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SILOS, ENSILAGE AND SILAGE.

A PRACTICAL TREATISE

ON THE

ENSILAGE OF FODDER CORN.

BY

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PREFACE.

The literature of ensilage consists, in the main, of the experience of individuals under a great variety of conditions, and the inferences or impressions derived from a limited range of observation, as recorded in Agricultural reports and papers.

In experiments relating to the chemistry of ensilage, the factors of dominant interest, so far as the cause of the changes taking place in the fodder are concerned, have been almost entirely neglected, and but little real progress has been made in our knowledge of the economies of the silo.

From a practical standpoint it seems desirable, at the present time, to collate the well known facts in regard to the practice of ensilage and bring them into some consistent relation with definite principles, in harmony with the latest developments of science.

This will not only aid the farmer in deciding upon the best methods of practice, but it will clear the way for needed scientific investigations, by suggesting and defining the lines of research that may be profitably followed to obtain a consistent explanation of the complex changes taking place in the ensilage of fodder.

LANSING, Michigan, June, 1889.

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CHAPTER I.

FIRST PRINCIPLES.

The preservation of green fodder for winter feeding has for many years engaged the attention of practical men as a matter of great economic interest, and the results obtained in the many attempts to solve the problem mark a gradual process of development which must be recognized as a phase of the law of evolution, which is now generally accepted as an essential factor of human progress.

In his "History of the Inductive Sciences," Whewell emphasizes the fact that "in all cases the arts are prior to the related sciences," and that "powers of practical skill"—"prepare the way for theoretical views and scientific discoveries."

The history of the development of the best practice in the preservation of green fodder furnishes a good illustration of the correctness of Whewell's views in regard to the relations of Art and Science, as we find that the progress of practical discovery has always been in advance of the theoretical or scientific explanation of the results obtained, and, moreover, it must even be admitted that the indiscreet application of theories in science, based on imperfect data and hasty generalizations, have a tendency to retard the real progress of practical methods, by directing attention to unimportant details.

For at least half a century green fodder has been successfully preserved in silos, and yet we knew nothing of the causes of fermentation until Pasteur established the true theory of the process by his masterly investigations, from 1857 to 1869, and proved conclusively that living organisms were the active and essential factors of fermentation and putrefaction, and even then the new theory was reluctantly adopted by chemists.

It has been difficult to obtain a general recognition of the fact that the changes taking place in green fodder, when preserved in silos, are essentially, and perhaps almost exclusively, the result of biological processes, and that the observed chemical transformations are but incidents of physiological activities and therefore to a greater or less extent independent of the ordinary laws of combination which obtain in inorganic chemistry.

From what is now known of the phenomena of fermentation it is evident that biological lines of investigation must be followed to place the science of ensilage fully abreast of the best practice.

The terms "silo" and "ensilage" were familiarly used in the French agricultural papers as early as 1870, while the English papers of the same date referred to the French experiments as the "pitting" or "potting" of green fodder. In a communication to the "Country Gentleman" of October 5th, 1876, giving an outline of the discovery and progress of ensilage in France, and of my own experiments in 1875, I made use of the word silo, and suggested the adoption of the word ensilage, in the absence of any English equivalent. Since that time these terms have been in common use in this country, but as the word ensilage is used in a double sense, one of its meanings may be best expressed by the word silage, which has been introduced in England with advantage within the past four or five years.

For the convenience of those not familiar with these terms, the following definitions may be given as representing the present nomenclature of the subject.

Silo: a closed pit, or reservoir, in which either dry grain, or green fodder is preserved.

Silage: the green fodder preserved in a silo.

Ensilage: the process of preserving green fodder in silos.

Any green crops may be preserved in silos; in England, meadow grass, clover, tares, rye, oats, and rye-grass, are the leading crops ensilaged, while in this country, the ensilage of fodder corn has received a larger share of attention.

In studying the history of ensilage it will be necessary to keep in mind the two leading purposes to which silos are adapted. Among the ancients they were only used for storing and preserving dry grain; while in modern practice they are used almost exclusively for preserving green fodder.

CHAPTER II.

HISTORICAL.—SILOS FOR STORING GRAIN.

From the earliest times of which we have any record, silos have been used for the storage of grain, either threshed, or in the ear. According to the best authority, the word silo is derived from the Greek, and introduced to France from Spain.*

Pliny says, "the best plan, however, of preserving grain, is to lay it up in trenches, called 'Siri,' as they do in Cappadocia, Thracia, Spain, and at ——— in Africa. Particular care is taked to dig these trenches in a dry soil, and a layer of chaff is then placed at the bottom; the grain, too, is always stored in the ear. In this case, if no air is allowed to penetrate to the corn, we may rest assured that no noxious insects will ever breed in it. Varro says, that wheat, if thus stored, will keep as long

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*E. Littre, "Dictionnaire de la langue Francaise." La Chatre, "Noveau Dictionnaire Universal." See also Jenkins' "Practice of Ensilage," Jour. Roy. Ag. Soc. 1884, pp. 127-8.

as fifty years, and millet a hundred; and he assures us that beans and other leguminous grain, if put away in oil jars with a covering of ashes, will keep for a great length of time. He makes a statement, also, to the effect that some beans were preserved in a cavern in Ambracia, from the time of King Pyrrhus until the piratical war of Pompeius Magnus, a period of about two hundred and twenty years."*

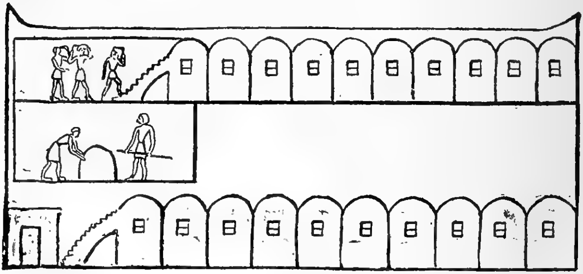

FIG. 1. *Beni Hassan.*

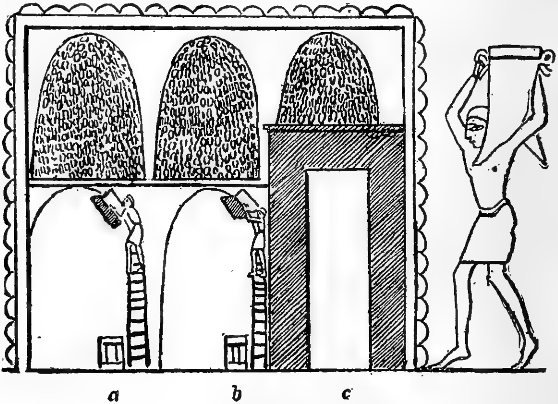

FIG. 2. *Thebes.*

In ancient Egypt, according to Wilkinson, "The granaries were also apart from the house, and were en-

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*Nat. Hist. Vol. IV, p. 106. Bohn's Classical Library. Foure Bookes of Husbandrie, by Conradus Heresbachius, 1586, p. 48.

closed with a separate wall; and some of the rooms in which they housed the grain appear to have had vaulted roofs. These were filled through an aperture near the top, to which the men ascended by steps, and the grain when wanted was taken out from a door at the base." *

These storage rooms were, in fact, silos of masonry above ground, and a marked improvement on the rude trenches mentioned by Pliny.

In an interesting article on Ensilage by Mr. H. W. Jenkins, Secretary of the Royal Agricultural Society of England, it is stated that the practice of storing grain in silos was brought by the Moors into Spain; but the statement of Pliny given above, in connection with other historical data, would lead to the more probable supposition that the Romans introduced the system into Spain, as well as other grain-growing provinces of the Empire, and that if the Moors brought silos into notice for the preservation of grain, it was but a revival of an old Roman practice. †

From the many valuable suggestions in regard to the storing of grain contained in the paper by Mr. Jenkins, we quote as follows: "In France, the system of ensilage was originally imported from Spain, with a view to the preservation of cereals from years of plenty to years of scarcity. It is recorded by Mons. L. Doyère, that the proprietor of the estate of Palerne, in the Puy de Dôme, put his corn, harvested in 1820 and 1821, in silos constructed for the purpose, and kept the grain in them until the end of 1828, when, prices having risen to

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* "The Ancient Egyptians," by Wilkinson, Vol. 1, pp. 31-32, from which Figs. 1 and 2 are copied.

† In a foot-note to Mr. Jenkins' paper (l. c. p. 128), a quotation is given from a French work published in 1804, as follows: "In 1707 there was discovered in the citadel of Metz a large quantity of corn (grain), placed there in 1528, in one of the underground rooms, where it was so well preserved that the bread which was made from it, two centuries after it had been placed there was found very good. There exists now (1804), at Ardres, department of the Pas de Calais, one of these underground places made by the Romans."

double their figure of seven years before, he opened the silos and found the grain practically uninjured. It is true that a small layer at the top, immediately under the straw which separated the grain from the hermetically sealed cover, was a little mouldy, and the silo contained a quantity of carbonic-acid gas when first opened. But the bulk of the grain was perfectly preserved, and the proprietor of the estate was so satisfied with his success that he gave instructions for other silos to be built. Unfortunately, his death shortly afterwards put an end to his projects.

"So far as I can judge, the first Frenchman to call attention to this method of preserving corn was Count de Lasteyrie, who published a work on the subject in 1819. Then a trial of the system was made by M. Ternaux, at Saint Ouen, and the 'Sociète royal et centrale d'Agriculture de France' appointed a commission to report on the experiment. This report, presented in December, 1826, was eminently unfavorable, and for a considerable time prevented any further attempts at the ensilage of corn. M. Doyère explains that the conditions under which the experiment was made were so extremely unfavorable, that failure was a foregone conclusion. He mentions specially a very porous sub-soil close to the Seine, and subject to infiltrations of water from it, no attempt to render the walls of the silo water-tight, and so forth. Therefore one need not wonder that the corn was not well preserved.

"After the publication of M. Doyère's report on the *Alucite* of wheat, he was commissioned by the French government to investigate more closely the question of the preservation of cereals in *silos*, more especially in Spain. His report was presented to the French Academy of Sciences at the end of 1855, and published the following year as a pamphlet. Without stopping to analyze this report, I think it desirable to give the following translation of an article from a French Encyclopedia,* which embodies most of M. Doyère's conclusions".

"*The Preservation of Cereals.* This question interests in the highest degree every civilized country. It is important for the welfare of nations that, when the harvest is superabundant and the corn at a low price, a part of the produce in excess should be preserved, so as to circulate the same when a bad harvest arrives unexpectedly, and the price of corn tends to rise above the ordinary value. But two natural obstacles exist to the preservation of corn. They are (1) the dampness, which causes it to ferment, and (2) the insects which destroy considerable quantities of it.

"In Egypt, where it never rains, and in other countries where rains are rare, the problem is easily solved by the employment of the 'silo.' The 'silo' is simply an excavation, the sides of which are lined with masonry, then relined, as also is the bottom, with a layer of very dry straw. After the pit or silo has been filled, the grain is covered with straw, and the silo is closed by means of an arch in masonry, in which is placed an opening with a movable lid, so that one can take out the grain from it as needed.

"The grain is preserved in the silo, without injury, for an indefinite time. But in France, as in all northern countries, the ensilage of the grain has not succeeded, and this is attributed to the humidity of the soil, which penetrates to the interior of even the best-constructed silos. Then it has been observed that corn, properly ventilated, is less liable to become heated in the granaries, than that left alone. It was believed that the problem had been solved by the airing and ventilation of the grain.

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* Dictionnaire Francaise illustré et ency'l. Universelle, par B. Dupiney de Vorepierre, Paris: Michael-Levy frères, 1867, T. 1, p. 503.

"Moving granaries, and granaries with ventilators, were suggested, but they are all extremely expensive, and they do not safely prevent fermentation. They also present no obstable to the development of insects. The success that has been obtained by using these means appears to be simply due to the dryness of the wheat. But, as Doyère has asserted, dry grain can be preserved for a certain time by any means. But it is not the same with wet grain,—that is to say, grain containing more than 16 per cent. of water, as the greater part of French corn does. 'I found,' says Doyère, 'that corn containing 21 per cent. of water, furnishes, at 68° Fahr. (20° centigrade), 120 milligrammes of carbonic acid per day and per kilogramme (about 2 1-2 lbs. English), in a state of rest; and about 17 milligrammes per hour under the influence of a constant current of air, which latter amount would make 408 milligrammes per day. Ventilation, therefore, trebles the amount of decomposition, of which carbonic acid is one of the products.

"The last of these losses is enormous, for it represents not less than 2 1-2 per cent. of dry matter destroyed each month, owing to alcoholic fermentation. It is probable that it would not be continued indefinitely to the same extent as it happens for several hours; but it is renewed with the same energy during the whole time of an intermittent ventilation. Otherwise, the loss of 120 milligrammes of carbonic acid per day, which hardly requires any renewal of air, suffices to repel the hope of a preservation of long duration, for it represents a destruction of dry matter amounting to 7 per 1000 per month.

