	1·3	2·8	5·3	5·2	0·4	1·6	4·7	2·7	0·2
Beans just in bloom	86·1	1·5	3·0	3·4	5·5	0·5	2·2	3·9	1·6	0·4
Peas in bloom	81·5	1·5	3·2	5·6	7·6	0·6	2·2	4·6	2·8	0·3
Vetch in bloom	82·0	1·8	3·5	5·5	6·6	0·6	2·5	4·0	2·7	0·3
Lupines, average	85·0	0·7	3·1	5·1	5·7	0·4	2·0	3·2	3·5	0·2
,, very good	85·0	0·7	4·2	4·5	5·2	0·4	3·1	3·2	3·3	0·2
Sand Peas (*Pisum arvense*)	83·2	1·2	3·5	5·9	5·6	0·6	2·4	3·7	3·0	0·4
Meadow Vetch (*Lath. sylvestris*)	81·0	1·1	4·2	6·0	6·5	1·2	3·2	4·2	3·0	0·7
Sand Vetch in bloom (*Vicia villosa*)	83·3	1·2	4·3	5·5	5·0	0·7	3·3	3·0	2·5	0·4
Tufted Vetch (*Vicia cracca*)	75·0	2·9	4·6	4·9	11·9	0·7	3·2	7·7	4·4	0·4
Polish Vetch (*Vicia monantha*) in bloom	83·8	1·7	3·9	3·4	6·7	0·5	2·9	4·0	2·0	0·3

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
(c) *Other Fodder-plants.*										
Spurry	80·0	2·0	2·3	5·3	9·7	0·7	1·5	6·5	3·3	0·3
Buckwheat in bloom	85·0	1·4	2·4	4·2	6·4	0·6	1·5	4·0	2·6	0·4
„ end of blooming	73·4	2·4	1·8	6·2	15·3	0·7	1·0	8·5	3·1	0·3
Thistle (young)	86·7	2·0	2·9	1·4	6·1	0·9	2·2	5·0	1·0	0·6
Heather	54·6	3·7	3·7	19·7	15·1	3·0	1·9	9·1	6·5	1·0
Winter Rape in bloom	85·9	1·3	2·8	3·5	5·7	0·8	2·0	3·9	1·9	0·5
Brushwood in winter	25·0	1·5	4·6	26·7	40·3	1·9	2·1	20·2	6·7	0·8
„ in spring	30·0	1·6	2·6	28·2	36·2	1·4	1·2	18·1	7·1	0·6
Beech brushwood fodder [1]	44·0	1·4	2·4	23·9	27·2	1·1	1·1	13·6	6·0	0·4
Mustard, full bloom	82·7	1·4	2·1	5·8	7·5	0·5	1·4	4·9	3·0	0·3
Gorse	48·7	2·8	5·3	24·0	18·1	1·1	2·2	10·9	9·6	0·5
Prickly Comfrey before bloom	87·7	2·2	3·0	1·7	5·0	0·4	1·8	4·3	0·3	0·3
Water Thyme (*Elodea canadensis*)	88·0	2·4	2·2	2·0	5·1	0·3	1·4	3·5	1·0	0·1
(d) *Foliage, Herbs, Leaves.*										
Birch foliage, August	55·0	1·6	7·9	6·9	24·7	3·9	4·8	16·3	3·7	2·5
Beech foliage, Aug.–Sept.	57·0	3·1	6·9	9·8	21·7	1·5	4·2	14·3	4·4	0·8
Cabbage	84·7	1·6	2·5	2·4	8·1	0·7	1·8	6·5	1·7	0·4
Leaves, July	55·0	3·8	5·6	7·6	26·5	1·5	3·8	17·5	3·0	0·9
Hop bines and leaves	66·0	4·1	4·7	9·2	14·7	1·3	3·0	9·4	3·8	0·9
Potato haulm, October	78·0	3·0	2·3	6·0	9·7	1·0	1·0	6·0	2·3	0·3
„ „ July to August	85·0	1·6	3·6	3·0	6·2	0·7	2·1	3·8	1·4	0·2
Kohl Rabi leaves	85·0	1·8	2·8	1·4	8·2	0·8	2·0	6·7	0·9	0·4
Swede leaves	88·4	2·3	2·1	1·6	5·2	0·5	1·5	4·1	1·0	0·3
Carrot leaves	82·2	3·6	3·2	3·0	7·1	1·0	2·2	5·3	1·7	0·5
Poplar leaves, beginning of October	55·0	4·0	5·8	9·3	21·3	4·6	3·2	14·0	3·1	3·6
Mangold leaves	90·5	1·8	1·9	1·3	4·0	0·5	1·2	3·2	0·8	0·2
Cabbage stalks	87·6	1·1	2·3	2·0	6·8	0·2	1·7	5·0	1·3	0·1
Prickly Comfrey leaves	91·7	1·9	2·6	0·9	2·4	0·5	1·5	1·7	0·5	0·3

[1] Brushwood pressed, moistened, and mixed with 1 per cent. of malt and left to ferment 24 hours.

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
Pine and Fir needles	53·5	3·0	2·5	14·8	22·5	3·7	1·3	11·3	5·9	1·5
Artichoke tops	67·7	5·0	3·4	5·4	17·4	1·1	2·0	13·1	2·2	0·6
White Cabbage	89·0	1·2	1·5	2·0	5·9	0·4	1·1	4·6	1·4	0·2
Sugar-Beet leaves	88·0	2·4	2·6	2·2	4·4	0·4	1·7	3·4	1·2	0·2
(e) *Sour Fodder, Silage, "Brown Hay."*										
Brown hay: Sainfoin	11·0	6·3	17·3	31·0	30·2	4·2	11·4	19·3	13·0	2·8
,, ,, Grass	15·8	7·3	10·2	23·5	40·2	3·0	6·6	28·1	13·9	1·8
,, ,, Lucerne	20·0	8·8	12·9	21·4	33·8	3·1	9·0	18·6	9·6	1·6
,, ,, Maize	30·0	6·6	5·7	21·8	34·3	1·6	2·7	21·9	12·9	1·0
,, ,, Red Clover	14·5	8·6	13·8	23·7	36·8	2·6	8·9	25·0	11·4	1·6
Sour fodder: Sainfoin	83·3	1·3	3·4	5·9	5·1	1·0	1·7	3·0	2·4	0·7
,, ,, Rye	86·9	0·9	1·6	4·4	5·7	0·5	0·9	3·4	2·6	0·3
,, ,, Oats	76·3	1·8	1·9	8·5	10·7	0·8	1·1	5·9	5 1	0·4
,, ,, Grass	80·6	2·0	2·0	6·5	8·1	0 8	1·4	4·7	3·8	0 5
,, ,, Maize	83·0	1·4	1·3	5·4	8·0	0·9	0·8	5·4	3·4	0·7
,, ,, Potato haulm	77·0	5·3	2·9	4·7	7·5	2·6	1·2	4·4	1·8	1·2
,, ,, Clover	80·0	2·4	3·4	6·0	7·2	1·0	2·2	5·1	3·3	0·6
,, ,, Lupines	84·0	1·1	3·1	4·9	4·4	2·1	2·2	2·7	3·4	1·1
,, ,, Lucerne	82·9	2·1	3·8	5·0	4·7	1·5	2·8	3·3	2·0	0 9
,, ,, Red Clover	79·2	2·1	4·2	5·9	6·4	2·2	2·8	4·3	2·9	1·5
,, ,, Alsike	75·4	2·1	3·3	6·7	10·6	1·8	2·0	6·1	3·3	1·2
,, ,, Mangold leaves	80·0	4·1	3·0	2·7	9·0	1·2	2·0	4·8	1·5	0·7
,, ,, Serradella	78·3	1·9	3·9	5·8	9·2	0·9	2·6	6·5	2·9	0·5
,, ,, Artichoke tops	77·7	3·4	2·3	6·0	10·1	0·5	1·2	6·1	3·0	0·5
Silage: Buckwheat	72·3	2·2	2·8	7·7	14·1	0·9	1·7	9·1	3·9	0·5
,, Grass	68·0	2·7	3·8	9·9	12·9	2·7	1 9	7·5	5·9	1·6
,, Maize	81·8	1·7	2·0	5·5	7·8	1·2	1·2	4·8	3·2	0·8
,, Lupines	80·3	1·4	2·9	9·5	4·9	1·0	1·8	2·9	5·2	0·6
,, Lucerne	72·5	3·5	4·0	10·7	6·1	3·2	3·0	4·2	4·3	1·9
,, Red Clover	70·0	2·3	5·6	8·5	11·6	2·0	3·9	7·8	3·8	1·3
,, Meadow Vetch	65·0	3·2	10·3	8·9	10·1	2·5	7·6	6·7	4·5	1·6
,, Oat Vetch	81·3	2·4	3·4	5·5	6·6	0·8	2·0	4·0	3·0	0·5

TABLE I. (*continued*).

FOOD-STUFFS.	Total. Water.	Total. Ash.	Total. Crude albumen.	Total. Crude fibre.	Total. Nitrogen-free extract.	Total. Crude fat.	Digestible. Albuminoids and amides.	Digestible. Nitrogen-free extract.	Digestible. Crude fibre.	Digestible. Fat.
III. Straw.										
(a) *Cereals.*										
Oats	14·3	4·0	4·0	39·5	36·3	2·0	1·4	16·7	23·4	0·7
Millet	15·0	7·4	4·6	35·0	35·5	2·5	1·4	13·8	19·3	0·9
Maize	15·0	4·2	3·0	40·0	36·7	1·0	1·1	16·5	24·0	0·3
Rice	15·6	15·3	5·7	37·6	24·0	1·8	2·6	9·4	21·4	0·9
Summer Barley	14·3	4·1	3·5	40·0	36·7	1·4	1·3	18·6	22·0	0·5
,, ,, with Clover	14·3	6·7	6·5	38·0	32·5	2·0	3·2	16·2	20·9	1·0
,, Straw, average	14·3	4·1	3·8	39·7	36·4	1·7	1·4	17·7	22·7	0·6
,, ,, very good	14·3	6·7	6·9	36·7	32·9	2·5	2·5	16·7	20·2	0·8
Winter Spelt	14·3	5·0	2·5	45·0	31·8	1·4	0·7	9·6	22·5	0·4
,, Barley	14·3	5·5	3·3	43·0	22·5	1·4	0·8	9·9	21·5	0·4
,, Rye	14·3	4·1	3·0	44·0	33·3	1·3	0·8	12·3	24·2	0·4
,, Wheat	14·3	4·6	3·0	40·0	36·9	1·2	0·8	13·6	22·0	0·4
,, Straw, average	14·3	4·8	3·0	42·0	34·9	1·3	0·8	12·9	23·1	0·4
,, ,, very good	14·3	5·3	4·5	37·8	36·7	1·4	1·2	13·5	20·9	0·4
(b) *Leguminosæ.*										
Beans	16·0	4·6	10·2	34·0	34·2	1·0	5·0	20·9	14·2	0·5
Peas	16·0	4·5	6·5	38·0	34·0	1·0	3·2	18·2	15·2	0·5
Vetch	16·0	4·5	7·5	42·3	29·0	1·0	3·4	15·1	16·8	0·5
Garden Beans	15·0	6·2	7·0	31·2	39·1	1·5	3·7	28·4	12·5	0·8
Leguminous Straw, average	15·0	4·5	8·1	38·0	32·4	1·0	3·8	18·1	15·4	0·5
,, ,, very good	16·0	5·1	10·2	34·5	33·2	1·0	5·0	19·6	15·0	0·6
Lentils	16·0	6·5	14·0	33·6	27·9	2·0	6·9	16·8	14·0	1·2
Lupines	16·0	4·1	5·9	40·8	32·1	1·1	2·2	20·9	20·7	0·3
Meadow Vetch	14·0	4·8	12·0	32·7	33·6	2·9	6·0	18·1	13·1	1·5
Sand Pea	15·5	3·9	7·0	41·0	31·2	1·4	3·2	16·9	16·4	0·7
Sand Vetch	11·3	4·8	6·2	40·2	36·1	1·1	2·9	19·5	16·1	0·6
Soja Beans	15·0	10·2	6·7	27·0	38·6	2·5	3·4	25·1	10·5	1·5
(c) *Other Plants.*										
Buckwheat	10·4	5·0	3·9	45·9	33·2	1·6	2·0	17·3	20·6	0·7

TABLE I. (*continued*).

FOOD-STUFFS.	Total. Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Digestible. Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
Poppy	14·8	9·4	6·7	31·5	36·1	1·5	3·0	20·8	14·2	0·7
Rape	16·0	4·1	3·5	40·0	35·4	1·0	1·4	19·0	16·0	0·5
Clover seed	16·0	5·6	9·4	42·0	25·0	2·0	4·2	12·5	16·0	1·0
IV. Chaff, Hulls, &c.										
(a) *Cereals.*										
Dari	5·7	8·0	3·9	25·8	55·7	0·9	1·5	33·4	12·9	0·4
Spelt	14·3	8·3	3·5	40·0	32·6	1·3	1·1	13·9	20·0	0·4
Oats	14·3	10·0	4·0	34·0	36·2	1·5	1·6	19·6	17·0	0·6
Millet husks	11·2	11·2	4·8	40·8	29·0	2·3	1·9	14·5	16·0	1·0
Barley	14·3	13 0	3·0	30·0	38·2	1·5	1·2	18·5	16·5	0·6
Green corn chaff	9·8	6·6	2·3	29·2	50·6	1·5	0·9	25·4	14 6	0·6
Maize cob	13·1	2·3	3·5	38·9	41·3	0·9	1·6	22·2	19·5	0·4
Rice husks	9·7	15·7	3·4	42·8	27·0	1·4	1·2	13·9	17·5	0·5
Rye	14·3	7·5	3·6	43·5	29·9	1·2	1·1	13·1	21·8	0·4
Wheat	14·3	9·2	4·5	36·0	34·6	1·4	1·4	15·6	17·2	0·4
(b) *Leguminosæ.*										
Beans	15·0	5·5	10·5	33·0	34·0	2·0	5·1	21·4	14·3	1·2
Peas	15·0	6·0	8·1	32·0	36·9	2·0	4·0	22·1	14·1	1·2
Lentil husks	14·0	8·5	21·2	18·9	35·3	2·1	11·7	21·2	9·5	1·3
Lupines	14·3	3·5	4·5	37·0	39·0	1·7	1·7	25·8	18·5	0·5
Soja Beans	14·0	8·1	5·1	29·0	42 5	1·3	2·2	31·1	14·7	0·8
Vetches	15·0	8·0	8·5	33·0	33·5	2·0	4·2	20·1	14·2	1·2
(c) *Other Plants.*										
Buckwheat	13·2	2·2	4·6	43·5	35·3	1·1	2·1	14·8	13·1	0·6
Earth-nut shells	10·6	3·0	7·1	60·8	15·3	3·2	2·5	6·1	18·2	1·4
Chestnut shells	84·4	0·9	0·1	4·5	9·8	0·3	0·1	5·8	2 3	0·1
Linseed	11·6	5 8	3·5	40·7	35·0	3·4	1·7	17·5	16·3	1·7
Gold of Pleasure (*Camelina sativa*)	11·2	7·2	2·7	45·2	32·6	1·1	1·3	17·1	18·1	0·5
Rape	12·9	7·6	4·2	38·7	35·0	1·6	2·1	17·5	17·4	0·7

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
V. Roots and Tubers.										
Mangolds	88·0	0·8	1·1	0·9	9·1	0·1	1·1	9·1	0·9	0·1
Potatoes	75·0	0·9	2·1	1·1	20·7	0·2	2·1	20·7	1·1	0·2
„ fermented	73·5	1·4	2·2	0·6	21·8	0·5	2·2	21·8	0·6	0·5
„ frozen	61·6	1·2	1·6	0·8	34·7	0·1	1·6	34·7	0·8	0·1
„ frozen and steamed	66·5	0·7	2·1	1·0	29·6	0·1	2·1	29·6	1·0	0·1
„ „ „ fermented	68·9	0·9	1·7	0·9	27·5	0·1	1·7	27·5	0·9	0·1
Kohl Rabi	88·2	1·0	2·3	1·5	6·9	0·1	2·3	6·9	1·5	0·1
Swede	87·0	1·0	1·3	1·1	9·5	0·1	1·3	9·5	1·1	0·1
„ fermented	85·6	1·1	1·8	2·2	9·1	0·2	1·8	9·1	2·2	0·2
Carrots	85·0	0·9	1·4	1·7	10·8	0·2	1·4	10·8	1·7	0·2
Parsnips	88·3	0·7	1·6	1·0	10·2	0·2	1·6	10·2	1·0	0·2
Large Carrot	87·0	0·8	1·2	1·2	9·6	0·2	1·2	9·6	1·2	0·2
Late Turnips	91·5	0·7	0·9	0·8	6·0	0·1	0·9	6·0	0·8	0·1
Artichokes	80·0	1·0	2·0	1·3	15·5	0·2	2·0	15·5	1·3	0·2
Turnips	92·0	0·7	1·1	0·8	5·3	0·1	1·1	5·3	0·8	0·1
Sugar Beet	81·5	0·7	1·0	1·3	15·4	0·1	1·0	15·4	1·3	0·1
VI. Grain and Fruits.										
(a) *Cereals.*										
Dari	11·1	2·6	10·2	1·7	71·3	3·1	8·2	66·4	0·8	2·5
Spelt	14·8	3·7	10·0	16·5	52·3	1·5	7·5	36·1	6·6	1·1
„ grain	14·5	1·7	13·5	1·5	67·2	1·6	12·2	63·6	0·8	1·3
Barley	14·0	2·7	10·0	4·9	66·1	2·3	7·7	56·1	1·5	2·3
Oats	12·4	3·0	10·4	11·2	57·8	5·2	8·0	42·5	2·2	4·3
Millet	14·0	3·3	11·8	9·5	57·4	4·0	8·9	40·2	4·8	3·2
Maize	12·7	1·6	10·1	2·3	68·6	4·7	8·0	67·5	1·1	4·0
„ (whole cob)	11·5	1·5	8·0	6·7	68·4	3·9	6·0	58·1	4 0	3·1
Golden Millet	12·4	3·3	10·0	11·6	58·6	4·1	7·6	43·9	5·8	2·7
Rice without husks	14·0	0·5	7·7	2·2	75·2	0·4	6·9	71·6	1·1	0·3
Rye	14·0	1·8	11·0	3·5	67·4	2·0	9·9	63·7	1·7	1·6
Sorghum (Durra)	15·2	1·7	9·8	2·5	67·5	3·3	7·8	55·8	1·3	2·7
Wheat	14·4	1·7	13·0	3·0	66·4	1·5	11·7	62·8	1·5	1·2

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen-free extract.	Crude fibre.	Fat.
(b) *Leguminosæ.*										
Beans	14·4	3·2	25·0	6·9	48·9	1·6	22·0	45·0	5·0	1·4
Peas	14·4	2·7	22·6	5·4	53·0	1·9	20·1	49·5	3·5	1·4
Lentils	14·5	3·0	23·8	6·9	49·2	2·6	21·4	46·8	4·4	2·2
Lupines, blue,	14·0	2·9	29·5	11·2	36·2	6·2	26·3	31·2	10·1	5·2
„ white	14·0	3·0	29·4	12·2	34·2	7·2	26·1	29·4	11·1	6·1
„ yellow	14·0	3·3	36·6	14·2	27·2	4·7	32·9	24·7	14·2	4·2
„ „ sweetened	66·0	0·7	16·7	7·1	7·3	2·2	15·0	5·8	7·1	2·0
„ „ „ air-dried	14·0	1·8	42·3	18·0	18·4	5·5	38·1	14·7	18·0	5·0
Meadow Vetch	11·6	2·9	25·0	4·1	54·5	1·9	22 6	50·7	2·7	1·6
Rice (without husks)	14·0	0·5	7·7	2·2	75·2	0·4	6·9	71 6	1·1	0·3
Sand Vetch	16 0	3·0	23·1	7·1	49·3	1·5	20·4	45·8	4·7	1·4
Serradella	8·7	3·5	22·0	21·0	37·5	7·3	16·5	22·5	6·3	6·2
Soja Beans	10·0	5·0	33·4	4·8	29·2	17·6	30·1	18·1	7·0	15·8
Vetch	13·4	3·2	26·4	6·6	48·6	1·8	23 3	45 0	5·0	1·6
Vetches and Barley	17·0	4·0	19·3	7·6	49·8	2·3	16·4	47·3	2·4	1·8
Sugar Beet	12·2	17·7	10·8	27·6	27·5	4·2	6·5	16·5	9·7	2·5
(c) *Oil Seeds.*										
Cotton seeds	11·4	4·3	19·9	18·9	20·2	25·3	14·5	9·3	4·4	22 8
Beech-nuts	11·0	4·2	13·3	18·5	25·5	27·4	10·7	16 8	7·4	24·1
Earth-nuts	6·3	3·2	28·2	13·9	7·2	41·2	23·7	5·0	6·9	39·1
Hempseed	12·2	4·5	16·3	2·1	1·3	33·6	12·2	15·2	1·0	30·2
Gold of Pleasure (*Camelina sativa*)	8·4	6·8	21·5	11·5	21·8	30·0	17·2	15·3	5·7	27·0
Linseed	12·3	3·4	20·5	7·2	19·6	37·0	20·1	12·4	6·5	35·2
Madia	8·4	4·7	20·6	20·5	7·0	38·8	15·4	4·2	8·0	36·9
Poppy seeds	14·7	5·3	17·5	6·1	15·4	41·0	14·7	12·3	3·0	39·0
Palm-nuts	7·6	1·8	8·4	6·0	26·8	49·2	8·0	25·4	4·9	48·2
Rape seeds	11·8	3·9	19·4	10·3	12·1	42·5	15·5	9·6	0·6	42·5
Sesame	4·6	8·7	18·9	11 5	19·1	37·0	16·1	13·4	4·6	34·2
(d) *Other Seeds and Fruits.*										
Apples	84·8	0·5	0·4	1·5	12·5	0·3	0·3	10·6	0·6	0·2
Cyder residue, fresh	74·0	0·8	1·6	4·9	17·5	1·2	0·8	12·3	2·0	0·7

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen free-extract.	Crude fibre.	Fat.
Cyder residue dried	14·8	5·8	5·6	21·4	49·1	3·3	2·8	34·4	8·6	2·0
„ „ fermented	75·0	1·1	2·0	5·6	14·5	1·8	1·0	10·2	2·2	1·1
„ „ mashed	44·3	2·1	4·7	12·7	32·2	4·0	2·3	22·5	5·1	2·4
Pears	83·8	0·3	0·3	3·4	12·0	0·2	0·2	11·5	1·7	0·1
Buckwheat	13·2	1·8	10·1	15·0	58·4	1·5	7·5	43·8	8·0	1·1
Acorns, fresh	55·3	1·0	2·5	4·4	34·8	1·9	2·0	31·3	2·7	1·5
„ half-dry	37·7	1·6	3·5	7·8	46·6	2·8	2·8	41·9	4·8	2·2
„ without shells and dried	17·0	2·0	5·1	4·5	67·4	4·0	4·1	60·7	2·8	3·2
Pumpkins (field)	90·9	0·5	1·3	1·7	5·2	0·4	1·0	4·7	1·1	0·3
„ (garden)	80·8	0·9	1·8	1·8	7·9	0·8	1·4	7·1	1·2	0·8
Carob Beans	13·0	1·8	4·0	5·9	73·3	2·0	2·7	69·6	4·6	1·1
Horse Chestnuts, fresh	49·2	1·6	4·3	2·0	41·3	1·6	3·4	36·9	1·2	1·3
„ without shells, fresh	49·0	1·8	3·1	0·8	43·2	2·1	2·5	41·0	0·5	1·7
„ „ dried	18·8	1·8	6·9	4·0	65·3	3·2	5·5	59·4	2·4	2·5
Vegetable Ivory	9·4	1·3	4·4	76·6	7·1	1·2	1·8	3·5	22·8	0·4
Cattle Melon	91·4	0·7	1·2	1·5	5·2	—	0·9	4·6	1·0	—
VII. By-Products and Refuse.										
(a) *Grain.*										
Buckwheat bran	20·9	2·6	11·6	28·3	33·8	2·8	7·7	23·7	8·5	2·0
Spelt bran	13·0	5·6	14·0	8·2	54·9	4·3	10·9	45·0	2·1	3·8
Pea hulls	12·3	3·0	8·0	43·7	30·5	2·5	5·6	24·4	21·9	2·0
„ ground	12·3	4·2	13·1	31·1	37·8	1·5	9·2	30·2	15·6	1·2
Pea meal	11·4	3·5	23·7	4·5	54·5	3·5	20·9	52·5	2·9	2·8
Earth-nut bran	10·8	5·1	22·4	18·7	23·8	19·2	16·8	15·7	9·3	16·3
„ „ with shells	8·0	10·2	8·2	53·7	16·3	4·1	4·9	8·1	16·1	2·4
Barley seed	13·2	2·9	12·6	3·0	65·4	2·9	10·2	54·3	1·5	2·4
„ groats	12·5	4·6	12·2	7·2	60·2	3·3	9·5	47·6	2·4	2·6
„ bran	12·3	7·0	10·3	16·5	50·6	3·3	7·8	36·9	4·1	2·5
„ refuse	12·1	6·9	11·1	15·7	50·7	3·5	8·8	42·5	7·8	2·3
Green Corn bran	9·1	12·9	10·6	15·2	45·5	6·7	7·4	37·3	4·6	5·0
Oat hulls	9·4	6·5	2·7	27·9	52·2	1·3	1·3	26·1	14·0	0·6
Oats, red meal	10·1	8·3	7·4	19·4	50·9	3·9	4·8	33·1	9·7	3·2
„ white meal	10·5	6·8	11·0	14·5	52·2	4·5	8·3	40·9	7·3	3 6
Oat bran	11·0	8·3	8·4	21 6	47·3	3·4	4·0	23·6	10·8	1·6

TABLE I. (*continued*).

FOOD-STUFFS.	Total. Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Digestible. Albuminoids and amides.	Nitrogen free-extract.	Crude fibre.	Fat.
Millet husks	10·6	11·5	4·4	41·6	28·3	3·6	2·4	15·0	10·4	2·0
Maize bran	11·8	3·4	10·2	9·0	61·8	3·8	7·9	53·6	3·0	3·4
Rice meal	10·5	9·9	12·0	10·0	45·6	12·0	7·3	42·0	5·1	10·3
„ husks	9·5	12·0	6·0	25·1	44·1	3·3	4·2	30·9	7·5	2·3
Rye meal	12·0	4·1	13·6	4·2	63·2	2·9	10·6	51·2	2·1	2·3
„ bran	12·4	4·8	14·7	6·2	58·7	3·2	11·5	45·2	2·1	2·2
Sorghum bran	10·5	2·0	13·8	3·4	65·8	4·5	11·0	52·6	1·4	3·2
Wheat meal	11·5	3·0	13·9	4·8	63·5	3·3	10·8	51·6	2·4	2·9
„ bran, fine	12·1	4·1	14·1	7·3	58·2	4·2	11·0	44·8	2·4	2·9
„ „ coarse	13·6	5·6	13·6	8·9	54·9	3·4	10·6	42·3	2·1	2·4
(b) *Agricultural Manufactures.*										
Brewers' grains, fresh	76·1	1·1	5·3	3·9	12·9	1·5	3·9	8·3	1·6	1·3
„ „ dried	9·3	4·2	20·2	15·0	43·6	7·7	14·9	27·9	6·0	6·4
Dry Malt, without sprouts	7·5	2·3	9·4	8·7	69·8	2·3	7·5	62·8	4·4	1·8
Green Malt, with sprouts	47·5	1·7	6·5	4·3	38·5	1·5	5·2	34·7	2·2	1·2
Maize sprouts	13·5	5·9	20·7	5·8	39·6	14·5	17·4	34·9	4·5	12·4
Malt sprouts	11·8	7·6	23·3	12·4	42·8	2·1	19·1	37·7	11·8	1·0
Distillers' grains, dried	6·9	10·4	22·1	14·7	40·6	5·3	16·1	26·1	5·8	4·5
Potato "slump"	94·4	0·7	1·4	0·6	2·7	0·2	1·4	2·6	0·6	0·2
„ „ dried	12·6	11·0	21·8	9·4	41·3	3·9	21·8	41·3	9·4	3·9
Maize „	90·6	0·4	2·0	0·8	5·2	1·0	1·6	4·7	0·4	0·9
„ „ dried	12·0	3·5	18·7	7·5	48·9	9·4	15·0	44·0	3·7	8·5
Molasses „	90·0	3·1	2·8	—	4·1	—	2·8	4·1	—	—
Rice „ dried	14·9	0·6	14·2	9·0	68·8	0·5	12·8	65·4	0·5	0·5
Rye „	91·0	0·5	2·3	1·9	4·8	0·5	1·8	4·6	0·5	0·4
„ „ dried	9·5	5·0	23·0	9·2	48·2	5·1	18·4	46·1	4·9	4·6
Rye and Maize "slump," dried	10·5	5·8	20·5	9·8	45·1	8·3	18·4	42·9	4·9	6·6
Yeast "slump"	94·8	0·4	1·0	0·4	3·1	0·3	0 8	2·8	0·2	0·2
Wheat „	90·5	0·5	2·7	0·8	5·0	0·5	2·2	4·5	0·4	0·4
„ „ dried	12·0	4·8	25·0	7·4	46·1	4·7	20·0	41·5	3·7	4·2
Starch Manufacture.										
Potato fibre, pulp	86·0	0·4	0·8	1·0	11·7	0·1	0·8	11·7	1·0	0·1
„ „ pressed	64·7	0·6	1·9	2·5	30·1	0·1	1·9	30·1	2·5	0·1

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen free-extract.	Crude fibre.	Fat.
Maize slime, half-dried	40·8	0·7	11·2	0·6	45·0	1·7	9·0	41·0	0·4	1·4
,, ,, dried	12·6	1·0	18·1	1·3	60·7	6·3	14·5	55·2	0·8	5·4
Rice ,,	55·8	0·6	12·3	0·5	29·5	1·3	9·8	26·9	0·3	1·1
,, ,, dried	13·9	1·2	18·1	2·1	61·8	2·9	14·5	56·2	1·3	2·5
Maize husks	7·8	1·2	11·9	10·1	59·5	9·5	9·0	53·6	5·0	8·5
Residue from manufacture of wheat starch	71·4	0·3	4·2	2·8	20·2	1·1	3·6	17·6	1·4	0·9
Residue from manufacture of rice, dried	7·8	1·7	36·3	0·5	52·6	1·1	29·0	47·4	0·3	0·9
Dried gluten	11·6	1·6	68·9	0·3	12·9	5·0	68·9	12·8	0·1	5·0
Sugar Manufacture.										
Sugar-Beet refuse from centrifugal machine	82·0	1·2	1·0	3·6	12·1	0·1	0·6	10·1	3·1	0·1
,, ,, from diffusion machine, fresh	94·0	0·4	0·5	1·4	3·6	0·1	0·3	3·0	1·2	0·1
,, ,, from diffusion machine, pressed	89·8	0·6	0·9	2·4	6·1	0·2	0·6	5·1	2·0	0·2
,, ,, from diffusion machine, fermented	88·5	0·9	0·9	2·3	7·2	0·2	0·5	6·0	1·9	0·2
,, ,, from diffusion machine, dried	11·6	7·1	6·6	19·3	54·8	0·6	4·1	45·9	16·0	0·6
Maceration residue	78 9	2·8	1·5	4·4	12·3	0·1	0·9	10·5	3·7	0·1
Sugar-Beet residue from press	73·0	2·2	1·9	5·4	17·3	0·2	1·2	14·5	4·4	0·2
,, ,, ,, ,, fermented	76·4	2·9	1·4	4·5	14·5	0·3	0·9	12·2	3·7	0·3
Sugar-Beet molasses	18·0	10·3	11·8	—	59·9	—	11·8	59·9	—	—
(c) *By-Products from Oil Factories*[1].										
Cotton cake	10·6	7·2	24·7	24·9	26·0	6·6	18·0	12·0	5·7	5·9
,, ,, purified	9·8	6·8	28·3	18·4	29·0	7·7	21·2	15·7	2·2	6·7
,, ,, decorticated	8·9	7·2	43·6	5·7	19·7	14·9	36·9	18·7	—	13·1

[1] The oil residues called "meal" are from extraction processes, those called "cake" from the other processes.