" 'This is not only the loss in weight, for the loss in quality which results from the formation of sour and rank products is incomparably more to be feared. Finally, as the loss takes place in a temperature relatively low, that of 68° Fahr., it would not only increase with the temperature, but even much more rapidly. Therefore when the grain is wet, the airing produces an effect very much opposed to that which is commonly looked for.' The results of the experiences of Doyère show that, in the grain containing less than 16 per cent. of water, there is only produced an alcoholic fermentation, excessively weak, without developing odor or taste, and only to be perceived by the most delicate processes of chemistry.

"In other cases even this fermentation is stopped in closed vessels. After the oxygen of the air, which is its primitive cause, has completely disappeared, no other acid but carbonic acid is formed ; the starch and gluten undergo no change. Towards 16 per cent. of humidity, or a little beyond it, the alteration in the grain begins to show itself, in the course of time, in the closed vessels. Its relative activity in corn of various degrees of humidity, increases with the proportion of water, but much more rapidly than the humidity itself. It is due to fermentation, called by the chemists lactic, butyric, and gaseous. Consequently, whatever may be the means employed, it is impossible to preserve grain wet, as it generally is in France. The excessive humidity of corn in our country ought not, however, to be attributed only to the climate, and climatic influences, in which the grain has been harvested. Agricultural customs have much to do with it. In the greater part of France the wheat is cut half green, and is hastily put into the granary, or made into ricks, where it immediately begins to ferment. If, as we think, the observations of Doyère are correct, it is evident that the corn intended to be preserved must be dried, in the first instance, if it contains 16 per cent. of humidity, or more. As to the place where it is best to keep it, the silo appears to us infinitely preferable to the granary, for the latter is open to the outer air, and exposed to all variations of temperature.

"Now, air introduces a means of fermentation of the grain, as well as a means of life for insects, while variations of temperature favor the chemical phenomena of which the grain becomes the seat.

"The underground silo in masonry offers this great advantage over the granary: that of preserving a low and constant temperature; but it is not completely inaccessible to the air, and it is impossible to render it impervious to humidity. As a set-off to these two last inconveniences, Doyère proposed employing metals. His system of construction consisted of some very thin sheets of iron, preserved exteriorly from oxydation by an impermeable covering, and enveloped in concrete, which sustains the whole weight. The sheet of iron, he says, only plays the part of an impervious and indestructible varnish. It offers, besides, the advantage of supplying holes which can be shut up hermetically. Finally, a silo of 500 hectolitres (1376 bu.), constructed according to this system, at Paris, with a sheet of iron of a mean thickness of 3 millimetres, and made at a cost of 2 l. the cwt. (1 fr. per kilo), has only cost, including the asphalte covering, 2250 francs (90 l.), or 4 fr. 50c. per hectolitre (1 s. 4 d. per bushel). Therefore it is seen that, instead of being led into error by ruinous experiments on the faith of theories, either preconceived, or else deduced from facts wrongly interpreted, it is simply a question of appropriating for our climate the means consecrated by the experience of centuries in all warm countries." *

Notwithstanding the defective theoretical views, which were in accord with the science of the time, these records of investigations, made more than thirty years ago, are of interest as showing the value of exact experimental methods in their relations to practice. As an outcome of these studies of the essential conditions for

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* **Jour. Roy. Agr'l. Soc. 1884 pp. 129-132.**

the preservation of grain, silos are used on an extensive scale, for the storage of grain, by the Paris Omnibus Company, "some silos being below ground and some above." *

In the evolution of the silo, for storing grain, from the rude trenches mentioned by Pliny, to the permanent structures of masonry of the Egyptians, and the more perfect construction required in the comparatively humid climate of France, there was undoubtedly a great variety of forms developed by experience to adapt the details of practice to the conditions of each locality; and it is probable that the system had a wider geographical range than our imperfect history of agricultural practice seems to indicate. At the time of the discovery of America by Columbus, Indian corn was stored in pits by the natives, and the tribes beyond the Mississippi still continue the practice.

It is, perhaps, reasonable to assume that it was a common method of storing grain, among savage and migratory tribes, to conceal it from their enemies and to provide against seasons of scarcity.

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* Jenkins, l. c. p. 129, who refers to a "Report by M Muntz, 'Etudes sur la conservation des grains,' published in the 'Annals de l'Institut National Agronomique' No. 4 of 1878–79, published in 1881."

CHAPTER III.

HISTORICAL.—SILOS FOR PRESERVING GREEN FODDER.

The preservation of green fodder in closed chambers or pits was practiced in Europe previous to the beginning of the present century, but the early history of the process is involved in obscurity.

In his "Observations made in Italy on the use of leaves in feeding cattle," published in 1786, Prof. John Symonds, of the University of Cambridge, says: "Among the various kinds of winter food provided for cattle in Italy, the use of leaves is not the least considerable. * * * *To preserve the freshness and verdure of the leaves* requires a great deal of attention. To effect this they gather them about the end of September, or the beginning of October, at the time of day when the heats are most piercing; and spread them very thin upon a pavement abroad, where they suffer them to lie three or four hours; after which they put them into wooden casks, and press them down as closely as possible, and cover them entirely with sand. The very moment after they have taken out the quantity which is wanted, they stop up the casks, lest the leaves should be exposed to the air; by which method they are enabled to keep them both fresh and tender during the whole winter. It is customary for the peasants in some parts of Italy to *bury them in a pit,* and to cover them with straw, upon which they lay either clay or sand; and both are equally calculated to answer the purpose." *

Green fodder was preserved in silos quite a number of years ago in Germany and Hungary, in the form of "sour," or "brown" hay, but we have no record of the

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* **Young's Annals of Agriculture (1786), Vol. 1, pp. 207-9.**

origin of the process, or of the conditions which led to its development. Although frequently mentioned by writers on continental agriculture, the first detailed description of the process, by an English author, so far as I can learn, was given by Prof. J. F. W. Johnston, in a paper "On the Feeding Qualities of the Natural and Artificial Grasses in different states of dryness," published in the "Transactions of the Highland and Agricultural Society of Scotland," for 1843–45.*

As Prof. Johnston's paper contains matter of general interest, that is not accessible to many of our readers, we make the following extended quotation. The first paragraph, as will be seen, may well be applied to our present knowledge of the economy of green feed.

"Much knowledge remains yet to be acquired in reference to the most economical mode of using green crops as food for cattle. It is true that there exists much valuable information *floating* among intelligent practical men, but when the unprejudiced inquirer begins to collect, with the view of *fixing* this floating knowledge, he meets with opinions so contradictory, even from men of equal intelligence and skill, that he must be well acquainted with those causes which affect the results of agricultural operations in different localities, before he can hope to approach the truth, or to extract anything like general principles from the testimony of practical men alone.

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* From a foot note to Prof. Johnston's paper it appears that the original source of information, in part, at least, was "*Verhandlung des Baltischen Vereins fur Forderung des* Landwirthschaft. Greifswald, 1842, p. 38." An abstract of Prof. Johnston's description of the sour hay process was published in Stephens' "Book of the farm," 1844, Vol. 3, p. 978. In H. R. Stevens' book on "Ensilage," 1881, p. 20, Prof. J. M. M'Bryde, in a notice of the sour hay of Germany says, "This process is fully described by *Grieswald* (1842); and a translation of the passage is given in *Stevens'* (sic.) large work, 'The Farmer's Guide,' which appeared in 1851," and "the extract in full" then follows. The extract here given is a reprint of the abstract of Prof. Johnston's article as printed in Stephens' Book of the Farm, above noticed, and Greifswald is a small town near the Baltic, in the province of Pomcrania, where the "Transactions of the Baltic Society for the promotion of Agriculture," the original authority, were published.

"The opinions of practical agriculturists are derived in general from their own experience, and from that of their neighbors, in a limited district only. In distant parts of the country, we know that these opinions are often quite opposed to each other; yet the phenomena from which the cultivators of each province have deduced their opposite opinions, are the natural results of the same general laws. It is these laws which the philosophical agriculturist seeks to discover.

"The above observations apply, among other topics, to the opinions held in different localities in regard to the relative feeding properties of the natural and artificial grasses in their green and dry states,—their relative value when made into hay after one or another method, and when used at one or another season of the year. * * * But it is also said,—and I believe, as a general principle, is also conceded,—that the same weight of the same grass will go further in the green state than when it is made into hay.

"But there appears to be a great, and so far as I am capable of judging, a well-founded difference in regard to the amount of nourishment lost by the act of drying. By some it is stated to amount to one-half; a ton of green rye-grass or clover going as far as two tons when made into hay. This proportion cannot be general; but since differences so great may exist, according to the evidence of practical men, it becomes a matter of interest to inquire how this difference arises, and if by any means it can be avoided or diminished." * * *

"When the soft young shoots of the dog-rose, the bramble, or the hawthorn, or the stem of the young cabbage, are cut off and peeled, they are found to be soft and eatable, and, like the heart of the young turnip, are readily digestible; but let a month or two elapse, and these shoots become woody and unfit for mastication, and, when taken into the stomach, pass through the intestines of most animals in a great measure unchanged. Thus, animals which thrive on the young shoots of early spring, can with difficulty sustain themselves on the more matured branches of the advancing summer. The reason of this difference is, that the starch and gum, and similar soluble and digestible substances of which the young shoot consists, are gradually changed into the insoluble and, in general, almost indigestible woody fibre of which the stem and branches of the mature plant are in great part composed.

"When green grass or clover, approaching to maturity, is first cut down, it contains a considerable proportion of starch, sugar, and gum, still unchanged into woody fibre, as it would mostly be were the plant allowed to become *fully* ripe. But when left to dry in the open air, the circulation proceeds to a certain extent, and, under the influence of light, woody fibre continues to be formed in the upper part of each stem, until it becomes completely dry. It may even be a matter of doubt whether this process of change does not often proceed after the hay has been carried off the field and stacked.

"The effect of this change will obviously be to render the dry hay less digestible, on the whole, and, consequently, less valuable as food, than the green grass from which it was prepared.

"Again, we know that by drying, many very digestible and nourishing substances become less soluble, and consequently, more difficult of digestion. The stomach of a growing animal cannot afford the time necessary to the complete digestion of such dry substances, and hence a larger portion of the really nutritive matter of their food is rejected in the droppings of animals which are fed upon them. How much of dry corn escapes, half digested, from the stomach of the horse,—how much, probably, of the animal matter of the bones it eats, from the stomach of the dog,—which either of these animals would have been able fully to digest, and to work up for its own sustenance, had the food been presented to it in a less hard and solid state! So it must be, to a certain extent, with dried hay. What was easily soluble and digestible in the green, has, without undergoing any chemical change, become less soluble and more tardily digestible in the dry, and hence a second reason why the hay should afford less nourishment than the grass from which it is made.

"The knowledge of these two causes of deterioration suggests the kind of inquiries which the practical farmer ought to make, and the kind of practice he ought to adopt, in order to retain as much as possible of the feeding property of his grass and clover crops, and thus to turn to the greatest advantage the annual produce of his land. Thus he may ask—Is it possible to preserve these crops in their moist state? Can I cut them down and so preserve them undried, as to obtain from them, for my cattle, an amount of food more nearly equal to that which the fresh cut grass is capable of affording? A method has lately been tried in Germany, which, by the aid of a little salt, seems in a great measure to attain this object.

"Pits are dug in the earth, from ten to twelve feet square and as many deep; these are lined with wood, and puddled below and at the sides with clay. They may obviously be made of any other suitable dimensions, and may be lined with brick.

"Into this pit the green crop of grass, clover, or vetches, is put just as it is cut. Four or five cwts. are introduced at a time, sprinkled with salt, at the rate of one pound to each cwt., and, if the weather, and consequently the crop, be dry, two or three quarts of water to each cwt. should be sprinkled over every successive layer. It is only when rain or a heavy dew has fallen before mowing that, in East Prussia, this watering is considered unnecessary.

"Much, however, must depend on the succulency of the crop. Each layer of four or five cwts. is spread evenly over the bottom, is well trodden down by five or six men, and, especially, is rammed as close as possible at the sides with the aid of wooden rammers.

"Each layer is thus salted, watered if necessary, and trodden in succession till the pit is perfectly full. Much depends upon the perfect treading of the grass for the exclusion of the air, and, therefore, for a pit of ten feet square, four cwts. are as much as ought to be put in for each layer. Between each layer may be strewed a few handfuls of straw, in order that, when emptying the pit afterwards for the daily consumption of the stock, the quantity taken out may be known without the necessity of a second weighing.

"When the pit is full, the topmost layer is well salted, the whole then covered with boards, or a *well-fitting lid,* and upon these a foot and a half of earth, for the more perfect exclusion of the air. A pit ten feet square and as many deep will hold about five tons of fresh grass, and each pit should, if possible, be filled in not less than two days.

"When covered up the grass speedily heats and ferments, and after the lapse of about six days, when the fermentation has ceased, the whole has sunk to about one-half of its original bulk.

"The lid must be examined during the fermentation, at least once a day, and the earth, as it sinks, carefully replaced wherever crevices appear; for, if the air be allowed to gain admission, a putrefactive fermentation will come on, which will impart a disagreeable odor to the fodder, though it will not prevent it from being eaten by the stock. When the first fermentation has ceased, the lid may be removed, the pit again filled with fresh grass, trodden in, salted, and covered as before.

A pit ten feet square, when perfectly full of this fermented grass, will contain nearly ten tons—equal to two or three tons of dry hay.

"The grass, when thus fermented, *has the appearance of having been boiled,* has a sharp acid taste, and is greedily eaten by the cattle. The pits should be kept covered for, at least, six weeks, after which they may be opened successively as they are required, and may be kept open till their contents are consumed by the cattle without suffering any injury from the contact of the atmospheric air. Of the feeding qualities of this salted fodder, one experimenter says that, by giving only twenty pounds a day of it along with chopped straw, he kept his cows in condition during the whole winter. His green crop was vetches, and the twenty pounds of salted fodder were equal to, or would have made, less than four pounds of vetch hay.

"Another experimenter says that, on a daily allowance of twenty-eight pounds of his salted fodder, his cows gave a rich and well-tasted milk.

"This method of salting and preserving green crops in their moist state appears to afford an answer to the first question which is naturally asked when we are told of the difference in feeding value between the same grass when first cut and when dried into hay. It is probable that the fermentation which takes place in the pit may in some degree diminish the nutritive value of the grass, but the likelihood which exists that a very large proportion of this value will be retained renders the method of salting in this manner well worthy the attention of our more skillful agriculturists. It would greatly benefit both theory and practice also, were careful series of experiments to be made in different localities, with the view of determining the true relative value in feeding stock of the grass of the same field when newly cut, and when salted and preserved in the manner above described." *

In connection with this paper by Prof. Johnston, and from its relations to the general system of ensilage and the economy of cattle foods, the experience of Mr. Samuel Jonas, of Saffron Walden, England, in the preservation and feeding of fermented straw chaff, reported to the Secretary of the Royal Agricultural Society in 1869, and published in 1870,† is of particular interest. He says, "Myself and sons have carried out this system of storing old chaff to such an extent that we are using on our occupation (which consists of 4,200 acres of arable land), seven barns which were previously used for storing corn."

He uses a 12-horse power engine, which threshes, cleans and sacks the grain, ready for market, and cuts the straw into chaff. The chaff is carefully packed in the barns, and mixed with tares, or rye, cut green and chaffed, in the proportions of about one cwt. of green chaff to one ton of straw chaff, and one bu. of salt. This is done in the spring or summer, and the chaff is not used until October and the winter months. In conclusion, Mr. Jonas says, "I am not stating that straw chaff can be rendered as valuable as hay chaff for feeding purposes, but that it may, by judicious management, be made a very important auxiliary to the production of meat food for our fast increasing population. I agree with Prof. Voelcker, that the straw used for chaff should be wheat and oat, for these may be cut without loss in a far greener state than is generally done."

Dr. Augustus Voelcker made an analysis of this fermented straw chaff, and compares the same with "a

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* Transactions of the Highland and Agricultural Society of Scotland, July, 1843,—March, 1845, pp. 57-61.

† Jour. Roy. Agr'l Society, 1870, p. 119.

sample of well-harvested wheat straw which was neither under nor over ripe,"* with the following results :

	FERMENTED STRAW CHAFF.	WHEAT STRAW.
Moisture,	7.76	13.33
Oil and fatty matter,	1.60	1.74
†Albuminous compounds,	4.19	2.93
Sugar, gum, and other organic compounds soluble in water,	10.16	4.26
Digestible fibre,	35.74	19.40
Woody fibre (cellulose),	34.54	54.13
Mineral matter (ash),	6.01	4.21
	100.00	100.00
†Containing nitrogen,	.67	.47

In his remarks on these analyses Dr. Voelcker says, "The addition of the green stuff causes the straw-chaff mixture to heat; the volatile and odoriferous principles produced by the fermentation are retained by the straw-chaff, itself undergoing a kind of slow cooking process, and they impregnate the whole mass with an extremely pleasant flavour, scarcely inferior to that which characterizes well made hay." * * * The fermentation to which the straw is submitted in Mr. Jonas' plan thus has the effect of rendering the hard and dry substance which constitutes the bulk of the straw more soluble and digestible than it is in its natural condition. But useful as is the effect of the slow and moist heat, developed in the mixture of straw-chaff with green rye or cut tares, no doubt is in rendering the fibre of the chaff more digestible, this is not the only recommendation of Mr. Jonas' admirable plan of preparing a really very nutritive and important food for stock.

"Another recommendation is the extremely delicate flavour and the palatable condition which is conferred upon the straw in the process of fermentation.

"The prepared straw-chaff, kindly sent by Mr. Jonas, had all the agreeable smell which characterizes good green meadow-hay, and a hot infusion with hot water produced

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* Jour. Roy. Agr'l Society, 1871, p. 85.

a liquid which could hardly be distinguished from hay-tea. * * * By Mr. Jonas' plan straw-chaff is not merely made more palatable, but, as it is mixed with a little green food, it undergoes a slow cooking process, and becomes more digestible, and permeated by a delicate hay-flavour.

"Thus the most is made both of the green stuff and of the straw, and an excellent food is produced at a trifling expense, greatly superior in feeding properties to treacled ordinary straw-chaff, which costs more money. The great simplicity of preparing and storing straw-chaff, and the inexpensiveness of Mr. Jonas' plan, are further advantages, which all who consume much straw for feeding purposes may secure to themselves.

"The more one looks into this subject, the more one becomes impressed with the great practical value of Mr. Jonas' plan of preparing a most useful and nutritious auxiliary food; and it is much to be desired that this extremely simple, inexpensive, and in all respects excellent plan of dealing with straw for feeding purposes may be spread throughout the length and breadth of the country."

In this review of the rise and progress of the use of fermented fodder, attention should here be called to the system of feeding pulped roots with hay or straw-chaff, which was extensively practiced in Great Britain from about the year 1855, as it practically provided, for winter feeding, a supply of succulent food which had many of the advantages obtained in the modern system of ensilage, and probably suggested to Mr. Jonas the method of preserving and utilizing straw-chaff by the addition of green clover and rye, which furnished the conditions required for the melioration of the food by the process of fermentation.

At the suggestion of Mr. Charles Lawrence, the Royal Agricultural Society of England offered a prize of three sovereigns "for the best machine to reduce roots to a pulp," which brought out but a single machine for the purpose at the Lincoln meeting in 1854. At the Chester meeting in 1858, "In the class of machines for pulping or grating roots, there were no less than twenty-three exhibitors, indicating that this description of machine is not only highly approved, but is steadily increasing in public favor."*

In 1859 a manufacturer of pulping machines published a pamphlet giving the experience of over 400 farmers in feeding pulped roots, in England, Scotland, and Ireland. In most of these reports the new method of feeding is praised in enthusiastic terms, and they resemble in their claims the modern testimonials in regard to ensilage, particularly as to the larger number of cattle that can be kept under this system of feeding.

As the root crop held an important place in British farm practice, the pulping process was at first adopted with the sole purpose of securing a better economy in the feeding of roots, but it was soon observed that this was one of the least advantages of the system, as the chaffed hay and straw, or other coarse fodder, were improved in feeding value, by the fermentation that took place when mixed with pulped roots. In a supplement to an article "On Pulping roots for Cattle food,"† the editor of the Journal says, "Statements of experience have been received from many who have adopted the practice of pulping roots, and they almost universally assert its economy and advantage."

From the number of published testimonials we copy one, as representing a moderate view of the economy claimed for the system, by the well-known writer, and breeder of Hereford cattle, Mr. T. Duckham, *Baysham Court, Herefordshire,* who says: "The advantages of

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* Jour. Roy. Agr'l Soc. 1858, p. 339.

† Jour. Roy. Agr'l Soc., 1859, p. 458.

pulping roots for cattle are—1st, economy of food; for the roots being pulped and mixed with the chaff either from threshing or cut hay or straw, the whole is consumed without waste, the animals not being able to separate the chaff from the pulped roots, as is the case when the roots are merely sliced by the common cutter; neither do they waste the fodder as when given without being cut.

"2nd. The use of ordinary hay or straw, after being mixed with the pulp for about twelve hours, fermentation commences; and this soon renders the most mouldy hay palatable, and animals eat with avidity that which they would otherwise reject.

"This fermentation softens the straw, makes it more palatable, and puts it in a state to assimilate more readily with the other food; in this respect I think the pulper of great value, particularly upon corn farms where large crops of straw are grown, and where there is a limited acreage of pasture, as by its use the pastures may be grazed, the expensive process of hay making reduced, and consequently an increased number of cattle kept. I keep one-third more, giving the young stock a small quantity of oil-cake, which I mix with the chaff, etc.

"3d. Choking is utterly impossible, and I have only had one case of hove in three years, and that occurred when the mixture had not been fermented.

"4th. There is an advantage in mixing the meal with the chaff and pulped roots for fatting animals, as thereby they cannot separate it, and the moisture from the fermentation softens the meal and insures its thorough digestion; whereas, when given in a dry state without any mixture, frequently a great portion passes away in the manure."*

The usual practice was to put a layer of chaffed hay or

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* Jour. Roy. Agr'l Soc., 1859, p. 463.

straw, or other coarse fodder, about eight to ten inches thick, on the floor of a room of convenient size (10 by 12 to 16 ft.), and cover this with a layer of pulped roots, then another layer of chaff, followed again by the pulped roots, and so on, with alternate layers until the mass was four or five feet deep. Each layer of chaff was carefully packed, so that the corners were well filled, and the thickness of the layer of roots was regulated by the supply at command for the season.

The whole was allowed to remain from twenty-four to forty-eight hours before feeding, when the mass was found to be thoroughly heated, and the chaff softened from the moisture, and mild cooking process. *

In tracing the history of ensilage, it appears that in Germany, previous to 1842, the preservation of green fodder in underground silos had been developed into a system, which, in its methods and results, compares favorably with the average practice of the present time.

The silos were lined with wood, or other materials, and the thorough packing of the fodder, the close-fitting cover of boards, and the final weighting of the mass with eighteen inches of earth, were looked upon as the best conditions for securing the desired result.

It cannot with reason be assumed that this well developed system sprung into existence at once, with its many well-planned, practical details, and we cannot avoid the conclusion that it was preceded by ruder methods and successive steps of improvement, extending over a number of years.

In England we also find that fermented fodder had

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* In July, 1868, I imported a root pulper from England for the Michigan Agricultural College, and the system of feeding pulped turnips (Swedes), with chaffed straw, cornstalks, and hay, was practiced with the most satisfactory results. As our crop of turnips averaged twenty-five acres each year, our experience was on a sufficient scale to fully demonstrate the great economy of the system when roots are grown to any extent for feeding cattle. The pulping system has been quite extensively practiced by a number of Canadian farmers of my acquaintance, and they were all well pleased with it.

been used on an extensive scale, in the form of a mixture of green food and chaffed hay or straw as early as 1855, and that for several years previous to 1869 it had been successfully preserved for winter feeding under essentially the same conditions that are now prescribed in the practice of ensilage.

We have, then, conclusive evidence that green fodder had been successfully used for winter feeding, and the practical principles involved in the process of preserving it in silos had been demonstrated long before the system was introduced into France (1870), where it received a new nomenclature, and was brought to the attention of farmers of other countries.

In France the ensilage of fodder passed rapidly through a series of experimental stages, which, although fully recorded in the French agricultural papers of the day, have been almost entirely ignored by American writers who attempted to give an account of the origin and history of the process.

"In 1867, Count Roederer, a well-known agriculturist and breeder of thorough-bred horses, living at Bois-Roussel, in the Department of the Orne, began to preserve green maize in silos for winter use by chopping it and mixing it with cut straw and oat cavings,"* which in effect was the method practiced by Mr. Jonas, in England, at the same time, to which we have called attention, the green maize in France taking the place of green rye and tares in England, as a complementary adjunct of the straw-chaff.

The credit of priority in the ensilage of maize, which gave rise to the present system of practice, must undoubtedly be awarded to Herr Adolph Reihlen, a sugar manufacturer and refiner, of Stuttgardt, who demonstrated the economy of the process by the ensilage of beet leaves, beet

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* This practice was described in a letter of June 18th, 1870, published in the "Journal d'agriculture progressive" the following week. See Jour. Roy. Agr'l Soc., 1884, p. 136.

root pulp, and maize, on an extensive scale. The beet leaves from a crop of 400 acres were preserved in a dozen silos, and the beet root pulp from his large sugar factory had been stored for winter feeding, in the same way. He had lived for a number of years in the United States, and on his return to Germany began the cultivation of the large dent corn (mais dent de cheval). As this "giant maize" did not always ripen in the climate of Stuttgardt, he became interested in utilizing it as a forage crop when the season was too short for the grain to mature.

The first account of his experience was in a letter published in a German paper in 1862, and he gave further details in another letter to the same paper, dated September 23d, 1865. These letters were translated and published in the Journal d'agriculture Pratique in 1870, forming part of a series of articles on the ensilage of green fodder, by M. Vilmorin-Andrieux, who called the attention of the farmers of France to the advantages of this method of preserving fodder, in connection with the growing of forage crops, as a remedy for the effects of the prevailing severe drought of that year. *

From these papers it appears that M. Reihlen was familiar with the sour hay process of Germany, and that his success in the ensilage of beet leaves, and beet root pulp, for a number of years, led him to try the same method with maize, in various stages of ripeness, with stalks and ears together, and separately, and also mixed with beet root pulp.