TABLE I. (*continued*).

FOOD-STUFFS.	Total.						Digestible.			
	Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Albuminoids and amides.	Nitrogen free-extract.	Crude fibre.	Fat.
Beech-nut cake	16·1	5·2	18·2	23·9	28·3	8·3	13·5	17·0	5·2	6·6
" " without shells	12·5	7·7	37·1	5·5	29·8	7·5	31·2	23·5	2·0	6·8
Earth-nut cake	9·8	6·9	31·0	22·7	20·7	8·9	24·8	15·5	3·5	7·2
" " without shells	10·0	4·6	47·5	5·2	24·9	7·8	43·2	24·4	0·8	6·7
Hemp cake	11·9	7·8	29·8	24·7	17·3	8·5	20·9	10·4	6·2	7·2
Cacao cake	10·0	8·1	18·8	15·5	36·4	11·2	12·4	25·5	2·5	10·3
Candle-nut cake	7·7	8·5	52·9	4·0	16·3	10·6	47·6	14·7	1·5	9·5
Capoc cake	13·3	6·5	26·3	28·2	19·9	5·8	19·5	10·0	5·6	5·2
Coconut cake	10·3	5·9	19·7	14·4	38·7	11·0	15·0	31·4	8·9	11·0
" meal	11·8	6·6	20·0	13·4	42·0	6·2	15·2	34·0	8·3	6·2
Pumpkin-seed cake	9·9	5·8	36·1	14·1	11·5	22·7	32·5	10·1	6·3	20·4
Cake from Gold of Pleasure seeds	11·8	6·9	33·1	11·6	27·4	9·2	26·5	21·9	4·7	8·3
Linseed cake	11·8	7·3	28·7	9·4	32·1	10·7	24·7	25·7	4·1	9·6
" meal	9·7	7·3	33·2	8·8	38·7	2·3	27·8	31·0	3·9	2·1
Madia cake	10·7	7·5	31·8	19·2	21·7	9·0	22·3	13·0	3 8	7·2
Maize "chit" cake	10·8	6·2	13·5	8·6	50·1	10·8	10·8	44·1	5·3	9·7
Almond cake	9·7	4·3	41·3	8·9	20·6	15·2	37·2	20·2	1·8	13·7
Poppy cake	10·7	11·2	35·4	11·3	21·6	9·8	30·4	17·3	4·5	8·8
Cake from Ramtilla seeds	11·5	8·0	33·1	19·6	23·4	4·1	26·5	18·7	5·3	3·3
Olive cake	13·8	6·8	6·0	33·4	26·8	13·2	3·6	18·8	13·4	10·6
Palm-nut cake	10·2	4·0	16·1	18·3	41·9	9·5	15·3	39·4	15·0	9·0
" meal	10·5	4·0	17·5	20·2	44·0	3·8	16·6	41·4	16·6	3·6
Rape cake	10·4	7·7	30·7	11·3	30·1	9·8	24·9	22·9	0·9	7·6
" dust	8·5	7·9	33·1	13·4	34·1	3·0	26·5	25·9	1·3	2·4
Summer Rape cake (*Br. rapa*)	10·7	7·7	32·7	7·8	31·1	10·0	26·2	23·4	0·8	7·9
Anise residue	8·5	10·3	18·2	29·6	15·4	18·0	10·0	7·7	13·3	12·6
Fennel "	8·7	7·8	21·5	15·6	32·5	13·9	11·8	19·5	7·0	9·7
Carraway residue	17·3	6·1	19·8	14·9	24·1	17·8	10·9	14·5	6·7	12·5
Thyme residue	5·7	11·9	17·1	27·1	13·2	25·0	9·4	6·6	12·2	17·5
Sesame cake	11·1	10·9	37·2	7·5	20·5	12·8	33·5	13·2	2·3	11·5
" meal	6·0	10·8	46·4	7·7	26·7	2·4	41·8	16·8	2·4	2·1
Soja-Bean cake	13·4	5·2	40·3	5·5	28·1	7·5	36·3	21·7	7·7	6·8
Sunflower cake	10·8	6·7	32·8	13·5	27·1	9·1	27·9	21·0	4·1	8·1
Walnut cake	13·7	5·0	34·6	6·4	27·8	12·5	31·1	26·6	1·6	11·2

TABLE I. (*continued*).

FOOD-STUFFS.	Total. Water.	Ash.	Crude albumen.	Crude fibre.	Nitrogen-free extract.	Crude fat.	Digestible. Albuminoids and amides.	Nitrogen free-extract.	Crude fibre.	Fat.
(d) *Animal Products.*										
Dried blood	12·0	4·1	80·8	—	2·6	0·5	54·1	2·6	—	0·5
Butter-milk	90·1	0·7	4·0	—	4·1	1·1	4·0	4·1	—	1·1
Ass's milk	89·0	0·4	2·2	—	6·0	1·6	2·2	6·0	—	1·6
Greaves	8·4	5·0	61·3	—	—	25·3	58·2	—	—	23·3
Norwegian fish guano	12·6	36·6	49·0	—	—	1·8	44·1	—	—	1·6
Flesh meal	10·8	4·6	71·0	—	0·5	13·1	67·5	0·5	—	12·8
Hens' eggs	73·7	1·1	12·6	—	0·6	12·1	12·6	0·6	—	12·1
Cow's milk	87·5	0·7	3·2	—	5·0	3·6	3·2	5·0	—	3·6
„ „ skimmed	90·0	0·8	3·5	—	5·0	0·7	3·5	5·0	—	0·7
„ „ separated	90·5	0·7	3·9	—	4·5	0·4	3·9	4·5	—	0·4
Cockchafers, fresh	70·4	2·3	18·8	4·8[1]	—	3·7	13·0	—	—	3·1
„ dried	13·5	6·7	55·3	13·9[1]	—	10·9	38·0	—	—	9·1
Whey (Cow's milk)	93·6	0·6	0·8	—	4·9	0·1	0·8	4·9	—	0·1
Cream	75·6	0·3	3·7	—	2·8	17·6	3·7	2·8	—	17·6
Ewe's milk	81·3	0·8	6·3	—	4·7	6·8	6·3	4·7	—	6·8
Sow's milk	84·0	1·1	7·2	—	3·1	4·6	7·2	3·1	—	4·6
Mare's milk	91·0	0·4	2·1	—	5·3	1·2	2·1	5·3	—	1·2
Animal albumen	11·8	11·5	63·7	—	—	13·4	60·5	—	—	12·4
Goat's milk	86·9	0·9	3·7	—	4·4	4·1	3·7	4·4	—	4·1

[1] The indigestible chitine of the Cockchafers.

TABLE II.

The Digestibility of Food-stuffs.

This Table contains the results of direct experiments on the *digestibility* of individual foods. I have deduced them from the results of about 1000 experiments, 600 with sheep and the rest on oxen, cows, goats, pigs, and horses. The subject was thoroughly discussed in Part II. of this book.

I have stated in each case the number of individual experiments, and the maximum and minimum values recorded; all the experiments conducted on the same sort of a particular food-stuff have been taken into consideration and the average values obtained are employed in all the calculations involved.

This was necessary because of the errors arising from the individual peculiarities of the animals experimented upon. We know, as a result of direct experiments, that the percentage digestibility of coarse and green fodder depends principally on its chemical composition, as determined by the conditions of soil, manuring, and season under which it was grown, while other conditions, such as the quantity supplied, whether green or in the form of hay, as well as the kind, breed, and age of the animal, have but a trivial influence on the digestibility of the food.

The differences observed between different individuals of the same species of animal are nearly always traceable to disturbances of digestion. The variable value of food for the production of milk, flesh, or fat, with different individuals, is an important item for consideration in feeding estimates, but has no real connection with the digestibility of a food or its digestive coefficient.

From the data given in this Table very interesting comparisons can be drawn between different food-stuffs or variations in the same kind brought about by different conditions of cultivation &c.

Table B offers a comparison between the actual and the digestible composition of the dry matter of a large series of food-stuffs.

TABLE II.

THE DIGESTIBILITY OF FOOD-STUFFS.

A. *Average and Extreme Variations of the Digestive Coefficients.* (Calculated from the results of direct experiments.)

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
I. EXPERIMENTS WITH RUMINANTS.							
(a) *Green Fodder and Hay.*							
Pasture-grass [1]	3	6	77 75—78	75 72—79	75 72—80	66 63—69	78 75—84
Meadow aftermath	6	30	64 62—71	62 61—68	64 59—68	46 31—56	66 63—74
Meadow-hay	44	118	62 46—71	61 42—72	57 46—71	53 10—63	64 49—76
,, ,, rich in nitrogen	16	46	65 56—71	64 57—70	62 55—71	51 31—63	68 58—76
,, ,, average	26	68	60 46—59	57 42—72	58 46—66	49 10—63	62 49—73
,, ,, inferior	7	18	55 46—59	51 42—56	54 46—61	41 10—57	58 49—61
,, ,, fed dry [2]	1	2	56	44	57	37	59
,, ,, steamed	1	2	56	30	58	41	59
Meadow-grass in autumn	1	4	60	56	62	46	61
,, ,, as ensilage	1	5	54	27 [3]	71	61	52
Timothy grass	3	4	58 52—67	50 45—60	52 43—62	47 35—55	64 58—72

[1] "Pasture-grass"=grass in good meadows, not too wet, April to middle of May.
[2] A poor and tough sample.
[3] Only the amides of the crude albuminoids were digested, the albumen was almost indigestible.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
Cock's-foot grass, end of flowering	1	1	56	59	51	51	54
Bent-grass, in flower	1	1	59	60	61	44	59
Couch-grass, in flower	1	1	61	64	59	60	62
Millet, end of flowering	1	1	64	62	63	60	54
Clover ley	1	2	75	78	67	64	78
Green Clover and Clover-hay...	18	46	61	62	49	62	69
			54—74	43—76	39—60	35—74	58—83
,, ,, before flowering .	6	15	66	66	53	64	73
			59—74	60—76	47—60	58—74	63—83
Clover-hay, very good	6	12	61	62	47	60	70
			58—63	55—69	39—52	44—72	67—72
,, average	6	19	57	55	45	51	65
			54—62	43—61	39—52	35—70	58—67
Green Clover before flowering [1].	1	2	74	74	60	65	83
,, ,, just in flower ...	1	2	68	76	53	67	75
,, ,, in flower	1	2	63	69	50	61	72
,, ,, end of flowering .	1	2	58	59	39	45	71
Alsike, full bloom..	2	4	58	58	47	49	67
			56—63	49—64	44—51	35—55	63—74
White Clover, full bloom	1	1	67	73	61	51	70
Lucerne hay, very good	9	28	60	74	43	39	66
			55—67	67—83	34—48	29—55	61—73
,, before flowering	5	18	62	77	43	39	70
			58—67	72—83	34—48	30—44	66—73
,, in flower	4	10	56	70	42	39	63
			55—57	67—73	37—45	29—55	61—66
,, fed green..................	1	4	58	78	34	44	67
Same, as dry hay	1	2	55	73	37	32	65
,, overheated hay	1	2	54	72	45	43	54
Lucerne, fed green	1	2	67	81	45	52	76
,, artificially dried	1	2	62	78	42	33	70
,, carefully dried	1	2	61	72	48	66	
,, wetted with rain	1	2	57	67	45	62	
Sainfoin, fed green	1	2	66	73	42	67	78

[1] The green clover was taken from the same field at four periods of growth, had grown very luxuriantly, and was much beaten down by the heavy rains.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
Same, as hay	1	2	62	70	36	66	74
„ 'brown hay'	1	2	59	64	45	76	67
„ ensilage	1	2	45	50	29	74	53
Vetches before bloom	1	6	65	76	54	60	66
Soja-Bean hay	2	4	61	69	53	30	66
			58—63	63—76	46—58	14—48	59—71
Lupine-hay in bloom	1	2	...	74	74	·30	62
Serradella in bloom	1	2	62	75	50	65	63
„ end of blooming	1	2	47	63	37	66	48
Rye, young	1	2	74	79	79	74	71
Green maize [1]	1	1	70	73	72	75	67
American maize, pickled	3	3	62	48	56	85	68
			61—63	45—54	47—64	82—86	66—72
„ „ dried	3	3	63	48	64	67	66
			62—68	44—52	56—71	52—79	64—68
Green Sorghum	1	1	73	62	59	85	78
Prickly Comfrey	1	2	69	58	18	71	85
Potato tops, beginning October	1	2	48	42	36	24	60
Poplar leaves „	1	2	58	56	35	79	65
Mangold leaves (silage)	1	2	57	65	54	60	54
Spent hops [2]	2	4	37	31	15	64	49
			33—41	26—37	5—24	52—77	45—53
Beech brushwood in winter	1	2	12	16	7	9	16
Acacia „ „	1	2	36	56	21	23	47
Poplar „ with foliage in July	1	2	42	39	28	39	51
(b) *Straw and Chaff.*							
Wheat straw	2	3	46	17	56	36	39
			45—48	8—26	52—59	27—44	37—40
Rye „	2	9	46	21	60	32	37
			42—51	17—25	49—70	21—41	35—38
Barley „	2	5	53	20	56	42	54
			51—55	17—24	55—56	41—43	51—57