The results obtained in these different methods were satisfactory, but he was so well pleased with the ensilage of maize, by itself, that he increased the area of corn

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* It is a matter of interest, in the history of ensilage, that the severe drought of 1870 had much to do with the rapid progress of the system in France from that time to the present, while in England the introduction and diffusion of the practice was owing to "a succession of wet seasons, which had rendered hay making almost impossible in some localities." Jenkins, in Jour. Roy. Agr'l Soc., 1884, p. 136.

grown, and in 1870, we are informed by M. Vilmorin-Andrieux, his silos of maize forage (10 feet deep, and 15 feet wide at the top, and slightly narrower at the bottom), which he filled every year, had an aggregate length of over 3200 feet, and they all turned out remarkably well.

Having in view the value of the grain, M. Reihlen's practice was to allow the corn to stand until the ears matured, when they were harvested and stored, and the stalks were cut up and placed in the silo. If, however, the season was unfavorable, the corn was cut up before it matured, and the green ears went with the stalks into the silo. In defense of this practice, M. Reihlen remarks, that, after fermentation in the silo, he found that the stalks that were allowed to mature their ears were excellent feed, that were relished by cattle, and he considers them but little inferior to the green stalks, with their attached ears, treated in the same manner.

In a communication to the Country Gentleman in 1876, * I gave the following account of his first experiment in the ensilage of maize: "Some twenty years ago M. Adolf Reihlen, the owner of a sugar factory near Stuttgardt, Germany, had a quantity of Indian corn injured by an early frost, so that he was unable to use it, as intended, for soiling purposes. Wishing to preserve it, as nearly as possible in the green state, he dug trenches, in which the stalks were placed and covered with a layer of soil, in the same manner that potatoes and other root crops are buried for winter in this country. On opening the trenches, after several months, the corn stalks were found to be well preserved, having passed through the first stage of fermentation without any marked change in color, and with a peculiar, though not disagreeable odor.

"As this *preserved* fodder was readily eaten by his cat-

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* Co. Gent., 1876, p. 627.

tle, M. Reihlen was so well pleased with his experiment that he has continued the same system to the present time." In the same article, as examples of the best practice in France, and illustrating the change from earth pits to silos of masonry, I likewise gave the experience of two farmers, as follows: "M. Crevat says, encouraged by the success of M. Moreul,* I prepared, in 1872, three pits in a good soil, with a gravel subsoil, of the following dimensions, in round numbers: Length at top, 26 feet; at bottom, 22 feet; width at top, 10 feet; at bottom, 6 1-2 feet; depth, 6 1-2 feet. September 12th, 13th and 14th filled the pits successively with corn fodder (*geant mais*), 6 1-2 to 10 feet high. The corn was harvested and left in bundles two or three days in a hot sun.

"The stalks were packed in the pits lengthwise, with care, in layers 6 to 8 inches in thickness, with salt at the rate of 73 pounds to each pit. On account of the scarcity of workmen two days were required to fill each pit. In the afternoon filled to the level of the soil, and next morning heaped above to the height of 6 or 7 feet, covering with soil in the afternoon following, to the depth of about 2 feet.

"The first week the settling of the heaps was great (at least 6 feet), when they were again covered with earth to protect them from the rain, and then left without other protection. April 15, 1873, a pit was opened. The corn was perfectly preserved, of a yellowish color, and of a peculiar but not disagreeable odor.

"A thickness of 1 to 2 inches of the outside was black and rotted. In 3 or 4 days 24 head of cattle became accustomed to the feed, and ate it readily; so that at the end of 8 days they had consumed at the rate of 880 pounds per day.

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* We should not fail to notice M. Moreul, of Grignonniere, as the pioneer of the new system in France, as he made his first silo in 1870, and continued the practice with success, as shown in reports to the Journal d'Agriculture Pratique.

"The second *silo* (pit) was fed after the first, lasting until July 31st, when green corn was substituted. The third *silo* (pit) was not opened until April 20, 1874, when the interior was perfectly good, but a greater thickness of the outside was spoiled."

"After this experience M. Crevat made pits of masonry of the following dimensions: Length, 26 feet at top, 24 feet at bottom; width, 8 1-2 feet at top, 6 1-2 feet at bottom; depth, 7 1-2 feet,—thus diminishing the width and increasing the depth, to save labor in the covering and uncovering of earth, and securing more completely the exclusion of the atmosphere.

"M. Crevat thinks it is not necessary to fill the pits in a single day, and prefers to dry the fodder from two to three days before putting in the pit. He does not believe that it pays to cut the stalks, and thinks the mixing with straw, as practiced by many persons, is unnecessary. He feeds green stalks from the field from July 20 to Oct. 20, and the stalks secured in the stooks from Oct. 20, to Jan. 20, following with the fermented fodder to July 20, when green stalks are again used."

"M. Houette has raised Indian corn for fodder for 10 years, and has practiced the system of ensilage for 4 years. On account of a wet soil, the earth *silos* were abandoned and *silos* of masonry were made, consisting of three parallel walls with ends, forming 2 *silos* 16 feet wide, 9 feet high, and 138 feet long; prefers to cut the stalks before putting in the *silo;* uses salt at the rate of 4 kilogrammes of rock salt to 1,000 kilos. of cut stalks, which is equal to about 8 3-4 lbs. of salt to 2,200 lbs. of stalks. He estimates the cost of harvesting, handling, cutting and placing in *silo*, and covering with earth, at 2 francs per 1,000 kilogrammes (2,200 lbs.), besides coal burned in engine. He says the maize thus preserved is fed until the end of May, without any alteration from fermentation beyond that taking place during the two or three days after being put in pit, and he has kept it even to the end of July without any change. The maize should be as nearly as possible to maturity before it is cut for ensilage. When fermented, the animals eat it as readily as when green."

Many similar statements of success in the ensilage of maize may be found in the agricultural papers of France previous to 1876, but these are sufficient to show that the system of M. Reihlen, as described by M. Vilmorin-Andrieux in 1870, was at once received with favor by the French farmers, and practically adopted on an extensive scale.

In 1877, M. Auguste Goffart, a gentleman farmer of France, published his book on Ensilage, which was translated and published in New York in the winter of 1878–9. As this translation had a wide circulation, some 2,000 copies having been sold and given away, it has generally been accepted as the standard authority on the subject, and it has been repeatedly claimed that M. Goffart was the inventor of the system which he so enthusiastically advocates. There is, however, nothing new in M. Goffart's methods, as the ensilage of maize had been extensively practiced in France and Germany for several years before the publication of his book, and a number of farmers in France were practically familiar with ensilage, at least two or three years previous to his first successful experiment.* The honors conferred on

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*In a note to his article already referred to Mr. Jenkins says: "Most English writers on ensilage during the last two years, have followed several American authors in saying that M. Goffart made his first experiment on ensilage with Indian corn, in 1852. This is a mistake. What M. Goffart says is, that in 1852 he began to study, practically, the important problem of the preservation of forage ('*C'est à problème de la conservation des* fourrages'). He also states (p. 185, 4th edition), that until 1873 he had scarcely believed in the possibility of preserving green maize, but in that year he was very successful, chiefly by accident, and he gives (p. 186) the following statement of what he heard his foreman say to the workpeople: '*M. Goffart nous fait faire là une sotte besogne; il ferait bien mieux de jeter, tout de suite. sou mai's sur la fumier, il fandra tonjours qu' il finisse par là.*'" Jour. Roy. Agr'l Soc., 1884, p. 135. "This work that we are doing is all foolishness; M. Goffart had better throw his maize into the dung-heap at once, because that is where it will go at last." *Brown's Translation of Goffart, p.* 42.

M. Goffart by agricultural societies in France, and by the government, were in recognition of his services in popularizing and extending the practice of ensilage, and not, as has been claimed, for the discovery that green maize could be practically preserved in silos.

From the prominence given by M. Goffart to his expensive silos of masonry, and the heavy weighting of the silage, these were claimed by his followers as the distinctive features of his system, and they came to be quite generally looked upon as the essential conditions of success in the practice of ensilage. As silos of wood have many advantages over the more expensive structures of masonry, and the weighting of the silage has been found unnecessary, the question may fairly be raised whether the methods of M. Goffart have led to any real improvements in the practice of ensilage, aside from the wider advertising of this method of preserving green fodder, that may be attributed to the extended circulation of his book.

The many favorable reports in regard to the ensilage of maize by the farmers of France, led me, in 1875, to make experiments in the ensilage of corn fodder, in two silos 12 feet long, and 6 feet wide, and with two similar silos of broom-corn seed, with the most satisfactory results.*

Mr. Francis Morris, of Maryland, made a silo in 1876, and the results of his experience were published in 1877. A number of silos were built in the United States within the next three or four years, nearly all of which were widely advertised in the agricultural press. After this time the practice was rapidly extended, and silos are now found in almost every state and territory.

In July, 1882, the Department of Agriculture at Washington published a report on ensilage, which contained statements of the experience of 91 persons dis-

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* Co. Gent. Oct. 5, 1876, pp. 627-8.

tributed as follows: Maine 4, New Hampshire 2, Vermont 11, Massachusetts 28, Rhode Island 1, Connecticut 5, New York 21, New Jersey 5, Maryland 2, Virginia 2, Kentucky 1, Tennessee 1, North Carolina 1, Wisconsin 3, Iowa 1, Nebraska 1, Canada 2,—but even at that time there were undoubtedly many silos in the country that were not included in this enumeration. The capacity of the silos reported vary from about 8 to 500 tons each.

Unfortunately, some of the first champions of the new system of ensilage made such extravagant claims, for advertising purposes, in regard to its advantages, ignoring the established principles of farm economy, and urging the ensilage of green fodder as the only thing needed to establish a golden age of agriculture, that practical farmers were not disposed to adopt it, as they could not readily perceive the substratum of truth underlying the many assertions that were obviously fallacious. As the real facts came to be better known the ensilage of fodder-corn was rapidly extended, and there are now few localities in which the silo is not a familiar appendage of the farm that must soon find its proper place in a consistent system of farm management.

As an adjunct or supplement to the ordinary methods of practice, the ensilage of green fodder for winter feeding, or to augment the scanty supply of feed during a prevailing drought, will undoubtedly be fully appreciated by intelligent farmers who wish to take advantage of every available resource of production, but it cannot be safely recommended as the only element required to insure success in the complex business of farming.

CHAPTER IV.

FERMENTATION.

In the ensilage of green fodder, as in the allied systems of preparing cattle feed, to which we have called attention, various kinds of fermentation take place, to a greater or less extent, which have an influence on the quality and feeding value of the silage, and from a practical stand-point it becomes a matter of the first importance that the causes and conditions involved in these changes in the constitution of the preserved fodder are clearly apprehended. The vague and incorrect popular notions that prevail in regard to the processes of fermentation and putrefaction lead to errors in practice, from a false interpretation of the results obtained.

In the first attempts to preserve green fodder in pits, and even in the storing of grain, it was naturally assumed that the air was the sole cause of putrefaction and decay, and that the exclusion of the air was the essential condition for the preservation of articles of food that were observed to decay when exposed to ordinary atmospheric conditions.

This empirical assumption was not only a plausible explanation of the observed facts, but it was apparently confirmed by the earlier investigations of science relating to the phenomena of fermentation. Gay-Lussac proved that "perfectly pure grape juice does not ferment unless the process has been started by at least temporary contact with ordinary air."*

It was found that the solid particles of yeast, a well-known active ferment, could be separated from the liquid in which they were diffused, and Liebig claimed

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* Encycl. Brit. 9th Ed., Vol. IX, p. 94.

that fermentation was excited by "the soluble part of ferment," and he says, however, "but before it obtains this power, the decanted infusion must be allowed to cool in contact with the air, and to remain some time exposed to its action. When introduced into a solution of sugar, in this state, it produces a brisk fermentation; but without previous exposure to the air it manifests no such property. The infusion absorbs oxygen during its exposure to the air, and carbonic acid may be found in it after a short time. Yeast produces fermentation in consequence of the progressive decomposition which it suffers from the action of air and water."*

As in the experiments of Gay-Lussac, the facts are correctly stated, but in explaining them the mistake is made of attributing to the air, and its oxygen, the effects produced by the germs of ferments floating in the air, which were so minute as to escape attention. But something further was needed to round out his hypothesis, and in 1848 Liebig published a theory of fermentation, which was substantially a revival of that of Willis (1659), and Stahl (1697), and a modification of his earlier views.

It was simply that "yeast, and in general, all animal and vegetable matters in a state of putrefaction, will communicate to other bodies the conditions of decomposition in which they are themselves placed; the motion which is given to their own elements by the disturbance of equilibrium is also communicated to the elements of the bodies which come in contact with them." †

This theory was generally accepted by chemists as a satisfactory explanation of the phenomena of fermentation, but in its applications it seems to have been interpreted in accordance with the earlier views of Liebig, from the frequent references to oxygen as an active

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* Chemistry in its applications to Agriculture and Physiology, 1842. N. Y. Ed., p. 46.

† As quoted in Schutzenberger "On Fermentation," p. 40. See also article Fermentation, Encycl. Brit., 9th Ed., vol. IX, p. 94.

agent in the changes taking place in all processes of fermentation and decay. What are now known to be the essential factors of fermentation and putrefaction were entirely ignored by Liebig; and yet his theories were unquestioned for many years, and even now their influence is apparent in the popular literature of agricultural science, notwithstanding the repeated disproof of the assumptions on which the theory was based, by the results of direct experiments, beginning in 1838 and continued to the present time.

More than twenty-five years ago, Pasteur verified the results obtained by previous investigations, and supplemented the work by a masterly series of researches which proved conclusively that fermentation was a biological process, the result of the vital activities of living organisms.

If real progress is made in our knowledge of the complex changes involved in the ensilage of green fodder, the biological theory of fermentation, which can no longer be consistently questioned, must be accepted as the only safe guide in experimentation, and the obsolete theories of Liebig, that were based on assumed data, must be entirely discarded.

A brief historical summary of the progress of discovery will enable us to form a correct estimate of the present conditions of science relating to the subject, and lead to a recognition of the real significance of the biological factors of fermentation.

In 1680 the Dutch naturalist, Leuwenhoek, with lenses made by himself, examined yeast and found it was composed of minute granules, the real nature of which he was unable to determine.

Fabroni, of Florence, in 1787 again noticed the granules of yeast, which he looked upon as a "vegeto-animal" substance, and a further step in advance was made by Astier in 1813, who claimed that the yeast granules were living organisms that derived their nourishment from sugar and thus produced the phenomena of fermentation. This was in effect the first announcement of the true theory of fermentation, but from the prominence given to the popular chemical hypothesis, it was soon overlooked and forgotten.

In 1838 Cagniard de la Tour (who was afterwards elected to succeed Gay-Lussac in the Paris Academy of sciences) re-discovered the yeast granules of Leuwenhoek, and found them to be minute plants that were multiplied by a process of budding, and these he claimed, in the processes of their nutrition, were the cause of fermentation, as had been asserted by Astier twenty-five years before. "The chemists, with Berzelius and Liebig at their head, at first lauged this idea to scorn,"* but Schultze and Schwann, about the same time (1836–8), by the simple device of passing air through red-hot tubes, or through sulphuric acid, to destroy any organic germs associated with it, without altering its proportion of oxygen, proved that it did not excite fermentation when introduced into infusions of fermentable materials that had previously been boiled, which was of course fatal to that part of the chemical theory of fermentation which made oxygen an active agent in the process.

Helmholtz, in 1843, was equally successful in demonstrating the fact that the liquids or the gases of fermenting materials had no power to excite fermentation. He separated putrescent and fermenting liquids from putrescible and fermentable materials by a simple membrane which allowed the fluids and gases to pass through it by osmosis, but did not permit the transfer of the solid particles from one side to the other. As the process of fermentation or putrefaction, under these conditions, was confined to one side of the membrane, it is evident that the cause of fermentation was something that could not

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* Huxley, British Association Address, 1870, Nature, 11, 402.

pass through the membrane, and that the liquids and gases were entirely inert.

Another assumption of Liebig's theory was thus disproved by direct experimental evidence, and in the controversy which was carried on for many years, we find repeatedly enacted what Prof. Huxley terms "the great tragedy of science—the saying of a beautiful hypothesis by an ugly fact."

These experiments, which in themselves appear to be a conclusive refutation of the chemical theory, were fully corroborated by the investigations of Schroeder and Dusch in 1854, which were conducted on an entirely different plan. They found that liquids which were particularly liable to take on putrefactive or fermentative changes, were preserved indefinitely (after boiling, to destroy all contained germs), when freely exposed to air that had been filtered through cotton wool. As no change in the composition of the air could be produced by this process of filtration, aside from the removal of the solid particles floating in it, these last must contain the efficient causes of fermentation and putrefaction.

The chemists, however, continued to ignore this accumulation of evidence, which was in direct conflict with Liebig's theory, and it remained for Tyndall and Pasteur to clear up all possible doubts, and establish the biological theory of fermentation by a series of experiments that are unsurpassed in the history of science, for the accuracy and skill with which they were planned and conducted to answer all objections that had been raised, and avoid all possible elements of error.

Instead of filtering air through cotton, as in the experiments of Schroeder and Dusch, another method of purifying it was adopted by Tyndall with quite as satisfactory results. "A chamber, or case, was constructed with a glass front, its top, bottom, back and sides being of wood. At the back is a little door which opens and closes on hinges, while into the sides are inserted two panes of glass facing each other. The top is perforated in the middle by a hole 2 inches in diameter, closed air tight by a sheet of India rubber. This sheet is pierced in the middle by a pin, and through the pin-hole is passed the shank of a long pipette, ending above in a small funnel. A circular tin collar, 2 inches in diameter and 1 1-2 inches deep, surrounds the pipette, the space between both being packed with cotton wool moistened with glycerine. Thus the pipette, in moving up and down, is not only firmly clasped by the India-rubber, but it also passes through a stuffing-box of sticky cotton-wool. The width of the aperture closed by the India-rubber secures the free lateral play of the lower end of the pipette. Into two other smaller apertures in the top of the chamber are inserted, air-tight, the open ends of two narrow tubes, intended to connect the interior space with the atmospheric. The tubes are bent several times up and down, so as to intercept and retain the particles carried by such feeble currents as changes of temperature might cause to set in between the outer and the inner air.

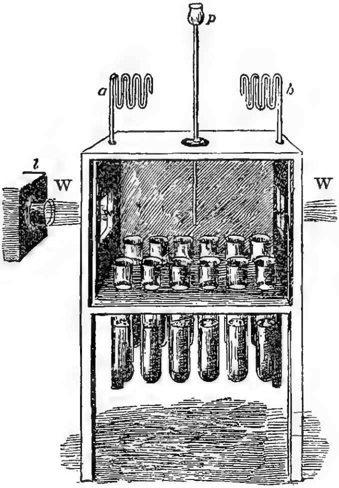

FIG. 3.

*"Tyndall's closed chamber for exposing sterilized putrescible solutions to the air without producing putrefaction."

"The bottom of the box is pierced with two rows of holes, six in a row, in which are fixed, air-tight, twelve

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*"Floating Matter of the Air," p. 132. D. Appleton and Co.

test tubes, intended to contain the liquid to be exposed to the action of the moteless air.

"The arrangement is represented in Fig. 3, where *w w* are the side windows (through which a searching beam passes from a lamp *l* across the case); *p* is the pipette, and *a*, *b*, are the bent tubes connecting the inner and outer air. The test tubes passing through the bottom of the case are seen below.

"On the 10th of September, 1875, this case was closed. The passage of a concentrated beam across it through its two side windows then showed the air within it to be laden with floating matter.

"On the 13th it was again examined. Before the beam entered, and after it quitted the case, its track was vivid in the air, but within the case it vanished. Three days of quiet had sufficed to cause all the floating matter to be deposited on the interior surfaces, where it was retained by a coating of glycerine, with which these surfaces had been purposely varnished." *

After the air was thus purified by the subsidence of the floating particles with which it was contaminated, the test tubes were partly filled through the pipette, with a variety of solutions that were readily acted upon by the micro-organisms of putrefaction, as dilute infusions of beef and mutton broth, urine, and of different vegetables, as turnips, cucumbers, etc., and these were sterilized by dipping the test tubes that project below the bottom of the case, in a bath of boiling brine for five minutes. It will be seen that these putrescible materials in the test tubes were in immediate contact with the purified air of the chamber, which freely communicated with the external atmosphere through the bent tubes at the top of the case.

Under these conditions the contents of the test tubes were kept for months without undergoing any change.

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* "Floating Matter of the Air," pp. 49-51.

"In upwards of fifty chambers thus constructed, many of them used more than once, it was, without exception, proved that a sterilized infusion in contact with air shown to be self-cleansed by the luminous beam, remained sterile. Never, in a single unexplained instance, did such an infusion show any signs of life. That the observed sterility was not due to any lack of nutritive power in the infusion was proved by opening the back door and permitting the uncleansed air to enter the chamber. The contact of the floating matter with the infusions was invariably followed by the development of life."*

The organisms which cause putrefaction were as readily removed from the air by the simple process of subsidence, as by filtration through cotton, or by passing through a red-hot tube, or through sulphuric acid. Pasteur practiced a still different method, that enabled him to separate the different organisms concerned in fermentation and putrefaction, and cultivate them as "*pure breeds*" for many generations, and thus determine the specific physiological action of each species.

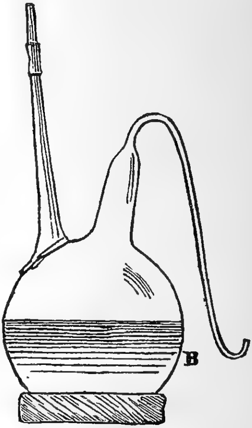

FIG. 4.
† One of Pasteur's culture flasks, giving free access of air through the curved tube.

By means of small glass flasks of different forms, to isolate the different ferments, he proved that each species produced a particular form of fermentation, as the alcoholic, the lactic, the butyric, the acetic and the putrefactive, and this, he claimed, was the result of their vital activities in the processes of nutrition.

Like all living beings, the micro-organisms of fer-

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* Tyndall, l. c. p. 133.
† "Studies on Fermentation," p. 241. Macmillan & Co., N. Y.

mentation require certain conditions of temperature, moisture and food supply, for the normal exercise of their vital activities; and each species needs some special adjustment of these conditions to furnish it the best facilities for carrying on its processes of nutrition and reproduction, and give it the advantage, in the struggle for existence with other species.

The living organisms of fermentation must not, however, be looked upon as engaged in the direct manufacture of some special product that characterizes the kind of fermentation with which they are associated. Beer yeast, for example, is not directly engaged in making alcohol, and the lactic ferment is not directly engaged in making lactic acid, although alcohol and lactic acid are, respectively, the dominant products resulting from the exercise of their physiological activities, when they are provided with the food that is best adapted to their wants. The fermentable materials constitute their food supply, from which they take what is needed for their nutrition, and the resulting residue we recognize as the product of fermentation.

When beer yeast feeds on sugar it leaves alcohol as a prominent constituent of the residue, which, as a whole, will of course vary with the other materials associated with the sugar; the lactic ferment feeds on milk, and leaves lactic acid as a characteristic constituent of the residue, and the same may be said of each specific ferment, that it appropriates from its food what is needed for its nourishment, and the remains of the feast will vary with the character of the food and the organism that fed upon it.

The chemical notions of fermentation, the legitimate consequence of Liebig's theory, were, that the saccharine, alcoholic, acetic, lactic, butyric and putrefactive fermentations were successive stages of a consecutive series of changes tending to putrefaction as a final result, and each fermentation was expressed by a chemical formula, or equation, indicating the supposed rearrangement of the elements involved in the process.

In regard to these equations Pasteur says: "Originally, when fermentations were put amongst the class of decompositions by contact-action, it seemed probable, and, in fact, was believed, that every fermentation had its own well-defined equation, which never varied. In the present day, on the contrary, it must be borne in mind that the equation of a fermentation varies essentially with the conditions under which that fermentation is accomplished, and that a statement of this equation is a problem no less complicated than that in the case of the nutrition of a living being. To every fermentation may be assigned an equation, in a general sort of a way; an equation, however, which, in numerous points of detail, is liable to the thousand variations connected with the phenomena of life.

"Moreover, there will be as many distinct fermentations brought about by one ferment, as there are fermentable substances capable of supplying the carbon element of the food of that same ferment, in the same way that the equation of the nutrition of an animal will vary with the nature of the food which it consumes.

"As regards fermentation producing alcohol, which may be effected by several different ferments, there will be, in the case of a given sugar, as many general equations as there are ferments, whether they be ferment-cells, properly so called, or cells of the organs of living beings functioning as ferments. In the same way the equation of nutrition varies in the case of different animals nourished on the same food. And it is from the same reason that ordinary wort produces such a variety of beers when treated with the numerous alcoholic ferments which we have described. These remarks are applicable to all ferments alike; for instance, butyric ferment is capable of producing a host of distinct fermentations, in consequence of its ability to derive the carbonaceous part of its food from very different substances, from sugar, or lactic acid, or glycerine, or mannite, and many others.

"When we say that every fermentation has its own peculiar ferment, it must be understood that we are speaking of the fermentation considered as a whole, including all the accessory products.

"We do not mean to imply that the ferment in question is not capable of acting on some other fermentable substance and giving rise to fermentation of a very different kind.