[1] Early maize exceptionally rich in nitrogen and probably grown on a rich soil.
[2] Hops left after making beer.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
Oat straw	5	9	50	35	57	35	45
			43—56	14—48	48—64	20—49	39—45
Maize ,, ...	1	1	...	37	52	28	40
Straw from paddy rice...........	1	2	50	47	58	41	35
,, upland rice	1	2	44	44	55	52	29
Bean straw	2	5	51	49	39	56	64
Garden ,, ...	1	2	...	54	?	53	72
Soja ,, ...	2	4	55	50	38	60	66
Lupine ,, ...	1	2	55	37	51	30	65
Pea ,, very good[1]	1	2	59	61	52	46	64
Soja-Bean pods...........	1	2	63	44	51	57	73
(c) *Grain.*							
Oats	8	39	70	78	20	83	76
			62—77	68—86	0—44	75—92	67—88
Barley	2	4	86	70	50	89	92
			81—91	63—77	0—100	78—79	87—86
Maize...........	3	10	91	72	77	85	94
			89—92	60—79	62—100	82—89	91—96
Dari	1	2	86	65	51	70	91
Beans...........	7	27	89	88	72	86	93
			83—94	81—95	25—92	55—100	88—95
Soja Beans	1	2	85	87	168	91	62
Peas	1	2	90	89	66	75	93
Vetches	1	2	92	88	...	92	100
Lupines	4	8	95	91	139	92	106
			92—100	90—94	95—176	90—94	84—134
,, steamed at 100° C. ...	1	2	92	92	95	90	89
,, ,, and sweetened	1	2	97	94	121	94	84
Other sorts of Lupines...........	1	4	84	88	79	87	81
,, ,, sweetened	1	6	85	90	85	88	70
Lupines, not steamed	1	2	81	87	77	71	76
,, steamed at 140° C. ...	1	2	68	67	69	84	66
Linseed	2	7	77	91	61	86	55
			70—85	84—98	30—91	85—87	42—68

[1] Pea-straw of unusual quality and fed freely.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
Acorns	1	2	88	83	62	88	91
Horse-chestnuts	1	1	87	60	0	85	93
Carob or Locust-beans	1	2	94	68	78	54	95
(d) *Manufactured Products and Refuse.*							
'Diffusion' residue	2	7	82	63	83	100	84
Wheat-bran, fed dry	5	12	72 67—78	78 71—89	33 20—39	70 50—80	77 70—82
,, ,,	1	2	76	88	20	79	80
Same, made sour[1]	1	2	67	79	13	83	71
,, cooked	1	2	64	70	0	87	74
Wheat-bran, fed dry	2	5	74	74	34	74	80
,, scalded with chopped hay	2	5	69	71	9	74	78
,, scalded as a sloppy mash	2	5	69	67	13	83	78
Spelt chaff	1	2	76	78	25	89	82
Residue from manufacture of wheat-starch	1	1	91	88	100	46	92
Rice meal	2	4	78	61	51	86	92
,, other sorts	1	2	67	45	34	83	84
Malt sprouts	3	7	81 80—84	78 73—82	85 65—95	50 35—65	86 82—88
Brewers' grains	2	6	65 63—67	72 71—73	42 33—45	84 81—84	67 64—70
Rape meal (extracted)	1	1	68	84	0	...	85
,, cake	2	7	66 56—75	81 76—86	8 0—16	79 69—88	76 74—78
Linseed meal (extracted)	1	8	71	82	0	91	73
,, cake	2	10	81 78—83	86 84—87	44 26—62	90 89—91	80 70—91
Palm-nut cake	1	2	75	77	54	94	79
,, meal (extracted)	2	3	91 89—93	95 89—100	82 72—92	95 89—100	94 92—96

[1] Made sour by addition of ferment.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
Earth-nut cake	1	2	85	91	16	86	98
Sesame cake	1	4	77	90	31	90	63
Sunflower cake	1	4	76	90	31	88	77
Cotton-seed cake	1	4	50	73	23	91	46
,, ,, (purified)	2	4	56	75	12	89	54
			55—57	74—76	10—15	88—91	53—55
,, ,, (decorticated).	1	2	80	85	0	88	95
Coconut ,,	1	2	78	76	62	100	81
Flesh meal	1	2	95	95	...	98	...
Dried blood[1]	1	2	63	62	...	100	100
Fish guano	1	2	...	90	...	76	...
New milk	5	5	98	94	...	100	98
			97—98	91—97	...	99—100	93—98
(e) *Roots and Tubers.*							
Potatoes	3	23	88	65	...	...	93
			83—90	64—67	...	...	89—96
Sugar Beet	2	28	89	62	...	...	95
			84—93	56—68	...	...	95—96
Mangold	2	16	88	76	...	...	95
			87—88	66—86	..	...	94—96
Turnips[2]	1	8	78	57	...	...	89
Swedes	1	2	97	62	100	94	99
II. COMPARATIVE EXPERIMENTS WITH HORSES AND SHEEP.[3]							
Meadow-grass—Sheep	12	27	62	60	61	52	66
			57—76	53—73	51—80	43—65	56—76
,, ,, Horse	12	15	50	60	41	22	59
			43—62	54—69	33—57	10—42	49—67
,, ,, ,,	16	23	51	59	41	20	59
			43—62	51—69	33—57	7—42	49—68

[1] Hard and solid.
[2] The turnips were full of holes inside and somewhat tough and hard.
[3] These comparative experiments on Sheep and Horses were carried out at Hohenheim.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	No. of experiments.	Organic matter.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.
Pasture-grass from meadows—Sheep ...	1	2	76	73	80	65	76
Do. do. Horse ...	1	1	62	69	57	13	66
Meadow-hay rich in nitrogen Sheep	4	10	64	65	63	54	65
			63—65	59—72	61—66	48—63	62—68
Do. do. Horse ...	4	6	51	62	42	20	57
			49—55	55—66	36—46	14—42	52—61
Meadow-hay, average—Sheep ...	4	8	59	57	56	51	62
			57—63	55—61	51—60	45—56	56—68
,, ,, ,, Horse ...	4	4	48	57	36	24	55
			43—56	55—60	33—42	19—31	49—67
Meadow-hay, poor in nitrogen Sheep	3	7	59	54	58	46	62
			58—61	53—56	54—61	43—49	56—65
Do. do. Horse ...	3	4	47	57	39	24	56
			45—51	54—62	38—40	16—33	48—61
Clover-hay—Sheep	4	8	56	56	50	56	61
			55—58	55—58	48—52	56—62	58—64
,, ,, Horse	4	5	51	56	37	29	64
			49—45	51—60	35—39	28—31	61—67
Lucerne—Sheep	4	12	59	71	45	41	66
			56—62	68—74	40—47	29—56	64—70
,, Horse	4	6	58	73	40	14	70
			55—61	70—75	36—44	0—30	67—71
Wheat-straw—Sheep	1	2	48	—	59	44	37
,, ,, Horse	1	2	23	19	27	—	18
Spelt straw—Horse	1	1	25	23	30	20	18
Oats—Sheep	3	13	71	80	30	83	76
			66—74	67—87	21—44	75—89	72—79
,, Horse	3	8	68	86	21	71	74
			63—71	82—89	1—38	63—78	72—76
,, ,, ...	8	22	67	79	20	70	74
			62—71	68—89	1—38	60—78	72—76
Barley—Horse	1	1	87	80	100	42	87
Maize—Sheep	1	2	89	79	62	85	91
,, Horse	2	2	89	77	70	61	94
			87—91	75—78	41—100	59—63	94—94
Beans—Sheep	1	6	90	87	79	84	91
,, Horse	1	5	87	86	65	13	93

TABLE II. (*continued*).

FOOD-STUFFS.	No of samples.	No. of experiments.	Organic matter.	Crube albuminoids.	Crude fibre.	Crude fat.	Nitrogen free-extract.
Peas—Sheep	1	2	90	89	66	75	93
,, Horse	1	1	80	83	8	9	89
Lupines—Sheep	1	2	88	88	97	78	78
,, Horse	1	1	72	94	51	27	51
Linseed cake—Horse	1	1	69	88	—	53	94
Linseed—Horse	1	1	64	75	—	52	98
Potatoes—Horse	1	1	93	88	9	—	99
Carrot—Horse	1	1	87	99	0	—	94
III. EXPERIMENTS WITH PIGS.							
Barley-meal	4	8	83	78	12	68	90
			82—85	75—80	0—27	65—77	89—91
Maize-meal	3	4	92	86	40	76	95
			90—95	84—88	19—57	76—77	93—96
Pea-meal	5	10	91	88	71	49	96
			88—95	85—90	55—89	36—67	95—99
Rice, boiled	1	1	99	89	—	67	100
Rye-bran	1	2	67	66	4	58	75
Coconut cake [1]	1	2	80	74	60	83	89
Flesh-meal	1	8	95	97	—	87	—
Dried blood [2]	1	1	72	72	—	—	92
Cockchafers	1	6	57	69 [3]	—	83	—
Sour milk	1	1	95	96	—	95	99
Potatoes	5	8	93	73	55	—	98

[1] Poorly digested by the pigs, despite apparent richness.
[2] Same sample as in previous table.
[3] Excluding chitine.

TABLE II. (*continued*).

B. *Average Composition and Digestibity of Foods as found by direct Experiments.*

(Calculated as percentage of dry matter.)

FOOD-STUFFS.	No. of samples.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.	DIGESTIBLE.		
							Albumen and amides.	Carbohydrate.	Fat.
I. EXPERIMENTS WITH RUMINANTS.									
(a) *Green Fodder and Hay.*									
Pasture-grass from meadows	3	19·7	19·5	4·8	43·9	12·1	14·7	49·0	3·2
Meadow aftermath	6	13·8	26·3	3·9	46·7	9·3	8·6	48·0	1·8
Meadow-hay	38	11·3	30·2	3·0	47·5	7·9	7·0	47·8	1·6
,, ,, rich in nitrogen	14	14·1	25·8	3·9	47·4	8·9	9·0	48·0	2·0
,, ,, average	24	10·0	30·9	2·9	48·6	7·7	5·7	48·2	1·4
,, ,, inferior	7	9·3	34·6	2·4	46·3	7·2	4·7	45·7	1·0
,, ,, fed dry	1	8·2	34·5	2·1	48·6	6·6	3·7	48·2	0·8
,, ,, steamed	1	8·1	35·8	2·1	47·5	6·5	2·7	48·8	0·9
Clover ley	1	27·1	16·7	5·1	42·1	9·0	21·2	45·1	3·3
Hay from Timothy grass	1	7·9	34·4	2·6	50·6	4·5	3·3	51·1	1·2
Green Clover and Clover-hay..	18	15·9	29·6	3·3	43·8	7·2	9·9	44·7	2·1
,, ,, before blooming	6	18·3	26·6	3·8	42·8	8·4	12·1	45·2	2·4
Clover-hay, very good	6	15·5	28·2	3·4	46·5	6·3	9·6	45·8	2·1
,, ,, average	6	13·9	33·7	2·3	43·5	6·7	7·6	43·4	1·2
Green Clover before blooming	1	18·4	26·6	4·2	43·5	7·3	13·6	51·9	2·7
,, ,, just in bloom	1	18·7	27·9	4·7	41·7	7·0	14·2	45·9	3·1
,, ,, in bloom	1	15·3	26·3	3·7	47·9	6·8	10·6	47·5	2·3
,, ,, end of bloom	1	15·6	29·9	4·2	43·8	6·5	9·1	42·6	1·9
Lucerne-hay, very good	9	17·9	32·0	2·8	39·6	7·4	13·2	39·9	1·1
,, ,, before blooming	5	18·9	29·7	2·8	40·7	7·9	14·6	41·3	1·1
Lucerne in bloom	4	16·8	35·0	2·8	38·2	6·8	11·7	38·9	1·1
,, fed green	1	20·6	30·3	3·7	37·6	7·8	16·1	35·3	1·6
,, as hay	1	18·4	34·0	2·3	38·0	7·3	13·5	37·1	0·7
,, as 'Brown hay'	1	22·4	37·0	2·7	29·6	8·3	16·2	32·5	1·5
,, fed green	1	17·4	28·2	3·0	42·8	8·6	14·2	45·1	1·6
,, dried artificially	1	17·2	29·9	2·2	42·1	8·3	13·4	42·1	0·7
,, dried without loss	1	17·0	31·8	43·8 (crude fat and N-free extract together)		7·4	12·2	44·4 (carbohydrate and fat together)	
,, dried and rained upon	1	14·9	33·9	44·2 (crude fat and N-free extract together)		6·9	9·9	42·7 (carbohydrate and fat together)	
Sainfoin fed green	1	23·8	26·0	4·0	39·8	6·4	17·3	42·1	2·7

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.	Digestible. Albumen and amides.	Digestible. Carbohydrate.	Digestible. Fat.
Sainfoin as hay	1	23·1	26·9	3·9	39·7	6·4	16·2	39·3	2·6
" as brown hay	1	21·0	31·8	4·9	35·2	7·1	13·3	38·0	3·7
" as silage	1	21·2	34·2	6·2	31·4	7·1	10·6	26·6	4·6
Vetch-hay (before bloom)	1	23·8	28·1	2·8	34·3	11·1	18·2	37·7	1·7
Soja-Bean hay	1	16·9	42·3	2·5	31·3	7·0	10·8	43·4	0·3
Lupine-hay (in bloom)	1	27·8	30·2	2·4	34·8	4·9	20·7	43·6	0·7
Serradella (in bloom)	1	22·6	29·7	5·2	30·9	11·6	16·8	34·2	3·4
" (end of bloom)	1	19·1	35·7	3·9	32·5	8·8	12·0	28·7	2·6
Green Maize	1	13·8	27·7	5·6	47·9	5·0	10·0	52·1	4·2
Green Sorghum	1	7·5	33·1	6·6	59·4	3·3	4·8	59·9	5·6
Prickly Comfrey	1	19·9	13·2	2·7	42·4	21·8	11·6	39·3	1·9
Potato haulm, beginning October	1	10·6	27·3	4·5	43·9	13·7	4·4	36·2	1·1
Poplar leaves " "	1	12·9	20·7	10·3	47·2	8·9	7·2	37·8	8·0
Mangold leaves, silage	1	11·8	10·8	4·8	36·3	36·3 [1]	7·6	25·5	2·9
Spent Hops	2	18·6	22·0	7·1	47·7	4·6	5·8	26·5	4·6
Beech brushwood in winter	1	4·7	45·6	1·8	44·8	3·1	0·8	10·5	0·2
Acacia brushwood	1	11·2	36·0	1·9	46·7	4·2	6·3	29·8	0·4
Poplar brushwood with leaves, July.	1	7·8	39·8	3·4	45·1	3·9	3·0	34·1	1·3
(b) *Straw, &c.*									
Wheat-straw	2	5·2	47·7	1·1	39·8	6·2	0·9	41·9	0·4
Rye-straw	2	4·4	46·2	1·4	43·1	5·3	0·9	43·3	0·5
Barley-straw	2	4·8	42·0	2·5	44·7	5·9	1·0	47·5	1·0
Oat-straw	5	6·2	42·0	2·3	41·7	7·6	2·2	41·8	0·8
Bean-straw	2	10·7	41·4	1·1	40·3	6·5	5·3	41·6	0·6
Soja-Bean straw	2	7·9	31·8	3·0	45·4	12·0	4·0	42·3	1·8
Pea-straw, very good	1	14·0	31·9	2·4	44·4	7·3	8·5	45·1	1·1
Lupine-straw	1	7·9	48·6	1·2	39·8	3·4	2·6	50·5	0·4
Soja-Bean pods	1	5·9	33·7	1·5	49·5	9·4	2·6	51·3	0·9
(c) *Grain.*									
Oats	6	12·5	12·7	6·3	64·1	4·4	9·7	49·3	5·2
Barley	1	11·6	5·9	2·2	77·2	3·1	8·9	67·2	2·2
Maize	1	13·3	1·8	4·8	78·4	1·7	10·4	72·7	4·1
Beans	5	30·9	8·2	1·8	54·9	4·2	27·2	56·2	1·6
Peas	1	29·9	6·6	1·6	58·3	4·6	26·6	58·7	1·2