"Moreover, it is quite erroneous to suppose that the presence of a single one of the products of a fermentation implies the co-existence of a particular ferment. If, for example, we find alcohol among the products of a fermentation, or even alcohol and carbonic acid gas together, this does not prove that the ferment must be an alcoholic ferment, belonging to alcoholic fermentation in the strict sense of the term. Nor again, does the mere presence of lactic acid necessarily imply the presence of lactic ferment. As a matter of fact, different fermentations may give rise to one, or even several, identical products." *

The products of fermentation will then vary with the character of the materials fermented and the specific organism that acts upon them. In accept ing the physiological theory of fermentation it will not be safe to assume that specific micro-organisms are the sole factors involved in the process. As a preliminary step, starch must be changed to sugar, and cane sugar must be transformed into grape sugar; that is to say, the true organized ferments cannot act directly on starch or cane sugar. This change is brought about by *zymases,* the so-called soluble ferments.

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* Studies on Fermentation, pp. 276-7.

These "soluble ferments are all derived directly from living organisms, in the midst of which they originate,"* but they must not be confounded with the true, or organized ferments which act in a different manner.

These *zymases* appear to be important factors in the processes of assimilation and nutrition in all forms of vegetable and animal life.

The starch formed in the green cells of the leaf in daylight is transformed into glucose (grape sugar) at night, and transferred to the body of the plant, where it is stored in the form of starch or cane sugar, as reserve materials for the future use of the plant. In the tuberous roots of beets, and in the stalks of the sugar cane and sorghum, for example, cane sugar is stored in considerable quantities, as reserve material, and starch, in the same way, is stored in the tubers of the potato. When needed again they are reconverted into glucose, by a zymase, elaborated by the living cells of the plant, and transported again where they can serve a useful purpose in its economy.

The salivary and pancreatic glands of the higher animals secrete zymases which convert starch and cane sugar into glucose, that is stored up by the liver in the form of glycogen, which appears to be reconverted into glucose, and distributed through the general circulation as the exigences of the system require. The gastric and pancreatic secretions likewise contain soluble ferments that convert insoluble proteids into soluble and diffusible peptones, and even in plants peptonizing ferments are secreted by the cells to serve a similar purpose. It likewise appears that the elaboration of soluble ferments in animals is not confined to the special glandular organs of secretion, but the general tissues of the system, as in plants, are to a greater or less extent concerned in performing the same function. It may, in fact, be said

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* Schutzenberger on Fermentation, p. 273.

that the cells of all living tissues, whether of plants or animals, in the exercise of their vital activities elaborate *zymases* as required in the complex metabolism * of the processes of nutrition.

The first step in the fermentation of starch and cane sugar, which is the work of a soluble ferment (zymase), seems to be identical with the first step, of the germination of seeds, of the transformation of the reserve materials in the growth of the seed stalk in tuberous roots, and of animal digestion.

In these nutritive processes of plants and animals, heat is liberated as one of the constant results of the metabolism of the cells in the exercise of their vital activities. The heat developed by plants, as an incident of their nutritive processes, is not noticeable under ordinary conditions, as it is obscured by the constant loss of

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* Under the old physiological theories many of the changes taking place in the tissues, or nutritive materials, were erroneously attributed to a process of oxidation. For example, respiration was assumed to be a combustive process of oxidation, in which the carbonic acid exhaled was formed by the direct union of carbon with the inhaled oxygen. It is now known that the carbonic acid of respiration is formed in the destructive metamorphoses of the tissues, and not by the direct combination of oxygen with carbon, as in ordinary combustion. With the progress of physiological knowledge, oxygen is, more and more, looked upon as an essential food constituent, required in the constructive processes of the tissues, and there is no evidence that destructive oxidation, in the ordinary acceptation of the term, occurs, to any considerable extent, in living organisms. *Metabolism* is the term now used to denote the assemblage of vital changes involved in the processes of nutrition, whether chemical or physical, without attempting to indicate their precise character, or attributing them to the more than questionable process of oxidation. "We may picture to ourselves this total change which we denote by the term 'metabolism,' as consisting on the one hand of a downward series of changes (katabolic changes), a stair of many steps, in which more complex bodies are broken down with the setting free of energy into simpler and simpler waste bodies, and on the other hand, of an upward series of changes (anabolic changes), also a stair of many steps, by which the dead food, of varying simplicity or complexity is, with the further assumption of vital energy, built up into more and more complex bodies. The summit of this double stair we call 'protoplasm.' Whether we have a right to speak of it as a single body, in the chemical sense of that word, or as a mixture in some way of several bodies, whether we should regard it as the very summit of the double stair, or as embracing, as well, the topmost steps on either side, we cannot, at present, tell. Even if there be a single substance forming the summit, its existence is absolutely temporary ; at one instant it is made, at the next it is unmade. Matter which is passing through the phase of life, rolls up the ascending steps to the top, and forthwith rolls down on the other side." Foster, Art. Phys. Encycl. Brit. 9th ed. XIX, p. 13.

heat from evaporation. Under special conditions, where the loss from evaporation is reduced to a minimum, and the plants are massed in an atmosphere saturated with moisture,* the heat evolved becomes sensible and is readily detected.

In the malting of barley a temperature of 110° has been observed, and this, too, under conditions that were not the best to prevent the loss of heat from evaporation and radiation ; and a thermometer placed in the center of twelve spadixes of Arum Cordifolium showed a temperature of 121° when the external air was only 66°.† The heat evolved by these flowers was greatest when the plants were freely exposed to the air and the exhalation of carbonic acid was most active. On the other hand, Dutrochet ‡ found that the evolution of heat in green growing plants, as in the young twigs and leaves, was subject to a diurnal variation, and that it was most active in the middle of the day, when the absorption of carbonic acid and the exhalation of oxygen was going on with the greatest rapidity. From these statements it appears that heat is most rapidly developed when the metabolism of plant cells is most active, and this is indicated by the maximum absorption of carbonic acid in the green parts, like the leaves, and the maximum exhalation of carbonic acid, in special organs, as the flowers and fruits, in which chlorophyll is not performing its special role of fixing the carbon of carbonic acid.

The living cells of various tissues may also, as pointed out by Pasteur, perform the function of the true, or organized ferments, in producing alcohol, lactic acid, etc., but this function is but an incident of their meta-

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* Tyndall's experiments on radiant heat show that pure dry air is transparent to heat (i. e., is not readily heated), but that moist air absorbs heat, and is, therefore, readily warmed. When air is nearly saturated with the vapor of water, the absorption of heat is ninety times greater than in dry air. Tyndall on Heat, pp. 398-399, etc.

† Carpenter's Comp. Phys., pp. 451-452.

‡ Ann. des Sci. Nat., 2d. series, XII, p. 277. Carpenter's Comp. Phys., p. 451. Dalton's Human Phys., pp. 240-244.

bolism, and not comparable in efficiency or degree with the action of the specific organisms of these fermentations.

In the ripening of fruits we have illustrations of cell metabolism that are of particular interest in this connection. That the changes taking place in the fruit cells in the process of ripening are not the result of direct oxidation by free atmospheric oxygen, is shown by the experiments of Lechartier and Bellamy,* and Pasteur,† who found that carbonic acid was exhaled, and alcohol formed in fruits placed in closed vessels, in an atmosphere of carbonic acid. As no organized alcoholic ferments could be found, this fermentation must have been produced by the metabolism of the fruit cells in the absence of free oxygen. In the maturation of fruits, the cell metabolism is exceedingly complex, and it cannot be formulated in definite chemical terms.

Bérard ‡ gives the amount of lignine (characteristic of wood tissue) and sugar, in 100 parts of fruits, at different stages of maturation, as follows :

Fruits.	Lignine		Sugar	
	Green	Ripe	Green	Ripe
Apricots	3.61	1.86	6.64	16.48
Currants (including seeds)	8.45	8.01	0.52	6.24
Duke cherries	2.44	1.12	1.12	18.12
Green Gage Plums	1.26	1.11	17.71	24.81
Melting Peaches	3.01	1.21	0.63	11.61
Jargonelle Pears	3.08	2.19	6.45	11.52

"The fruit, while still green, it may be remarked, decomposes carbonic acid and emits oxygen, like the leaves; but when it ripens, this chemical action on the atmosphere alters. In other words, carbonic acid is given out, accompanied by a sensible rise in temperature, while oxygen is absorbed.

"The fibrous and cellular tissues also diminish as the

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* Compt. rend., 69, p. 466, etc.

† Compt. rend., 75, pp. 784 and 1054. Pasteur, Studies on Fermentation, p. 268.

‡ Brown's Manual of Botany, p. 470, refers to Ann. de Chim. et de Phys., Ser. 2, XVI, p. 152.

sugar increases, the latter substance being partly produced at the expense of the former."[*] M. Cahours,[†] in 1864, observed that the volume of carbonic acid produced by fruits in ripening, exceeded the volume of oxygen absorbed, so that it was undoubtedly the result of cell metabolism, and not of direct oxidation.

These observations were confirmed by the experiments of Lechartier and Bellamy,[‡] who also noticed that the development of carbonic acid was not uniformly constant, but varied widely at different periods, and that it was more rapid in the day than at night, which is a further indication that it was elaborated as a function of the life of the fruit cells, and that the absorbed oxygen was utilized in these vital activities. But the metabolism of the cells in ripening fruits is not limited to the decrease in woody fibre and the exhalation of carbonic acid as the sugar increases. A. Hilger,[‖] in experiments on two varieties of grapes (Austrian and Riesling), found that the acid diminished as the sugar increased, in the process of ripening, as seen in the following table:

	Sugar				Acid	
	Austrian		Riesling		Austrian	Riesling
Date	Leaves	Fruit	Leaves	Fruit	Fruit	Fruit
May 19	0.18		1.20			
June 27	1.03	1.37	1.00	1.01		
Aug. 16	1.08	1.33	1.03	1.23	4.65	4.95
Aug. 22	1.02	2.18	1.05	1.81	2.55	2.47
Aug. 28	1.06	4.25	1.12	2.39	1.27	1.65
Sept. 1	1.08	2.53	1.14	2.58	1.27	1.20
Sept. 12	1.08	4.49	1.14	2.89	1.20	1.19
Sept. 17	1.82	5.33	1.43	3.87	0.67	1.05
Sept. 23	3.53	7.71	3.64	7.70	0.60	0.75
Oct. 10	1.33	9.90	1.84	8.64	0.52	0.67
Nov. 10	0.52	9.90	0.72	8.21	0.52	0.75

Mercadante found that both malic acid and sugar increased in plums while green, and that tannin diminished, but as the fruit ripened the tannin disappeared,

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[*] Brown, l. c. p. 469.

[†] Compt. rend. 69, p. 356, as quoted by Lechartier and Bellamy.

[‡] Compt. rend. 69, p. 466, etc.

[‖] Landw. versuchs-stat. XVII, pp. 245-251. Jour. Chem. Soc., 1875 (28), p. 281.

and sugar was formed at the expense of the malic acid, as shown in the following table :*

Date	Sugar	Malic Acid
June 20th	16.52	2.76 (p. c. in pulp).
June 24th	16.54	2.46 " "
June 30th	16.78	2.16 " "
July 4th	17.05	1.57 " "
July 12th	17.38	0.82 " "

The real significance of the facts already presented cannot be clearly seen if our attention is confined to the obvious chemical changes taking place at different stages of growth, without taking into consideration the law of the conservation of energy in its relations to organic life. With the progress of biological science, the metamorphoses of matter in organic processes, which have been the almost exclusive subjects of study until within a few years past, are coming to be looked upon as of less and less importance, while the transformations of energy are being recognized as dominant factors in all vital activities. Heat and light are the main sources of energy concerned in the processes of nutrition and growth, and in general terms, the leading phenomena of plant metabolism may be summarized as follows : In the building up of tissues (constructive metabolism), work is performed and an expenditure of energy is made at the expense of the heat and light supplied to the plant. Step by step comparatively simple food materials are converted into more and more complex organic compounds, resulting in the formation of living protoplasm, an essential constituent of every cell, as the final and most complex state of constructive metabolism.

An expenditure and storing up of energy is involved in every step of this process. This stored-up energy is spoken of as potential energy, that may afterwards become active in doing work, or become sensible in the form of heat.

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* Jour. Chem. Soc. XXVIII (1875), 904, quoted by Prescott, Mich. Pom. Rep't, 1877, p. 152.

From the complexity and high potential energy of the molecules of protoplasm, a reverse process at once begins (destructive metabolism), and complex compounds are resolved, step by step, into those that are relatively simple, and starch, cellulose, and other plant constituents are formed, in the retrograde metamorphosis of the protoplasm.

This destructive metabolism is quite as essential to the life and well-being of the plant as the parallel constructive process, and the two are simultaneously taking place in the normal nutritive changes of every cell.

The stored-up energy resulting from the cumulative effects of constructive metabolism appears as heat in the process of destructive metabolism, and when not utilized in work or dissipated by radiation, may be detected by the thermometer, as in the ripening of fruits, the malting of barley, and in the flowers of the Arum in the experiments to which reference has been made. In the normal life of plant cells there is, then, an expenditure of energy in work, and a storing up of energy in complex organic substances, which is immediately followed by the breaking down of complex molecules, the liberation of heat, and the elaboration of substances like starch, cellulose, various nitrogenous bodies, and zymases, which can be utilized by the plant, and intervene between the complex protoplasm on the one hand, and the final waste products on the other.

It is important that we keep in mind the fact that the heat resulting from the metabolism of plants and animals is evolved in accordance with the law of the conservation of energy which is as strictly applicable in the organic kingdom of nature as in the inorganic. Plants do not produce heat, in the ordinary acceptation of the term, but it is liberated from the stored-up energy of the more complex molecules when they are converted into simpler compounds, as, for example, when starch is formed from protoplasm. As heat is liberated in the manufacture of starch from the more complex molecules of protoplasm, it will be seen that starch has less potential energy than the protoplasm from which it is formed.

The stored-up energy of organic substances may also be transformed into heat by the process of combustive oxidation, as well as by the metabolism of the living cells. "The heat which is given out by burning the organic substance is but the conversion into kinetic energy of the potential energy stored up in the substance. The heat, for instance, which is given out by burning wood, or coal, represents the kinetic energy, derived principally from the sun's rays, by which were effected the processes of constructive metabolism of which the wood, or coal, was the product." *

When a healthy balance is maintained between the constructive and the destructive metabolism of the cell, its activities are vigorously carried on, if other conditions are favorable; but with a lowering or loss of cell vitality, an invasion by the true, or organic ferments cannot be resisted, and these in their turn become the leading factors in the changes which follow. And here we have a further illustration of the law of the conservation of energy. The heat evolved in the processes of fermentation and putrefaction has the same origin as that developed in the metabolism of plants and animals. The microbes that cause fermentation do not produce the heat observed, but they feed upon the fermentable materials, and among the results which follow, the stored-up energy of these organic substances is liberated in the form of heat. It will be seen, moreover, that when this heat is not dissipated by conduction or radiation it may be sufficient to prove fatal to the organisms that are concerned in liberating it.

The phenomena usually included in the general term

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* Encycl. Brit. 9th ed. vol xix p. 56.

fermentation may then be considered under two distinct heads: 1st, the zymases, or so-called soluble ferments, which are elaborated in the exercise of the normal functional activity of the living cells of the tissues. They "invert" cane sugar and convert it into glucose,—change starch into sugar, or like the pancreatic secretion, change insoluble proteids into soluble and diffusible peptones, or in general terms they may be said to bring about those changes which facilitate the transfer and assimilation of food materials, and according to Dumas, they "always sacrifice themselves in the exercise of their activity." They do not act like the true ferments, and they must be looked upon as essential factors in the physiological activities of both plants and animals.

2d, The true ferments, which, on the other hand, are living organisms that increase and grow at the expense of the substances fermented, and produce fermentation as an incident of their vital processes.

Pasteur defines the true fermentations as physiological activities, "the direct consequence of the processes of nutrition, assimilation and life, when they are carried on without the agency of free oxygen," or, "as a result of life without air." The true ferments may be divided into two groups:

1st, The saccharomyces, or budding fungi, of which beer yeast may be taken as the type. They are real microscopic plants that multiply by budding, and have likewise a process of reproduction by spores. The prominent members of this group are alcoholic ferments.

2d, The so-called schizomycetes, or fission fungi, that are perhaps better called microbes, or bacteria.*

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*De Bary, an acknowledged authority on these lower forms of life, says the members of this group are not properly fungi, and he prefers to call them Bacteria. He would likewise avoid the use of the term Bacterium as a generic name. If, however, Bacterium is retained as the name of a genus, the group will be better designated by the general term Microbes.

They multiply by fission, each individual "dividing into two similar daughter cells through an unlimited number of generations."

Reproduction by spores has been observed in many species, and it is probable that this process is common to all. To this group belong various specific ferments, as the lactic, acetic, butyric, etc., and a number of forms that produce putrefaction. They are all microscopic forms, many of them less than $\frac{1}{25000}$ of an inch in diameter, and they are, at present, classified from peculiarities of form.*

The conditions of temperature, moisture and food supply, as already noticed, have a marked influence on the vital activities of bacteria, and they will, to a considerable extent, determine the successful reproduction and growth of a particular species, to the exclusion, for the time, of other less favored species. In the struggle for existence, the individuals that are best adapted to the sum of the conditions in which they are placed, will have many advantages over their competitors, and this will enable them to take the lead in appropriating the materials required in their processes of nutrition, and thus become masters of the situation.

Any change in the surrounding conditions that places this favored form at a disadvantage, will tend to check its activities, and bring to the front some other form that is better adapted to the new conditions. The normal activities of a dominant form may prepare the way for its own suppression and favor the aggressions of its rivals. An exhaustion, or even scarcity, of its appropriate food supply, or the form in which the food is furnished, or an accumulation of residues resulting from

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*The globular forms are called *Cocci*, the smaller ones *Micrococci*, and the larger *Macrococci*. When grouped in pairs they are *Diplococci*, and when in chains or rows *Streptococci*. The rod-like forms, if short, have been called *Bacteria*, and the longer rods *Bacilli*. Spirally curved forms are *Spirilla*, *Spirochætæ*, or *Vibrios*.

its own processes of nutrition, will serve to check its vital powers, and at the same time prove of immediate advantage to some other species.

Many illustrations might be given of the well known fact that a repression of the vital powers, and even the death of an organism may be caused as a direct result of the exercise of its own normal activities. In a confined atmosphere animals are killed by the carbonic acid exhaled in the process of respiration. Yeast is an alcoholic ferment, but its activity as a ferment is checked or entirely suppressed by an accumulation of the alcohol resulting from its own processes of nutrition. "The wines produced from the rich juices of Southern grapes always contain unfermented sugar,"* the alcohol produced being sufficient to stop the process of fermentation before the sugar is all consumed.

When lactic acid is allowed to accumulate beyond a certain amount, the lactic ferment ceases to perform its function; the microbes of nitrification are unable to act as ferments in the absence of lime or some other salifiable base to combine with the nitric acid as it is elaborated, and under such conditions they are superseded by other forms that have no such special requirements. One ferment may thus succeed another, as the conditions of life are changed to favor it and restrain the activities of its predecessor. The process of putrefaction is not a single fermentation produced by any single specific form, but an indefinite series of fermentative changes brought about by a succession of microbes, each of which, in its processes of nutrition, prepares the way for those that follow, until, by their combined action, the putrefactive materials are reduced to their simplest chemical combinations.

The temperature most favorable for the activity of bacteria will vary with the species, the conditions of

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*Encycl. Brit. 9th ed. 1 x p. 94.

moisture, and the supply of nutritive materials in an available form. A temperature of from 60° to 100° F. seems to be best for the rapid reproduction and growth of most species, while that of 122° to 132° is fatal to the acid-producing ferments and to those of putrefaction. When perfectly dry, a higher temperature may be borne with impunity, but when wet, a considerably lower temperature, if continued for several hours, will prove fatal. In my experiments with the microbes of the acid fermentations, they have been observed to succumb to a temperature of 115°, under what may be considered exceptional conditions, but even at lower temperatures their vital activities are readily checked and their special functions as ferments reduced to a minimum without absolutely proving fatal. It is important to clearly distinguish the differences in the effects of temperature on the spores, or germs, and on the mature bacteria. The spores, of species that are readily killed in the mature form by a temperature of 122°, may be able to withstand a temperature of 212° for several minutes, or under special conditions for several hours.

The intermittent method of heating discovered by Prof. Tyndall is a convenient and efficient mode of destroying bacteria at comparatively moderate temperatures.* I have repeatedly succeeded in sterilizing culture fluids, which involves, of course, the destruction of all mature bacteria and their germs, by raising the temperature for one minute to 122°, at intervals of about twelve hours, for a week or ten days. A temperature of from 122° to 132°, if frequently repeated, or maintained continuously for several days, seems to be quite as efficient in killing the germs of bacteria as considerably higher temperatures for a short time. No arbitrary rule can then be laid down as to the precise thermal death-point of any particular species, as much will

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* Floating Matter in the Air. pp. 210, 337.

depend upon the conidtions under which the heat is applied.

From this outline of our present knowledge relating to the subject, it must be seen that the micro-organisms of fermentation and putrefaction cannot be overlooked in discussing the practical principles that must guide us in the ensilage of green fodder, and that generalizations based on observations in which their activities are ignored cannot safely be made.

CHAPTER V.

THE SILO.

A silo is, in effect, a tight box or chamber, in which green fodder may be stored and preserved. The sides must be smooth and vertical, so that the silage may settle uniformly and freely, and the bottom should be water-tight and without drainage. It may be made of any form, provided these essentials are secured, but, taking everything into consideration, the rectangle will be found most satisfactory for the ground plan.

MATERIALS.

Massive and expensive silos of masonry have been made by the followers of M. Goffart, and it has been claimed that they were essential to the successful ensilage of green fodder. Others have recommended concrete as the best material that can be used in their construction. The only valid argument that can be urged in favor of masonry or concrete for the walls of the silo is that of durability. On the other hand, it must be observed they are good conductors of heat (and frost), and this in itself is an objection that more than counterbalances any apparent advantages that may otherwise be claimed for them.

From a careful study of the subject and a personal examination of the silage in a large number of silos of all kinds, I cannot escape the conclusion that, taking everything into consideration, wood is the best material that can be used in the construction of the silo. As a nonconductor of heat, it is far better than masonry or concrete, and in most localities, and perhaps as a general rule, it is the cheapest.

If reasonable precautions are taken in building, and suitable preservatives, like crude petroleum, and roofing pitch, or tar, are judiciously applied, which can be done at a comparatively trifling expense, it cannot be objectionable on the score of durability. The application of preservatives will be considered under the head of construction.

FORM AND SIZE OF THE SILO.

The quantity of fodder to be ensilaged, and the number of animals it is desirable to provide feed for, should determine the size and general form and proportion of the silo. On the start, it may be well to bear in mind the fact that in feeding out ensilage, if a large surface is exposed to the air for a number of days, it is liable to be seeded with the germs of molds and putrefactive bacteria, so that its value as cattle food may be materially diminished.

To obviate this difficulty, it is a common practice to cut down the silage in narrow slices, or strips, but in this method the wall of silage remains exposed to atmospheric contamination during the time the strip cut off is being fed out; and, moreover, this involves an unnecessary expenditure of labor in feeding, particularly in cutting down and handling the fodder at a disadvantage. It would be better to make the proportions of the silo so that, by feeding from one end, or from the entire top surface, a fresh layer would be exposed every time the animals are fed. On the whole, several small silos will be found more convenient, so far as the economy of feed and labor is concerned, than one very large one of equivalent capacity, and these should be of such proportions as to require several inches in depth of the exposed silage to be removed each time the animals are fed.

Uniformity in the quality of the feed will thus be secured, with a minimum loss of nutritive materials. The small silos have also advantages in the process of filling, as will be noticed hereafter. The number of animals to be fed will thus have an influence in determining the dimensions of the silo in transverse section.

The walls of the silo may be 12, 14 or 16 feet high, and it will seldom be advisable to exceed the latter figure. Silos with walls from 20 to 30 feet high have been made, but without any apparent advantage.

The weight of a cubic foot of silage will vary with the condition of the crop when put into the silo, the depth of the silage, and the pressure applied when it is covered. From 35 to 50 lbs. per cubic foot will represent the range of variation reported, and 40 lbs. may be safely assumed as the weight of a cubic foot in approximately estimating the storage capacity of the silo.

It is better to err on the safe side in estimates of the amount of feed stored in the silo, when the actual weight is not determined at the time of filling. A considerable settling of the silage takes place after the silo is filled, and allowance must be made for this in estimating the storage capacity of the silo.

From the data presented, a silo 12x16 feet should hold from 46 to 56 tons; one of 12x24 feet over 80 tons; one of 14x32 feet over 125 tons; and one of 16x36 feet over 170 tons. In the reports on feeding silage the amount fed to a cow per day is usually stated at from 40 to 60 lbs. when supplemented with other feed, and 50 lbs. per day will perhaps fairly represent the average.

At this rate a cow would consume 1,500 lbs., or three-fourths of a ton, in 30 days, and 20 cows would require half a ton a day, or 15 tons in 30 days. The 56 tons which may be stored in a 12x16 feet silo would therefore serve as the silage ration of 20 cows for over 3 1-2 months. Such calculations, as a matter of course, will only serve to indicate approximately the amount of silage that may be fed, under fairly good management, and the storage capacity of the silo required for its preservation, as much will depend upon the animals to which it is fed, the complementary food supply, and the system of feeding practiced.

LOCATION OF THE SILO.

Much ingenuity has been displayed in building silos under the floor of the stable, in the side of a sloping bank, or partly below the level of the stable floor, but most of these plans are based on mistaken notions of what constitutes economy in the ensilage of green fodder. Silos that are below, or partly below the surface of the ground, may be easily filled, but the manual labor involved in raising the mass of silage to the level of the feeding floor is an unanswerable objection to this plan of construction.

As the green fodder, both before and after it is placed in the silo, contains a large proportion of water, and is therefore heavy to handle, the economy of labor in its management is an important consideration, if the largest benefit is to be derived from the process. Attention to a few simple propositions will be of material assistance in the planning and construction of a silo.

In the interests of a judicious economy the silo should be so placed that it can be conveniently filled, and as conveniently emptied, without any unnecessary hand labor in the transportation or handling of the silage.