[1] 19·9 of this was sand, so that the pure ash is only 16·4 per cent.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.	Digestible. Albumen and amides.	Digestible. Carbohydrate.	Digestible. Fat.
Soja Beans	1	39·3	5·4	19·4	31·6	4·3	34·3	28·8	17·7
Lupines	4	43·2	16·4	6·3	29·7	3·9	39·4	54·3	5·8
„ steamed	1	43·2	17·6	6·0	28·5	4·7	39·6	42·2	5·4
„ „ and sweetened	1	47·9	20·9	6·7	22·9	1·6	45·2	44·4	6·3
„ (different kind)	1	42·6	16·6	5·4	31·6	3·8	37·5	38·7	4·7
„ „ „ sweetened	1	49·2	20·9	6·5	21·3	2·1	44·3	32·7	5·7
Linseed	1	31·3	4·8	37·2	21·2	5·5	30·7	19·9	31·6
Acorns	1	6·5	10·4	4·6	76·7	1·8	5·4	76·6	4·0
Carob Beans	1	4·6	6·7	2·3	84·4	2·0	3·1	85·8	1·2
(d) *By- and Waste Products.*									
Wheat-bran	5	15·4	9·8	4·4	63·5	6·8	12·0	52·2	3·0
„ „ dry							14·2	52·6	3·7
„ „ fermented	1	16·1	8·6	4·6	64·0	6·7	12·7	46·3	3·8
„ „ boiled							11·2	47·4	4·0
„ „ dry							11·3	54·3	3·6
„ „ scalded and fed with hay	2	15·3	10·1	4·8	63·4	6·4	10·9	50·3	3·6
„ „ „ as a sloppy mash							10·2	50·6	4·0
Spelt chaff	1	16·1	9·4	6·1	62·0	6·4	12·5	53·3	5·4
Residue from manuf. of Wheat-starch	1	20·4	6·7	4·9	63·9	4·1	18·0	65·3	2·3
Rice-meal [1]	1	16·8	10·3	19·1	43·5	10·3	13·0	50·4	16·9
„ other sorts	1	12·1	13·3	10·0	56·0	8·6	5·5	51·5	8·3
Malt sprouts	1	32·1	14·4	2·5	40·7	10·3	26·2	49·4	1·2
Rape-meal (extracted)	1	40·6	13·5	0·9	35·7	8·5	34·1	30·3	0·3
Rape cake	2	36·2	11·9	13 5	30·9	7·5	29·3	24·5	10·6
Linseed-meal (extracted)	1	37·0	8·0	4·4	42·3	8·3	30·2	30·9	4·0
Linseed cake	2	34·5	9·5	12·0	34·2	9·8	29·6	31·7	10·8
Palm-nut meal (extracted)	2	21·5	27·6	3·7	42 8	4·4	20·3	62·9	3·5
„ „ (partly extracted)	1	15·9	26·0	18·1	35·2	4·8	12·4	37·3	16 9
Earth-nut cake	1	52·7	6·1	10·9	25·9	4·3	47·9	26·4	9·3
Sesame cake	1	49·1	7·1	11·5	21·3	11·0	44·3	15·6	10·3
Sunflower cake	1	39·4	14·8	16·2	21·8	7·7	35·3	21·4	14·2
Cotton-seed cake, decorticated	1	47·4	4·1	17·9	22·5	8·1	40·2	21·4	15·7
„ „ „ not decorticated	1	26·2	27·6	7·0	31·4	7·7	19·2	20·8	6·4
„ „ „ purified	2	32·2	18 2	9·0	33·1	7·5	24·1	20·0	8·0
Coconut cake	1	24·3	15·7	19·0	34·1	6·9	18·4	37·3	19·0

[1] A sample unusually rich in albuminoids and fat.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.	DIGESTIBLE.		
							Albumen and amides.	Carbohydrate.	Fat.
Flesh-meal	1	83·5	—	13·4	—	2·9	79·4	—	13·2
Dried blood	1	91·9	—	0·7	2·9	4·5	57·0	2·9	0·7
Fish guano	1	56·0	—	2·1	—	41·9	50·4	—	1·6
New milk	5	25·4	—	24·6	43·6	6·4	24·0	42·8	24·6
(e) *Roots and Tubers.*									
Potatoes	3	9·2	2·4	0·3	84·0	4·1	6·0	78·0	0·3
Sugar Beet	2	5·9	5·6	0·5	83·5	4·4	3·7	81·5	0·5
Mangolds [1]	2	11·6	7·2	0·9	69·4	9·4	8·8	66·1	0·9
Turnips [1]	1	12·7	13·1	1·8	57·0	11·5	7·3	50·6	1·8
II. EXPERIMENTS WITH HORSES AND SHEEP.									
Meadow-grass—Sheep							6·9	48·2	1·5
,, ,, Horse	10	11·3	32·5	2·9	44·4	8·9	6·9	38·3	0·6
Pasture-grass—Sheep							12·9	49·3	2·1
,, ,, Horse	1	17·6	23·0	3·2	40·9	15·3	12·1	40·0	0·4
Meadow-hay rich in nitrogen—Sheep							8·1	49·7	1·7
,, ,, ,, ,, Horse	3	12·1	32·9	3 1	43·9	8·1	7·8	39·0	0·7
,, ,, average—Sheep							5·4	46·7	1·2
,, ,, ,, Horse	5	9·6	34·1	2·6	45·0	8·7	5·5	37·2	0·6
Clover-hay—Sheep							7·9	42·0	1·2
,, ,, Horse	2	13·9	38·0	2·2	38·2	7·7	7·3	36·9	0·6
Lucerne-hay—Sheep							14·6	41·9	0·7
,, ,, Horse	1	19·8	32·0	2·4	38·6	7·1	14·8	40·9	0
Wheat-straw—Sheep							10·3	43·8	0·6
,, ,, Horse	1	3·8	48·5	1·4	40·7	5·6	10·7	20·0	0·7
Oats—Sheep							11·4	53·7	5·5
,, Horse	1	13·2	11·4	6·5	64·7	4·2	11·4	52·1	5·0
Barley—Horse	1	14·7	4·8	1·4	74·9	4·2	11·8	70·2	0·6
Maize—Sheep							10·4	72·7	4·1
,, Horse	1	13·3	1·8	4·8	78·4	1·7	10·3	75·4	3·0
Beans—Sheep							29·0	54·9	1·4
,, Horse	1	33·3	8·0	1·6	53·3	3·7	28·7	55·3	0
Peas—Sheep							26·6	58·7	1·2
,, Horse	1	29·0	6·6	1·6	58·3	3·6	24·8	52·4	0·1

[1] Deficit in total of percentages due to nitrates.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of samples.	Crude albuminoids.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.	DIGESTIBLE. Albumen and amides.	DIGESTIBLE. Carbohydrate.	DIGESTIBLE. Fat.
III. EXPERIMENTS WITH PIGS.									
Barley-meal	4	13·1	5·0	3·1	75·4	3·5	10·2	68·4	2·0
Maize-meal	3	12·3	2·2	5·1	78·1	2·3	10·5	74·8	3·9
Peas	5	27·4	7·5	1·7	59·8	3·6	24·1	62·8	0·8
Rice, boiled	1	6·8	0·1	0·5	92·1	0·5	6·0	91·6	0·3
Rye-bran	1	20·6	6·4	5·7	59·6	7·7	13·6	44·8	3·3
Coconut cake	1	26·6	14·0	8·6	44·3	6·2	19·8	48·2	7·2
Flesh-meal	1	82·4	—	13·5	—	4·2	79·6	—	11·8
Dried blood	1	91·9	—	0·7	2·9	4·5	65·8	2·7	—
Cockchafers	1	64·1	16·1[1]	7·3	4·7	7·8	45·2	—	6·1
Sour milk	1	31·5	—	6·7	53·5	8·3	30·2	52·7	6·4
Potatoes	5	10·2	2·8	0·5	82·4	4·2	7·4	82·3	—

C. *Extreme Variations in the Composition of Foods which have been used in Digestion Experiments.*

(Calculated as percentage of dry matter.)

FOOD-STUFFS.	No. of kinds.	Crude albuminoid.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.
I. EXPERIMENTS WITH RUMINANTS.						
Pasture-grass from meadows	3	16·3—25·1	17·4—23·0	3·2— 5·9	38·1—52·8	8·2—15·3
Meadow aftermath	6	10·7—16·1	23·0—31·1	3·1— 4·3	44·1—49·5	8·7— 9·7
Meadow-hay	38	7·4—19·4	21·8—38·2	1·6— 5·2	39·8—56·2	4·2—11·0
„ „ rich in nitrogen	14	11·8—19·4	21·8—29·0	1·6— 5·2	41·8—52·0	6·8—10·0

[1] Chitine.

TABLE II. (*continued*).

FOOD-STUFFS.	No. of kinds.	Crude albuminoid.	Crude fibre.	Crude fat.	Nitrogen-free extract.	Pure ash and sand.
Meadow-hay, average ...	24	7·4—11·2	24·1—38·2	1·6— 4·2	43·3—54·8	4·2—11·0
" " inferior ...	7	7·4—11·2	32·2—38·2	2·1— 2·8	43·3—48·7	4·2— 8·9
Green Clover and Clover-hay	18	12·2—19·6	24·5—38·9	1·4— 4·9	37·7—49·7	4·9—10·1
Green Clover before blooming	6	16·3—19·6	24·5—28·1	2·3— 4·9	40·2—45 0	7·0—10·1
Clover-hay, very good ...	6	13·4—19·9	25·7—31·5	1·6— 4·2	41·4—49·7	5·4— 6·8
" " average	6	12·2—16·6	28·1—38·9	1·4— 2·9	37·3—48·4	4·9— 7·8
Lucerne-hay, very good...	9	14·9—20·6	25·1—37·9	2·3— 3·7	35·5—44·1	6·3— 8·6
Lucerne before blooming	5	17·3—20·6	25·1—32·0	2·4— 3·7	37·6—44·1	7·1— 8·6
" in bloom	4	14·9—18·4	31·8—37·9	2·3— 3·7	35·5—41·4	6·3— 7·3
Spent Hops	2	17·5—19·7	21·7—22·3	6·3— 7·9	46·1—49·2	4·6— 4·7
Wheat-straw	2	3·8— 6·6	46·7—48·5	0·8— 1·4	38·9—40·7	5·7— 6·8
Rye-straw	2	4·0— 4·8	42·7—49·8	1·3— 1·6	41·0—46·2	5·0— 5·6
Barley-straw	2	4·7— 4·9	41·7—42·3	2·5— 2·5	44·2—45·2	5·7— 6·2
Oat-straw	5	3·7— 8·3	40·0—45·6	1·2— 3·1	36·6—48·9	6·0— 8·6
Oats..........................	6	9·3—14·6	10·2—16·2	5·5— 7·1	62·6—67·0	3·7— 6·3
Beans	5	28·9—33·6	7·1— 9·1	1·6— 2·4	52·2—58·0	3·0— 5·5
Lupines	4	36·1—47·9	14·5—20·9	6·0— 6·7	22·9—38·1	1·7— 4·8
Wheat-bran	5	14·7—16·1	8·7—10·6	3·1— 5·1	61·8—65·8	6·6— 7·1
Rape cake	2	34·8—37·5	10·0—13·9	13·2—13·7	27·8—34·1	7·4— 7·6
Linseed cake	2	32·6—36·5	9·2— 9·8	10·9—13·1	29·6—38·7	8·5—11·1
Palm-meal (extracted) ...	2	19·4—23·6	24·4—30·8	2·6— 4·9	42·6—42·9	4·1— 4·6
Potatoes	3	8·1—11·1	2·0— 2·9	0·3— 0·5	81·1—85·7	3·6— 4·6
Sugar Beet	2	4·8— 6·9	5·3— 5·9	0·4— 0·5	82·1—85·0	4·4— 4·5
Mangolds	2	10·6—12·6	6·8— 7·5	0·8— 1·0	67·1—71·8	8·6—10·2
Fresh milk	5	22·8—27·9	—	23·8—26·7	40·9—46·8	6·2— 6·7
II. EXPERIMENTS WITH HORSES AND SHEEP.						
Meadow-grass...............	9	8·5—17·7	23·0—38·2	2·2— 4·0	40·9—47·4	7·2—15·3
Meadow-hay, rich in nitrogen...	3	11·2—12·9	31·6—34·9	2·7— 4·0	43·3—44·8	8·0— 8·2
" " average ...	5	8·5—10·9	30·9—38·2	2·2— 2 8	43·3—47·4	7·2—11·0
Clover-hay	2	12·9—14·9	37·1—38·9	2·2— 2·2	37·3—38·2	7·5— 7·8
III. EXPERIMENTS WITH PIGS.						
Barley-meal	4	12·7—14·1	3·7— 7·1	2·7— 3·1	73·3—77·1	2·8— 4·3
Maize-meal..................	3	10·3—13·6	2·0— 2·3	5·0— 5·3	76·8—80·5	1·7— 3·2
Peas-meal	5	26·0—28·8	6·5— 8·7	0·7— 2·1	58·4—60·8	3·2— 4·3
Potatoes	5	8·2—12·7	1·9— 3·6	0·3— 0·6	80·5—84·3	3·8— 4·7

TABLE III.

Remarks.

Ammonia never occurs as a constituent of food, and nitrates are only occasionally met with in roots which have been heavily manured with dung or a powerful nitrogenous manure.

The Amides of organic acids and also certain *amido-acids* represent the nitrogenous substances in plants other than the albuminoids, and are generally included in the term *Amides.*

The following points with reference to amides and their occurrence in farm foods are worthy of notice :—

1. *Roots.*—Only one-third of the nitrogen in mangolds is in the form of albuminoids, while 40 per cent. of that in potatoes exists as amides. The reduction of amides into albuminoids during the fermentation of Potato Slump is an interesting fact.

2. *Germinating Seeds* contain large quantities of amides produced by the oxidation of the albuminoids. Young plants generally contain amides, but as they grow older the amount gradually decreases.

3. *Leafy Fodder-plants,* such as Clover and Lucerne, show a gradual decrease in amides as they advance towards maturity, but not so marked as in the case of grass.

4. *Young Grass and Clover* contain a good deal of amides; but as the albuminoids, as well as the amides, decidedly decrease as the plants advance towards maturity, it is evident that young pasturage is much more nutritious than mature hay. Liberal manuring with any nitrogenous manure increases the amount of amides.

5. *Sour Ensilage* involves loss of albuminoids, and frequently both the relative and actual amount of amides is decidedly increased in the process of fermentation.

6. *The Straw of the Cereals* contains but little amides if well ripened and harvested in good condition. If, however, straw be harvested in very wet weather, a considerable proportion of the nitrogen assumes the form of unprofitable amides.

7. *Cereal Grain* contains practically no amides under ordinary conditions. If a partial germination has taken place a large quantity of albuminoids is decomposed into amides. In the case of malt this amounts to over 20 per cent. of the total albuminoids.

8. *The Leguminosæ,* or Pod-plants, contain various organic nitrogenous substances which are neither amides nor true albuminoids. From ten to twelve per cent. of the nitrogen in Peas and Beans is in the form of non-albuminoids, while Lupines contain rather less.

9. *Bran and Oil-cakes* often contain appreciable quantities of non-albuminoids. Rape cake and Earth-nut cake are exceptionally rich in these substances, while Linseed and Poppy cake contain less, and Palm-nut cake frequently none at all.

It is impossible to decide *à priori* whether these products are derived directly from the seeds, or whether they are the result of a subsequent decomposition of the cake resulting from bad storage, &c.

It should always be remembered that damp and any form of fermentation will inevitably result in the decomposition of more or less of the valuable albuminoids.

TABLE III.—The Nitrogen in Food-stuffs expressed as Albuminoids and not Albuminoids.

FOOD-STUFFS.	Nitrogen as per cent. of dry matter.			Total N=100.	
	Total.	Albuminoids.	Not Albuminoids.	Albuminoids.	Not Albuminoids.
Hay and Green Fodder.					
Meadow-hay	1·780	1·550	0·230	87·2	12·8
	1·35—2·52	1·25—2·08	0·10—0·44	82·5—92·5	7·5—17·5
,, somewhat wetted with rain	1·491	1·317	0·174	88·3	11·7
,, old meadow, poor	1·120	0·816	0·304	73·2	26·8
Marsh-hay	1·305	0·960	0·345	73·8	26·2
Salt Meadow-hay	1·734	1·122	0·612	64·7	35·3
Meadow-hay, April 24	4·010	3·135	0·875	78·2	21·8
,, May 13	2·610	2·114	0·496	81·0	19·0
,, June 10	1·964	1·675	0·289	85·2	14·8
,, June 26	1·354	1·252	0·102	92·5	7·5
Pasturage from meadows	3·170	2·820	0·850	73·0	27·0
	2·6—4·01	1·84—3·14	0·5—1·05	65·2—81·0	19·0—34·8
Meadow-grass	1·600	1·344	0·256	84·0	16·0
,, as ensilage	1·894	1·163	0·731	61·4	38·6
,, soured	1·861	0·949	0·912	51·0	49·0
Young grass	4·360	3·180	1·180	73·0	27·0
	3·58—5·09	2·68—3·79	0·55—1·70	61·5—85·4	14·6—38·5
Grass, before and in bloom	1·800	1·380	0·420	76·8	23·2
	1·20—2·53	0·94—2·08	0·23—0·64	67·6—83·9	16·1—32·4
,, almost ripe	1·060	0·850	0·210	80·2	19·8
	0·94—1·21	0·74—0·98	0·20—0·23	78·2—85·0	15·0—21·8
Pasture-grasses	1·470	1·020	0·450	69·4	30·6

TABLE III. (*continued*).

FOOD-STUFFS.	Nitrogen as per cent. of dry matter.			Total N=100.	
	Total.	Albuminoids.	Not Albuminoids.	Albuminoids.	Not Albuminoids.
Rye-grass, English, in May	2·350	1·810	0·540	77·0	23·0
,, French, April 4	4·664	3·204	1·460	68·7	31·3
,, ,, May 23	2·420	1·783	0·637	73·7	26·3
,, Italian, April 1	3·921	2·781	1·140	70·9	29·1
,, ,, May 15	1·864	1·544	0·320	83·9	16·1
Timothy grass (manured), June 6	2·000	1·220	0·780	61·0	39·0
,, ,, ,, June 23	1·340	0·920	0·420	68·7	31·3
,, ,, (unmanured), June 6	1·200	0·860	0·340	71·3	28·7
,, ,, ,, June 23	0·830	0·640	0·190	77·1	22·9
Cocksfoot grass, in flower	1·400	0·964	0·436	68·9	31·1
,, ,, ripe	1·040	0·827	0·213	79·5	20·5
Meadow Soft-grass (*Holcus lanatus*), in flower	1·370	0·964	0·406	70·4	29·6
,, ,, ,, ripe	1·210	0·980	0·230	81·0	19·0
Rye, March 28	4·433	2·732	1·701	61·5	38·5
,, April 20	3·574	2·673	0·901	74·8	25·2
Oats, end of May	4·120	3·510	0·610	85·2	14·8
,, in June	2·290	2·030	0·260	88·7	11·3
Indian Millet	1·700	1·265	0·435	74·4	25·6
Maize (Baden), June 18	4·925	3·365	1·560	68·4	31·6
,, ,, July 9	3·969	2·480	1·489	62·6	37·4
,, ,, July 23	2·773	1·803	0·970	65·0	35·0
,, ,, Aug. 6	2·411	1·611	0·800	61·5	38·5
,, ,, Sept. 3	1·612	0·990	0·622	61·4	38·6
American Maize	1·220	0·884	0·336	72·5	27·5
,, ,, other sorts	1·456	1·135	0·321	78·0	22·0
,, ,, as ensilage	1·386	0·770	0·616	55·6	44·4

Green Maize	1·920	1·560	0·360	81·5	18·5
„ „ ensilage, examined Nov. 28	1·610	1·160	0·450	72·9	27·1
„ „ „ „ Dec. 7	1·490	1·020	0·470	67·5	32·5
„ „ „ „ Jan. 11	1·630	0·960	0·670	58·9	41·1
„ „ „ „ Feb. 3	1·620	0·710	0·910	43·8	56·2
Red Clover, quite young	3·880	2·660	1·220	68·6	31·4
	2·47—5 20	1·75—3·24	0·72—1·96	62·5—75·5	24·5—37·5
„ „ in bloom	2·230	1·810	0·420	81·0	19·0
	2·06—2·24	1·57—2·06	0·32—0·67	70·1—86·1	13·9—29·9
„ „ March 27	5·200	3·242	1·958	62·3	37·7
„ „ in bloom	2·244	1·571	0·673	70·0	30·0
„ „ almost ripe	2·040	1·713	0·327	84·0	16·0
Alsike	2·144	1·573	0·571	73·4	26·6
„ ensilage	2·150	1·532	0·682	68·3	31·7
Crimson Clover and Rye-grass, just in bloom	2·100	1·486	0·614	70·8	29·2
„ „ „ full bloom	1·341	1·055	0·286	79·0	21·0
„ „ „ end of blooming	1·078	0·902	0·176	83·7	16·3
Lucerne, quite young	5·420	3·630	1·790	67·0	33·0
	3·57—6·92	2·39—4·79	1·18—2·13	64·5—69·5	30·5—33·5
„ just in bloom	2·540	1·810	0·730	71·1	28·9
	2·36—3·01	1·55—2·28	0·65—0·92	62·7—75·8	24·2—37·3
„ April 23	5·760	3·718	2·042	64·5	35·5
„ in bloom	2·709	2·017	0·692	74·5	25·5
Sainfoin, March 27	3·028	2·217	0·811	73·3	26·7
„ April 27	3·251	2·394	0·857	73·6	26·4
Yellow Lupines, end of blooming	3·570	2·130	1·440	59·7	40·3
„ „ almost ripe	3·718	3·034	0·684	81·6	18·4
Lupines, fresh	3·341	1·681	1·660	50·3	49·7
„ ensilage	3·179	0 890	2·289	28·0	72·0
Blue Lupines, end of blooming	3·280	1·950	1·330	57·8	42·2
Vetches, before blooming	4·080	2·530	1·550	62·0	38·0
„ in bloom	4·050	2 983	1·067	73·7	26·3
„ almost ripe	3·090	2·594	0·496	86·7	13·3

TABLE III. (*continued*).

FOOD-STUFFS.	Nitrogen as per cent. of dry matter.			Total N=100.	
	Total.	Albuminoids.	Not Albuminoids.	Albuminoids.	Not Albuminoids.
Sand Vetch, July 8, just blooming	4·980	3·830	1·150	76·9	23·1
,, ,, July 16, full bloom	4·460	3·302	1·158	75·8	24·2
,, ,, July 29, end of blooming	3·290	2·896	0·394	88·0	12·0
Meadow Vetch, just in bloom	3·910	3·250	0·460	88·3	11·7
,, ,, quite young	4·760	3·650	1·110	76·7	23·3
Soja Beans, end of blooming	2·710	2·150	0·560	79·4	20·6
White Mustard, June 8	2·670	1·944	0·726	72·8	27·2
,, ,, June 22, full bloom	1·660	1·413	0·247	85·1	14·9
,, ,, June 29, end of blooming ...	1·290	1·235	0·055	95·7	4·3
Prickly Comfrey, young	4·896	3·586	1·310	73·2	26·8
,, ,, before blooming	3·890	3·380	0·510	86·9	13·1
Buckwheat, end of blooming	1·112	0·901	0·211	81·0	19·0
,, ensilage	0·939	0·706	0·233	75·2	24·8
Gorse, beginning of October	1·690	1·500	0·190	88·8	11·2
Cabbage heads	2·530	1·730	0·800	68·2	31·8
,, stalks	1·535	1·155	0·380	75·3	24·7
Mangold leaves, fresh	4·274	3·086	1·058	75·2	24·8
,, ,, ensilage	3·312	1·857	1·455	56·0	44·0
,, ,, July 16	3·448	2·214	1·234	64·2	35·8
,, ,, Aug. 13	2·747	2·033	0·714	74·0	26·0
,, ,, Sept. 10	2·466	1·919	0·547	77·8	22·2
Artichoke stalks	0 443	0·443	0	100	0
,, leaves	2·374	2·042	0·332	86·0	14·0

Tubers and Roots.					
Potatoes	1·467	0·831	0·636	56·6	43·4
	0·79—2·91	0·50—1·37	0·25—1·54	43·9—77·7	22·3—56·1
„ July 9	2·707	1·726	0·981	63·8	36·2
„ Aug. 7	1·962	1·262	0·700	64·3	35·7
„ Sept. 10	1·389	0·992	0·397	71·4	28·6
„ unmanured	1·140	0·950	0·190	83·4	16·6
„ manured, 1 cwt. nitrate per acre	1·221	1·060	0 161	86·8	13·2
„ „ 2 „ „	1·461	1·080	0·381	74·0	26·0
„ „ 3 „ „	1·808	1·080	0·728	59·7	40·3
(1) Mangolds, from various sources	2·220	0·800	1·420	36·1	63·9
	1·26—3·13	0·44—1·39	0·65—2·05	23·5—65·1	34·9—76·5
(2) „	1·700	1·053	0·651	65·1	34·9
(3) „	1·575	0·669	0·906	42·5	57·5
(4) „	1·110	0·558	0·552	50·3	49·7
(5) „	3·130	1·390	1·740	44·4	55·6
Swedes, strongly manured	2·645	1·595	1·050	60·3	39·7
Late Turnips	2·580	1·430	1·150	55·4	44·6
Carrots	1·800	1·075	0·725	59·7	40·3
Horse Carrots (Osdorf)	2·330	1·310	1·020	43·8	56·2
„ (Hohenheim)	1·830	1·270	0·560	69·4	30·6
Artichoke, large tubers	1·372	0·790	0·582	57·6	42·4
„ small „	1·038	0·599	0·439	57·7	42·3
Sweet Potatoes	1·800	1·205	0·675	64·1	35·9
Grains and Seeds.					
Winter Wheat	2·116	1·876	0·240	88·8	11·2
	1·96—2·27	1·78—1·97	0·18—0·30	86·8—90·8	9·2—13·2
Barley	1·974	1·923	0·051	97·1	2·6
	1·60—2·35	1·53—2·32	0·03—0·07	95·6—98·6	1·4—4·4
„ mature	2·050	1·550	0·500	75·6	24·4
Chevalier Barley (*Hord. distichum*), normal	1·800	1·761	0·039	97·8	2·2
„ „ rained upon	1·899	1·815	0·084	95·6	4·4

TABLE III. (*continued*).

FOOD-STUFFS.	Nitrogen as per cent. of dry matter.			Total N=100.	
	Total.	Albuminoids.	Not Albuminoids.	Albuminoids.	Not Albuminoids.
Chevalier Barley (*Hord. dis.*), mature	1·987	1·522	0·465	76·6	23·4
Oats	1·661	1·536	0·125	92·5	7·5
	1·32—2·0	1·17—1·79	0—0·21	88·6—100	0—11·4
Maize, Aug. 24, unripe	4·216	2·074	2·144	49·1	50·1
„ Sept. 6, „	2·623	2·029	0·594	77·4	22·6
„ ripe	1·819	1·729	0·090	95·1	4·9
	1·70—1·96	1·69—1·82	0—0·13	93—100	0—7·0
Millet	1·980	1·920	0·060	98·0	2·0
Hungarian Brome-grass, thrashed	1·350	1·240	0·110	91·8	8·2
Chinese Sugar Sorghum	1·970	1·730	0·240	87·8	12·2
Rice (shelled)	1·571	1·441	0·130	91·7	8·3
Peas	4·780	4·237	0·543	88·6	11·4
Beans	5·005	4·443	0·562	88·6	11·4
	4·78—5·23	4·10—4·79	0·44—0·68	85·8—91·5	8·5—14·2
Soja Beans	6·651	5·983	0·668	89·9	10·1
	6·29—7·09	5·51—6·45	0·28—0·90	86·8—95·8	4·2—13·2
Lupines, yellow	7·250	6·622	0·628	91·2	8·8
	5·31—7·59	4·90—7·01	0·41—1·22	83·9—93·2	6·8—16·1
„ ripe	6·840	6·330	0·510	92·5	7·5
„ unripe ...	7·000	5·460	1·540	78·0	22·0
„ sweetened	6·269	6·175	0·094	98·5	1·5
„ blue, ripe	5·310	4·900	0·410	92·3	7·7
Linseed	3·620	3·420	0·200	94·5	5·5
Mangold seed	2·040	1·679	0·361	82·3	17·7
Vegetable Ivory	0·820	0·709	0·111	88·7	11·3

By-Products.					
Molasses	1·909	1·252	0·657	65·6	34·4
	1·32—2·45	0·46—1·88	0·38—1·43	24·3—77·3	22·7—75·7
Malt	1·580	1·230	0·330	79·2	20·8
	1·10—1·73	1·12—1·34	0·28—0·39	76·4—83·3	16·7—23·6
„ sprouts	4·475	3·251	1·224	72·6	27·4
	3·56—5·52	2·23—4·10	0·62—1·61	64·1—78·1	21·9—35·9
Brewers' grains	3·211	3·092	0·119	96·4	3·6
	2·84—3·68	2·84—3·20	0—0·36	89·8—100	0—10·2
Potato slump	3·290	2·277	1·013	68·7	31·3
	2·74—4·28	1·80—3·08	0·94—1·20	65·8—71·9	28·1—32·2
Maize-Rye slump	3·682	2·551	1·131	69·3	30·7
Wheat-bran	2·190	1·930	0·260	88·3	11·7
Rice-meal	2·100	1·970	0·130	93·6	6·4
Rape cake	5·200	4·670	0·530	89·3	10·7
	4·77—5·41	4·20—4·96	0·45—0·71	86·7—91·7	8·3—13·3
Linseed cake	5·130	4·820	0·310	94·0	6·0
"Gold of Pleasure" seed cake	5·830	5·330	0·500	91·5	8·5
Poppy-seed cake	5·840	5·500	0·340	94·1	5·9
	5·07—6·23	4·80—5·82	0·28—0·40	93·5—94·5	5·5—6·5
Palm-nut cake	3·020	2·940	0·080	97·2	2·8
	2·72—3·23	2·53—3·10	0—0·24	91·2—100	0—8·8
Earth-nut cake	7·940	7·380	0·560	93·0	7·0
	7·58—8·51	6·79—8·12	0·34—0·90	85·9—95·5	4·5—14·1
Sesame cake	6·330	6·230	0·100	98·5	1·5
Cotton-seed cake	5·150	4·780	0·370	92·8	7·2
„ „ decorticated	6·710	6·480	0·230	95·6	4·4
Coconut cake	3·380	3·150	0·230	93·3	6·7

TABLE IV.

Feeding Standards for Farm Animals.

Remarks.

This table gives the daily requirements of the various farm animals in terms of "*real food*," or the actually digestible constituents of food. The term "*carbohydrates*" includes both the digestible fibre and nitrogen-free extract; this is practically identical in value with the "*nitrogen-free extract*" determined by analysis in the case of coarse fodders, but is somewhat less in the case of concentrated food-stuffs. The "*fat*" is calculated from the "*crude fat*" by applying the digestive coefficient of fat, but can only be regarded as pure fat in the case of grain or grain products. The "*albuminoids*" must be taken to include both the true albuminoids and the amides. Although our knowledge of the exact proportion of the amides in all food-stuffs is insufficient for a general classification, still the facts already established with regard to crude fibre, as well as the amides, should be borne in mind in arranging a feeding standard.

For calculating the "*albuminoid ratio*" from the digestible constituents the fats are multiplied by the factor [2·44], and the product added to the carbohydrates. The total organic matter is useful for regulating the bulk of a diet, and for arriving at its percentage digestibility.

The values given are strictly *averages,* and are well adapted for the guidance of a practical man as to the general lines he should adopt in feeding his stock without necessitating a slavish adherence to the exact quantities prescribed.

Variations above and below the standard will be required for animals of different breed, individuality, or milking-capacity.

The following points need consideration in calculating a feeding-ration :—

(*a*) Coarse fodders have been evaluated by direct digestion experiments.

(*b*) Values for the digestible constituents of concentrated food-stuffs are deducible from experimental results.

(*c*) Potatoes, roots, and potato slump can be safely considered to be completely digestible.

(*d*) If the amount of roots and potatoes in a mixed ration does not exceed 12 per cent. of the total food (referred to the *dry matter* only), the usual values still hold good ; but if the proportion of roots or tubers exceed this limit, an appreciable "depression" of the digestibility of the coarse and concentrated fodders included in the ration results. (See "Depression Table," p. 144.)

The latest results of experiments on animal nutrition have proved that the digestible value of a food cannot be simply determined by the difference found between the food eaten and the dung excreted.

Even if we ignore the many waste products of animal-digestion and other substances excreted in the dung (which are not directly derived from the food digested), on the ground that the food-supply is bound to make good their loss to the body, other difficulties in fixing the food-requirements of an animal arise. The *amides*, for instance, involve considerable difficulty, as we do not yet know for certain whether their formation in the body is more akin to that of the albuminoids or of the carbohydrates, and whether they can be regarded as a direct source of fat or not—a further difficulty is that of the *fermentation of cellulose* in the alimentary canal of cattle and horses. It has been found that as much as 40 per cent. of the crude fibre apparently digested is in reality decomposed with the production of Marsh-gas by fermentation in the intestines, and it is very open to question whether the fatty acids produced in this fermentative process (acetic and butyric acids, &c.) possess anything like the same feeding-value as the starch or cellulose they theoretically represent. (See p. 111.)

Crude fibre has been found absolutely useless for horses. (See p. 244.)

Experimental evidence of the fermentative decomposition of albuminoids in the intestines has been given, but the proposal to make an allowance of 10 per cent. on this score cannot be accepted until further and more reliable results have been obtained.

Despite these difficulties and sources of uncertainty, it would be very foolish to abolish all food calculations and standards, and for the farmer to ignore such guidance as is already obtainable on the subject. Notwithstanding their imperfections, digestible values remain the only sure guide as to the choice and selection of food-stuffs, and the only possible basis for a rational system of feeding farm animals.

The only thing to bear in mind is that the greater the proportion of amides or of crude fibre in a food-stuff the more uncertain is its feeding-value, and the greater the probability that the food-stuff will require some addition of one or other constituent to bring it up to its normal and theoretical value, or to enable it to achieve its "economic maximum" as a farm food.

For the practical valuation of food-stuffs, and all special food-calculations, two methods of calculation are possible, and provided they be carried out properly identical results will be obtained so far as the feeding-effect is concerned.

Method A.

After taking into consideration the conditions of soil, manuring, season, and harvesting under which the particular crop was grown, as well as the period of vegetation at which it was gathered, a general estimate of its quality is obtained, and values in accordance with that quality are selected from a table giving "maximum," "minimum," and "average" values for the different food-stuffs.

Allowance has then to be made for the probable percentage of amides, &c. The figures obtained by an intelligent use of the tables are then employed for further calculations.

Method B.

By consulting the table giving the average composition of food-stuffs, the average composition and percentage of digestible constituents of any food-stuff can be obtained. In Table I. several grades of quality are given in many cases, and the average values for a food of comparable quality with that under consideration can be selected.

It is now possible to try feeding-stuffs with a legal guarantee, and by comparing the analytical values with those given in the tables, a very close estimate of the feeding-value of purchased food can be obtained. Allowance must of course be made for amides and crude fibre.

The practical man can choose either method, but I am personally in favour of Method B, and give an illustration of its practical application.

Example I.

A farmer owns 25 milch-cows averaging 900 lbs. apiece, or weighing 22,250 lbs. altogether. He wishes to feed them for 7 winter months, or 212 days, on an economical diet that will maintain a maximum production of milk. His stores at the end of harvest are as follows :—

40,000 lbs. hay.
20,000 lbs. clover.
30,000 lbs. oat-straw.
150,000 lbs. mangolds.

The hay was of rather poor quality because it was cut a little over-ripe and was harvested rather badly. As great care was taken to make the best of it, however, and it was stacked before it was really sodden, it will be fairly represented by the quality marked "inferior" in the Table.

From a neighbouring brewery a constant supply of brewers' grains and malt-sprouts can be obtained, so that with this addition to the food already on the farm the following ration per 1000 lbs. live-weight of the cows can be provided every day.

	Organic matter.	Digestible Constituents.				
		Albuminoids and Amides.	Carbo-hydrates.	Fat.	Amides.	Crude fibre.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
8 lbs. hay	6·5	0·27	2·79	0·04	0·03	1·25
4 lbs. clover	3·1	0·28	1·48	0·05	0·05	0·47
4 lbs. oat-straw...	3·3	0·06	1·60	0·03	—	0·94
30 lbs. mangolds .	3·4	0·33	3·00	0·03	0·21	0·27
Total	16·3	0·94	8·87	0·15	0·29	2·93
30 lbs. grains ...	6·8	1·17	2·97	0·39	0·04	0·48
$2\frac{1}{2}$ lbs. sprouts ...	2·0	0·48	1·24	0·03	0·13	0·30
Total	25·1	2·59	13·08	0·57	0·46	3·71
Feeding Standard	24·0	2·5	12·5	0·4	—	—

As the cows are of a good milking-breed it is highly important that their diet should be fully as high as that laid down in the standard, especially with regard to albuminoids. With cows of poor milking-capacity this is not so important a consideration.

The proportion of roots referred to "dry" or "organic matter" amounts to 16 per cent. of the total, so that a small "depression" will result. This amounts (see p. 144) to 5 per cent. of the albuminoids in the rest of the diet (2·26 lbs.), so that a reduction of 0·11 lb.

must be made from the albuminoids on the score of "depression."

The carbohydrates are already in excess of that required by the standard, and we need not trouble about them further, as the amides will probably compensate for any "depression" brought about by the roots.

The proportion of amides needs no practical consideration provided it be not abnormal, but if a ration contains several food-stuffs with a high percentage of amides it requires especial consideration.

Ordinary hay and clover contain but a moderate proportion of amides, while the tender herbage of a pasturage frequently contains a much larger proportion.

For practical purposes in the present state of our knowledge, we will restrict our especial consideration of amides to roots and such concentrated food-stuffs as malt-sprouts, which contain very large quantities of these nitrogenous compounds.

In the above ration there are two foods highly charged with amides, viz. the mangolds and the malt-sprouts. The former usually contains about two-thirds of its total nitrogen in the form of amides, the latter about a quarter. We must deduct the following amounts from the total albuminoids in the table, viz.:—

Amides in mangolds . . .	=0·21 lb.
Amides in sprouts . . .	=0·13 lb.
"Depression" due to roots	=0·11 lb.
Total	=0·45 lb.

This amounts to about one-fifth of the total amount of albuminoids (2·59 lbs.). A deficit of one-third of a pound of albuminoids is thus apparent if we compare the ration with the standard we have laid down.

Provided the cows be good milkers, it would most probably be found in practice that the addition of 10 oz. of flesh-meal, or 1 lb. of earth-nut or sesame cake, or 0·4 lb. of digestible albuminoids in some form or other, would considerably improve the yield of milk.

Example II.

Let us next consider the case of a farm on sandy soil producing poor crops of hay and corn, but growing excellent potatoes.

A distillery is started for working-up the potatoes, and 100 lbs. of potato-slump is thus provided for every

	Total organic matter.	Digestible Constituents.				
		Albuminoids and Amides.	Carbo-hydrates.	Fat.	Amides.	Crude fibre.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
8 lbs. hay	6·5	0·27	2·71	0·04	0·03	1·25
8 lbs. oat-straw ...	6·6	0·11	3·20	0·06	—	1·88
6 lbs. chaff.........	4·5	0·09	2·10	0·03	—	1·02
100 lbs. "slump"	4·9	1·40	3·30	0·20	0·44	0·60
Total	22·5	1·87	11·31	0·33	0·47	4·75
1½ lbs. rape cake .	1·2	0·37	0·36	0·11	0·04	0·01
2 lbs. sesame cake.	1·6	0·67	0·38	0·23	0·01	0·05
Total	25·3	2·91	12·05	0·67	0·52	4·81
Feeding Standard	24·0	2·5	12·5	0·4	—	—

1000 lbs. live-weight of the cows on the farm. The farm crops provide 8 lbs. of poor hay, the same weight of very fair oat-straw, and 6 lbs. of chaff per 1000 lbs. live-weight of the cows per day. The table on p. 345 gives the composition of these various food-stuffs.

Despite the large proportion of slump in this diet, I do not consider that it would bring about any appreciable "depression." If we deduct the 0·44 lb. of amides in the slump we still have 2·47 lbs. of albuminoids left, or practically that required by the standard (2·5). It would only be desirable to exceed the ration laid down in the case of cows of remarkable milking-capacity.

It may also occur that the oil-cake provided proves richer in nitrogen than the values quoted, which are those of average samples.

It is very easy to make allowance for the quality of such cake as represented by the analysis.

Average samples of sesame cake contain 37·2 per cent. of albuminoids; and if a sample contains 42 per cent., the digestible albuminoids would be increased in the same proportion.

This method can be employed with any food-stuff by comparing the analysis with the figures given in the tables, and altering the digestible constituents in proportion.

The slight deficit of carbohydrates in the above ration is more than made good by the digestible albuminoids and fat. It is quite another question, however, whether the excessive amount of crude fibre would not make the albuminoids too small in proportion.

With the help of Table II. we calculate out the total crude fibre as 4·81 lbs., and deduct this from the total carbohydrates :

$$12{\cdot}05 - 4{\cdot}81 = 7{\cdot}24 \text{ lbs.}$$

In the first example we have

$$13{\cdot}08 - 3{\cdot}71 = 9{\cdot}37 \text{ lbs.}$$

If we assume that the crude fibre possesses half the nutritive value of the carbohydrates we get the following :—

Ex. I. . . $9{\cdot}37 + 1{\cdot}86 = 11{\cdot}23$ lbs.
Ex. II. . . $7{\cdot}24 + 2{\cdot}41 = 9{\cdot}65$ lbs.

It is thus evident that the carbohydrates in Example I. are 1·58 lb. in excess of those in Example II. Our present knowledge does not permit us to decide whether this is a matter of serious moment with cows as has been demonstrated in the case of horses.

If it be found that the diet is not succeeding well with the cows, it would be highly advisable to supply an addition of digestible carbohydrates in the form of roots, potatoes, starchy meals, &c.

Example III.

Let us now take the case of a farm without any meadow-land at all, but growing good crops of red clover, roots, and beans. There is a plentiful crop of clover, but unfortunately one half of it was harvested in wet weather and is only of average quality, while the rest was completely soaked and sodden, but was eventually dried, and provided useful winter fodder. This latter will correspond with that described as "inferior" in the Table. Roots, beans, and straw of very fair quality have also been harvested.

The following distribution of these food-stuffs, supplemented with a little oil-cake, would suffice to keep a herd of good dairy cows in first-rate milking condition.

(lbs. per 1000 lbs. live-weight.)

	Total organic matter.	Digestible Constituents.				
		Albuminoids and Amides.	Carbo-hydrates.	Fat.	Amides.	Crude fibre.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
8 lbs. clover (average).	6·3	0·56	2·96	0·10	0·11	0·94
8 lbs. „ (poor) ..	6·4	0·46	2·90	0·08	0·07	0·93
4 lbs. straw	3·3	0·06	1·62	0·02	—	0·91
25 lbs. mangolds	2·8	0·28	2·50	0·03	0·18	0·23
4 lbs. beans	3·3	0·88	2·00	0·06	0·10	0·20
Total	22·1	2·24	11·98	0·29	0·46	3·21
2 lbs. palm-nut cake...	1·7	0·31	1·09	0·18	0·01	0·30
Total ration	23·8	2·55	13·07	0·47	0·47	3·51
Standard	24·0	2·5	12·5	0·4	—	—

As the poor clover had been thoroughly soaked with rain, the values given for carbohydrates are probably about one-third too high. As the roots are not supplied in large quantity they will not exercise any appreciable "depression," but a deduction of 0·18 lb. for the amides they contain is necessary. This could easily be made good by substituting a cake richer in nitrogen for the palm-nut cake in the Table. Considering the wonderful results produced by palm-nut cake with milch-cows, I do not recommend such a change, and consider that the small deficit of nitrogen would be more than accounted for by the specific value of the palm-nut cake and the beans for promoting a large yield of good milk.

The crude fibre amounts to 3·51 lbs. and is even less than that given in Example I. No objection can therefore be made to this item, and I consider this ration eminently suited for the requirements of milch-cows.

TABLE IV.—Feeding Standards.

	Total organic matter.	Digestible. Albuminoids.	Carbo-hydrates.	Fat.	Total.	Nutritive or "Albuminoid" Ratio.
A. Per Day and per 1000 lbs. Live-weight.						
	lbs.	lbs.	lbs.	lbs.	lbs.	
1. Oxen at rest in stall	17·5	0·7	8·0	0·15	8·85	1 : 12·0
2. Wool Sheep, coarser breeds	20·0	1·2	10·3	0·20	11·70	1 : 9·0
„ „ finer breeds	22·5	1·5	11·4	0·25	13·15	1 : 8·0
3. Oxen in moderate work	24·0	1·6	11·3	0·30	13·20	1 : 7·5
„ hard work	26·0	2·4	13·2	0·50	16·10	1 : 6·0
4. Horses in light work	20·0	1·5	9·5	0·40	11·40	1 : 7·0
„ average work	21·0	1·7	10·4	0·60	12·70	1 : 7·0
„ hard work	23·0	2·3	12·5	0·80	15·60	1 : 6·0
5. Milch-Cows	24·0	2·5	12·5	0·40	15·40	1 : 5·4
6. Fattening Oxen*, 1st period	27·0	2·5	15·0	0·50	18·00	1 : 6·5
„ „ 2nd „	26·0	3·0	14·8	0·70	18·50	1 : 5·5
„ „ 3rd „	25·0	2·7	14·8	0·60	18·10	1 : 6·0
7. Fattening Sheep*, 1st period	26·0	3·0	15·2	0·50	18·70	1 : 5·5
„ „ 2nd „	25·0	3·5	14·4	0·60	18·50	1 : 4·5
8. Fattening Pigs*, 1st period	36·0	5·0	27·5		32 50	1 : 5·5
„ „ 2nd „	31·0	4·0	24·0		28·00	1 : 6·0
„ „ 3rd „	23·5	2·7	17·5		20·20	1 : 6·5
9. Growing Cattle.						
Age: months. — Average live-wt. per head.						
2—3 — 150 lbs.	22·0	4·0	13·8	2·0	19·8	1 : 4·7
3—6 — 300 „	23·4	3 2	13·5	1·0	17·7	1 : 5·0
6—12 — 500 „	24·0	2·5	13·5	0·6	16·6	1 : 6·0
12—18 — 700 „	24·0	2·0	13·0	0·4	15·4	1 : 7·0
18—24 — 850 „	24·0	1·6	12·0	0·3	13·9	1 : 8·0
10. Growing Sheep.						
5—6 — 56 lbs.	28·0	3·2	15·6	0·8	19·6	1 : 5·5
6—8 — 66 „	25·0	2·7	13·3	0·6	16·6	1 : 5·5
8—11 — 76 „	23·0	2·1	11·4	0·5	14·0	1 : 6·0
11—15 — 82 „	22·5	1·7	10·9	0·4	13·0	1 : 7·0
15—20 — 86 „	22·0	1·4	10·4	0·3	12·1	1 : 8·0

* The food-quantities refer to original 1000 lbs. live-weight before fattening.

TABLE IV. (*continued*).

		Total organic matter.	Digestible. Albuminoids.	Digestible. Carbohydrates.	Digestible. Fat.	Digestible. Total.	Nutritive or "Albuminoid" Ratio.
11. Growing fat Pigs.							
Age: months.	Average live-wt. per head.	lbs.	lbs.	lbs. (Carbohydrates and Fat)		lbs.	
2— 3	50 lbs. ……	42·0	7·5	30·0		37·5	1 : 4·0
3— 5	100 „ ……	34·0	5·0	25·0		30·0	1 : 5·0
5— 6	124 „ ……	31·5	4·3	23·7		28·0	1 : 5·5
6— 8	170 „ ……	27·0	3·4	20·4		23·8	1 : 6·0
8—12	250 „ ……	21·0	2·5	16·2		18·7	1 : 6·5
B. Per Head per Day.							
Growing Cattle.							
2— 3	150 lbs. ……	1·65	0·30	1·05	0·15	1·50	1 : 4·7
3— 6	300 „ ……	3·50	0·50	2·05	0·15	2·70	1 : 5·0
6—12	500 „ ……	6·00	0·65	3·40	0·15	4·20	1 : 6·0
12—18	700 „ ……	8·40	0·70	4·55	0·14	5·39	1 : 7·0
18—24	850 „ ……	10·20	0·70	5·15	0·13	5·98	1 : 8·0
Growing Sheep.							
5— 6	56 lbs. ……	0·80	0·090	0·435	0·023	0·548	1 : 5·5
6— 8	60 „ ……	0·85	0·085	0·425	0·020	0·530	1 : 5·5
8—11	76 „ ……	0·85	0·080	0·425	0·019	0·524	1 : 6·0
11—15	82 „ ……	0·90	0·070	0·445	0·016	0·531	1 : 7·0
15—20	86 „ ……	0·95	0·060	0·440	0·013	0·513	1 : 8·0
Growing fat Pigs.				(Carbohydrates and Fat)			
2— 3	50 lbs. ……	1·05	0·19	0·75		0·940	1 : 4·0
3— 5	100 „ ……	1·70	0·25	1·25		1·500	1 : 5·0
5— 6	124 „ ……	1·95	0·27	1·48		1·750	1 : 5·5
6— 8	170 „ ……	2·30	0·29	1·73		2·025	1 : 6·0
8—12	250 „ ……	2·60	0·31	2·025		2·335	1 : 6·5

TABLE V.—Percentage Proportions of the various parts of Cattle, Sheep, and Pigs.

	Ox.			Fat Calf.	Sheep.					Pig.	
Parts of Carcase.	Well-fed.	Half-fat.	Fat.		Lean.	Average store.	Half-fat.	Fat.	Very fat.	Good store.	Fat.
	%	%	%	%	%	%	%	%	%	%	%
Contents of Stomach and Intestines	18·0	15·0	12·0	7·0	16·0	15·0	14·0	12·0	10·0	7·0	5·0
Blood	4·7	4·2	3·9	4·8	3·9	3·9	3·6	3·2	3·2	7·3	3·6
Skin and Horns	8·4	7·4	6·0	6·8	9·6	9·3	8·0	7·2	6·5	—	—
Legs to Gambrel-joint	1·9	1·7	1·6	1·9						—	—
Washed Wool	—	—	—	—	5·0	4·7	4·3	4·0	3·6	—	—
Wool-dirt	—	—	—	—	4·8	4·5	4·0	3·6	3·2	—	—
Head	2·8	2·7	2·6	4·8	4·6	4·3	3·7	3·2	2·8	0·5	0·4
Tongue and Gullet	0·6	0·6	0·5								
Heart	0·4	0·5	0·5	0·6	0·4	0·3	0·4	0·3	0·2	0·5	0·3
Lungs and Wind-pipe	0·7	0·7	0·6	1·2	1·5	1·5	1·2	1·0	1·0	1·4	0·9
Liver and Gall-bladder	1·5	1·3	1·3	1·6	1·4	1·3	1·3	1·3	1·0	2·6	1·7
Diaphragm	0·5	0·5	0·5	0·4	0·3	0·3	0·3	0·2	0·2	—	—
Spleen	0·2	0·2	0·2	0·3	0·2	0·2	0·2	0·1	0·1	0·2	0·2
Stomach without contents	4·5	3·0	2·7	1·2	2·4	2·3	2·3	2·0	1·5	1·2	0·7
Intestines " "	2·0	1·5	1·4	2·4	2·3	2·2	1·9	1·7	1·3	3·9	2·2
Fat of Omentum and Intestines	2·3	2·9	4·5	2·4	3·0	4·1	4·9	6·8	8·0	1·7	2·5
Four Quarters, including Kidneys and Kidney-fat	47·4	55·7	60·3	60·0	43·3	45·3	49·4	52·8	57·1	72·8	82·1
Loss	4·1	2·1	1·4	4·6	1·3	0·8	0·5	0·6	0·3	0·9	0·4
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

Parts taken in Groups.											
Blood	4·7	4·2	3·9	4·8	3 9	3·9	3·6	3·2	3·2	7·3	3·6
Skin, Head, Legs, Tongue	13·7	12·4	10·7	13·5	24·0	22·8	20·0	18·0	16·1	—	—
Entrails	9·8	7·2	7·7	7·7	8·5	8·1	7·7	6·6	5·3	9·8	6·0
Flesh and Fat	49·7	58·6	64·8	62·4	46·3	49·4	54·3	59·6	65·1	74·5	84·6
Contents of Stomach and Intestines	18·0	15·0	12·0	7·0	16·0	15·0	14·0	12 0	10·0	7·0	5·0
Constituents of Carcase. (Dressed weight, including fat of Omentum, &c.)											
Flesh without Fat and Bones	36·0	38·0	35·0	43·0	33·2	33·5	33·1	29·0	27·0	46·4	40·0
Bones	7·4	7·3	7·1	9·3	7·1	6·6	5·9	5·5	5·2	8·0	5·8
Fat in Flesh	2·0	7·9	14·7	5·5	2·0	3·3	8·0	14·7	20·5	16·5	32·4
Fat on Kidneys	2·0	2·5	3·5	2·2	1·0	1·9	2·4	3·6	4·4	1·9	3·9
Fat on Omentum and Intestines	2·3	2·9	4·5	2·4	3·0	4·1	4·9	6·8	8·0	1·7	2·5
Total	49·7	58·6	64·8	62·4	46·3	49·4	54·3	59·6	65·1	74·5	84·6
Flesh of Carcase without Fat and Bones.											
Dry matter	8·0	8·4	7·5	8·8	6·8	6·7	6·3	5·4	5·1	8·1	7·3
Water	28·0	29·6	27·5	34·2	26·4	26·8	26·8	23·6	21·9	38·3	32·7
Total	36·0	38·0	35·0	43·0	33·2	33·5	33·1	29·0	27·0	46·4	40·0

TABLE V. (*continued*).

	Ox.			Fat Calf.	Sheep.					Pig.	
	Well-fed.	Half-fat.	Fat.		Lean.	Average store.	Half-fat.	Fat.	Very fat.	Good store.	Fat.
In 100 parts of Flesh without Bones.	%	%	%	%	%	%	%	%	%	%	%
Fat	5·3	17·2	29·4	11·3	5·7	9·0	19·5	33·6	43·2	26·2	45·5
Muscle	19·8	17·5	14·5	17·0	18·0	17·1	14·5	11·7	10·2	12·3	9·7
Ash	1·2	0·9	0·8	1·1	1·3	1·1	0·8	0·7	0·6	0·6	0·4
Water	73·7	64·4	55·3	70·6	75·0	72·8	65·2	54·0	46·0	60·9	44·4
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Percentage Composition of Live Animal.											
Fat	7·1	14·9	26·8	13·1	8·6	13·2	18·3	28·1	37·2	22·5	40·2
Nitrogenous matter	15·8	15·5	13·7	15·3	15·4	14·8	13·8	12·2	11·0	13·9	11·0
Minerals	4·8	4·4	3·9	4·5	3·4	3·3	3·2	2·9	2·8	2·7	1·8
Water	54·3	50·2	43·6	60·1	56·6	53·7	50·7	44·8	39·0	53·9	42·0
Contents of Stomach and Intestines	18·6	15·0	12·0	7·0	16·0	15·0	14·0	12·0	10·0	7·0	5·0
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

Do., after deducting contents of Stomach and Intestines.											
Fat	8·7	17·5	30·5	14·1	10·2	15·5	21·3	31·9	41·4	24·2	42·3
Nitrogenous matter	19·2	18·3	15·6	16·5	18·3	17·4	16·0	13·9	12·2	15·0	11·9
Minerals	5·9	5·2	4·4	4·8	4·0	3·9	3·8	3·3	3·1	2·9	1·9
Water	66·2	59·0	49·5	64·6	67·5	63·2	58·9	50·9	43·3	57·9	43·9
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Mineral Substances in 100 parts of Live Animal.											
Phosphoric Acid	1·92	1·76	1·56	1·64	1·33	1·29	1·25	1·13	1·09	1·10	0·73
Lime	2·14	1·96	1·74	1·93	1·40	1·35	1·31	1·19	1·15	1·15	0·77
Magnesia	0·06	0·06	0·05	0·06	0·05	0·04	0·04	0·04	0·04	0·05	0·03
Potash	0·18	0·16	0·14	0·29	0·16	0·16	0·15	0·14	0·13	0·10	0·15
Soda	0·14	0·13	0·12	0·07	0·15	0·15	0·14	0·13	0·12	0·10	0·07
Silica	0·02	0·01	0·01	0·01	0·02	0·02	0·02	0·02	0·02	—	—
Sulphuric Acid, Chlorine, Carbonic Acid	0·34	0·32	0·28	0·50	0·29	0·29	0·29	0·25	0·25	0·15	0·10
Total	4·80	4·40	3·90	4·50	3·40	3·30	3·20	2·90	2·80	2·70	1·80

Note to Tables V. *and* VI.

Table V. is based principally on the results of Lawes and Gilbert ('Philosophical Transactions of the Royal Society,' 1859, pp. 493–680); at the same time some German "slaughter" results have been included, and the proportion of individual mineral constituents has not been determined directly, but calculated from the various analyses of the chief parts of the animal body.

It must also be noted that the figures given in the table refer to young animals, or those which have only just reached maturity. If animals of a more advanced age are fattened the proportion of fat, especially that on the kidneys, is generally greater, while the weight of the four quarters is less in proportion. Recently Lawes and Gilbert have published the results of the analyses of the ash of whole animals and of certain parts as well (Phil. Trans. 1883, pp. 865–890).

Table VI. consists of the proportional quantities of mineral substances expressed as percentage of the total live-weight as deduced from this latter memoir; while the average of the directly determined amounts of nitrogenous matter, fat, water, and ash, as well as the live-weight of the animals calculated from all the results published in 1859, has been appended.

TABLE VI.—COMPOSITION OF CARCASE OF OXEN, SHEEP, AND PIGS, CALCULATED FROM RESULTS OF LAWES AND GILBERT.

	Ox.		Fat Calf.	Sheep.				Fat Lamb.	Pig.	
	Half-fat.	Fat.		Thin.	Half-fat.	Fat.	Very fat.		Thin.	Fat.
	%	%	%	%	%	%	%	%	%	%
Fat	19·1	30·1	14·8	18·7	23·5	35·6	45·8	28·5	23·3	42·2
Nitrogenous matter	16·6	14·5	15·2	14·8	14·0	12·2	10·9	12·3	13·7	10·9
Minerals *	4·66	3·92	3·80	3·16	3·17	2·81	2·90	2·94	2·67	1·65
Water	51·5	45·5	63·0	57·3	50·2	43·4	35·2	47·8	55·1	41·3
Contents of Stomach, &c.	8·2	6·0	3·2	6·0	9·1	6·0	5·2	8·5	5·2	4·0
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Mineral Substances.										
Phosphoric Acid	1·839	1·551	1·535	1·118	1·199	1·040	1·108	1·126	1·066	0·654
Lime	2·111	1·792	1·646	1·321	1·350	1·184	1·240	1·281	1·079	0·636
Magnesia	0·085	0·061	0·079	0·056	0·052	0·048	0·055	0·052	0·053	0·032
Potash	0·205	0·176	0·206	0·173	0·168	0·148	0·158	0·166	0·196	0·138
Soda	0·146	0·126	0·148	0·120	0·104	0·097	0·129	0·103	0·110	0·073
Iron Oxide	0·040	0·024	0·021	0·037	0·042	0·034	0·030	0·026	0·022	0·013
Sulphuric Acid	0·038	0·033	0·041	0·052	0·035	0·031	0·028	0·039	0·053	0·029
Carbonic Acid	0·087	0·071	0·047	0·037	0·053	0·041	0·049	0·043	0·021	0·021
Chlorine	0·059	0·055	0·063	0·072	0·051	0·044	0·066	0·053	0·056	0·043
Silica	0·013	0·006	0·005	0·021	0·020	0·026	0·016	0·012	0·005	0·003
Total	4·623	3·895	3·791	3·077	3·074	2·693	2·879	2·901	2·662	1·642
Live-weight (pounds)	1232·0	1419·0	258·8	97·6	105·1	127·2	239·4	84·4	93·9	185·0
Age	4 years.	4 years.	9–10 weeks.	1 year.	3¼ years.	1¼ year.	1¾ year.	½ year.	From same farrow: fattened 10 weeks.	
Breed	Aberdeen.		Durham.	Hampshire Down.						

* Including small quantities of carbon and sand.

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