As the filling of the silo is almost entirely done by machinery, under proper management, the last-mentioned consideration should have the most weight in determining the plan and location of the silo. It will cost less to elevate the cut fodder to the top of a silo above ground, by a carrier attached to the cutter, at the time of filling, than to raise it by hand a less distance, from the pit to the level of the feeding floor, as the silage is fed out, even if a windlass or pulley is used to save manual labor. As large a proportion of the work as possible should be done with a machine, and hand labor should be economized as far as practicable. In the application of this principle, there can be no doubt that the bottom of the silo should be on the same level with the feeding floor, and continuous with it, so that a truck can be used to distribute the silage with the least expenditure of hand labor. The silo may be an independent structure or annex to the barn, in immediate and convenient proximity to the stables, or it may be built inside the barn, in which case a roof would not be needed. If the stable accommodations are limited, the latter plan would, however, be of questionable economy. If the barn is so situated that the silo must be built in the side of a sloping bank to secure convenience of access from the stables, three plans of construction may be suggested: 1st, the lower part of the silo may be of masonry, where it is in immediate contact with the bank; or 2d, a retaining wall of masonry may be built as a protection to the walls of the silo, which may be built of wood inside of, but not in connection with it;

or, 3d, the entire structure may be of wood, if sufficient care is taken to prevent decay, and it has strength to resist the pressure of the bank of earth. In the latter case, hot roofing pitch should be freely used on all of the scantling and boards that are below the surface of the ground, and the outside sheathing, between the studs and the wall of earth, should be of two-inch planks, to withstand the external pressure. Large sills of timber should not be used, as scantling two inches thick will furnish sufficient strength, and they can be better saturated with the hot pitch applied for their protection. Of these plans, the second, although costing somewhat more than the others, has many advantages, which, on the whole, should give it the preference.

When the silo forms part of the original plan of the barn and the stables, it will not be difficult to secure an arrangement of details that is consistent with the strictest economy in the system of management.

CHAPTER VI.

HOW TO BUILD A SILO.

As wooden silos are, on the whole, to be preferred, we may proceed to consider some of the leading principles involved in their construction, without stopping to give directions for the building of silos of masonry or concrete. Aside from the conditions required for the preservation of green fodder, the silo should be made so that it may be classed among the permanent improvements of the farm, and every reasonable precaution should be taken in its construction, to insure the essential qualities of stability and durability. The least expensive structure will not prove to be the cheapest, if these indispensable qualities are not secured.

The decay of a wooden silo does not, as a general rule, arise from a necessary and inherent defect in the character of the material used, but from the neglect of certain principles in the details of construction, which in themselves involve but a comparatively slight increase in the original cost of the structure. Too often considerable expense is incurred in attempts to make the building more durable by devices that in effect are sources of weakness, and tend to favor the processes of decay.

For strength, economy of materials and labor, the "balloon frame" has many advantages that recommend it as the best, in the construction of the silo. Persons who are not familiar with the "balloon system" of building are liable to err on the side of excess, in the size and number of timbers, and unnecessary details are often planned which add to the cost of construction, without any compensating advantages. Sills of timber are frequently framed together for the foundation of the balloon frame, and in many respects they are a source of weakness instead of strength. In the balloon frame proper, scantling from 2x4 to 2x12 are all that are needed, and the larger sizes (2x10 and 2x12) are seldom required. The scantling should all have the ends cut square, without any pretence of framing, and the junctions should be toe-nailed, or secured with spikes. Round steel nails of all sizes can now be bought at nearly the same price per pound as cut nails and spikes, and as the steel nails are lighter, the greater number in a pound makes them, on the whole, the cheapest, and they are also much better for all purposes in building a silo. The scantling and boards for the walls of the silo should be sound, well seasoned and free from sap-wood. Green lumber should never be used, as it is more liable to decay, and, moreover, when the usual preservatives, petroleum or roofing pitch, are applied, disappointment in the results will probably follow. Among the precautions to secure durability, the liberal and judicious use of petroleum and roofing pitch or tar, may be urged as of the first importance.

The manner in which these preservatives are applied is a matter of no little consequence, if the best results are to be obtained. When applied boiling hot to dry, seasoned wood, they penetrate the fibres to a considerable depth, and a permanent effect is produced. A superficial coat of cold tar will not be found an efficient protection to timber, particularly if it is in contact with moist earth. A single application of hot roofing pitch to a dry, seasoned pine plank, will, however, usually penetrate to about the depth of one inch, as may be seen on examination of a cross section. If both sides of a two-inch plank are thus treated, the wood is practically saturated with the pitch, and its durability will be increased not only by resisting the ordinary elements of decay, but in its wearing qualities when used as a floor.* In building a silo the scantling and boards for sheathing may be cut of proper length, the ends being square, and the hot petroleum or coal tar may then be applied to

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*Mineral pitch and coal tar are refuse products of gas works. A mixture of the two is usually made for roofing purposes, and also for making sidewalks, when it is known as asphalt. Coal tar is too sticky at ordinary temperatures unless it has been boiled, as it should be if used alone, and the pitch, on the other hand, from its higher melting point, is liable to get too hard before it can penetrate the timber, and thus form a superficial coating. By a judicious mixture of the two these extremes are avoided and the most satisfactory results are obtained. In heating or boiling them care should be taken to prevent the inflammable vapors from coming in contact with the blaze. Crude petroleum, and coal tar too, may be used by themselves on the scantling and sheathing boards in the process of construction, but on timbers in contact with the ground, and for the inside finish of the walls when the silo is complete, a mixture of the tar and pitch will give a better body and is therefore to be preferred. A swab, consisting of a suitable stick for a handle about three or four feet long, with a strong cloth wound around one end and stoutly secured with a cord, will be found the most convenient instrument for applying the hot pitch and petroleum.

both sides and ends of each piece, before it is put in place.

It will be well, however, to remember that timber absorbs moisture, and rots more readily at the ends than the sides, and care should be taken to cover the ends, and also where the timbers are joined, with the preservative. To persons not familiar with work of this kind, it may appear to be an expensive job to treat all of the lumber of a silo with preservatives in this thorough manner, but an extended experience in the use of coal tar and pitch in the construction of barns and other buildings has satisfied me that it pays to make thorough work in their application as preservatives of woodwork when it is exposed to conditions that are favorable to decay. The materials are not expensive, and the extra labor involved is not considerable when compared with the advantages of a structure that is not liable to require expensive repairs in the course of a few years.

As a further precaution to secure durability a foundation of masonry or concrete should be laid below frost, and carried above the surface high enough to prevent water from settling against the wood work. Two or three pieces of 2x4 inch scantling one foot long (well coated with pitch) may be laid edgewise, at intervals, along the middle third of the long side, and also near the middle of the end walls, as shown at X, Fig. 5, to serve as anchors to the sills to prevent them from spreading.

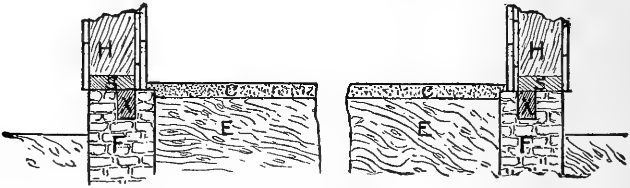

Fig. 5, Section of bottom of silo. E, E, earth; F, F, foundation walls; S. S. sills; H, H, studs; X, X, anchors for sills; C, C, concrete floor.

The pressure of the silage against the walls of the silo should of course be taken into consideration in deciding upon the size of the studs required to secure durability. From experiments made with the dynanometer, by Prof. E. M. Shelton at the Kansas Agricultural College, the lateral thrust of the silage in settling is less than it had generally been assumed to be.

At a distance of 19 and 20 feet from the surface, the pressure of the silage of corn fodder cut in one-half inch lengths, against the side walls, was found not to exceed 57 lbs. per square foot. From the data thus furnished it will be safe to use 2x4 inch studs for a wall 12 feet high; 2x6 inch studs for a wall 14 feet high, and 2x8 studs for a wall 16 feet high, if they are in each case placed from 16 to 18 inches apart, from center to center, and sheathed on the inside with two thicknesses of inch boards. The sizes given are in fact considerably in excess of what is actually required to secure stability, if reasonable care is exercised in other details of construction.

The inside sheathing boards should be of uniform width (10 to 12 inches), and surface dressed to secure uniformity in thickness. The sills, two inches thick and of the same width as the studs, are laid on a thin bed of cement mortar, and spiked to the anchor blocks in the foundation. No framing or lapping of the sills is required, but where they abut at the corners or on the sides, if the silo is longer than a single scantling, they are fastened together by toe-nailing. When the sills are in place, set the end studs (A, A, A, Fig. 6), one at a time, flush with the inside of the sill, fasten the lower ends by toe-nailing on each side, and keep them plumb by suitable stay laths. Then put on the bottom board (X, Fig. 6,) of the inside sheathing, with the lower edge resting on the foundation wall, and nail it to both sill and studs to bind all strongly together.

Then in the same manner set the studs of the sides (B, B, B, Fig. 6), and nail the bottom board II in the same way. The position of the corner studs and their relation to the sheathing boards is clearly shown in Fig. 6, the board X being nailed to the side of the stud B, while the board II is nailed to the edge of the same stud. This simple plan of building the corners gives ample strength with the least expenditure of materials and labor in the construction.

When the first layer of the inside sheathing, marked X and II (Fig. 6), is laid to the height of four or five feet, begin again at the bottom by putting on a sheet of tarred roofing paper, lengthwise, without lapping, but with the edges in contact, to completely cover the joints between the boards already laid, and upon this nail the inner layer of boards marked III and IV, Fig. 6. In order to break joints it will be seen by reference to Fig. 5 that the first, or bottom board, of one of the layers must be one-half the width of the other boards, and it is immaterial in which layer of the sheathing the narrow board is placed.

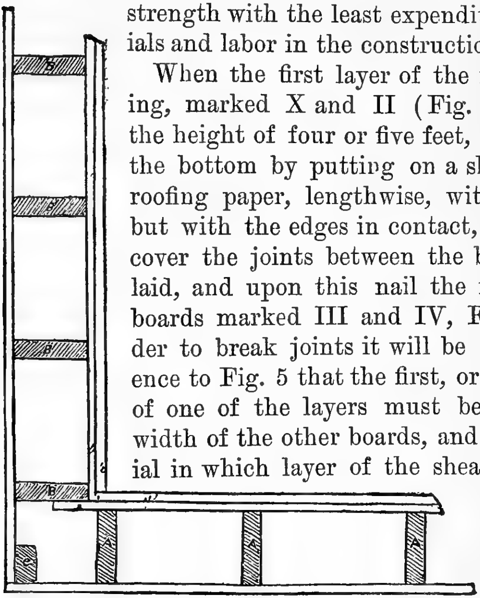

Fig. 6. Plan of silo showing construction of corners. A, A, A, B, B, B, B, studs; X, II, III, IV, inside sheathing boards. C, corner stud for outside sheathing.

After the first board of the inside sheathing is nailed on, it will be well to complete the frame by putting on the plates. These are two-inch scantling, and like the sills, of the same width as the studs, to the top of which they are spiked. The plates must run entirely around the walls, at the ends as well as the sides. The end studs may be two inches longer than the side studs, and then the plate on the end will lap over the side plate at the corner, to which it is firmly spiked.

The inside sheathing, with its intermediate layer of tarred roofing paper, may now be finished, and at the top of the wall it should cover the edge of the plate as shown in Fig. 7. If the silo is over sixteen feet long the plate may be doubled by spiking on another two-inch scantling that is two inches wider than the first, so that it will cover the top edge of the inside sheathing.

If the silo is in the barn the outside of the studs need not be covered with sheathing; but if it is an independent structure, the outside sheathing will form a desirable protection from frost and driving storms. It may be of vertical boards with the joints battened, by toeing horizontal laps of 2x4 inch scantling at convenient distances between the studs, or, to secure greater strength, the horizontal siding with rabbeted edges may be used. The corners may be made secure by nailing the siding to a 2x4 inch stud, as shown at C, Fig. 6.

The air spaces between the studs should never be filled with sawdust or other materials, but they should be closed in so that they are at least vermin proof. This can be done with a little care in construction, and a serious annoyance from rats and mice may thus be avoided.

The plate for the roof to rest on should be at least three feet above the top of the silo proper, to give head room in the work of filling. This can readily be done by extending the balloon frame by setting 2x4 or 2x6 inch studs three feet long (O, O, Fig. 7) on the side plates of the silo (P, P, Fig. 7), and spiking the roof plates (S, S,) on the top of them for the rafters to rest upon. The end studs of this extension will be nailed at the top to the rafters. These studs may be covered on the outside with siding, but the inside sheathing may be dispensed with.

If the silo is considerably more than sixteen feet long, a tie in the middle may be desirable to prevent any springing of the side walls. For this purpose a truss of the form sketched in Fig. 7 (T, T, T, T, V, V, V, V, V) will be less in the way than a tie beam, and quite as efficient. It may be made of two 2x8 or 2x10 scantling, T, T, T, T, nailed together at the top, to which are nailed inch boards, V, V, V, ten or twelve inches wide, as ties of the truss. The ends of the truss are toe-nailed to the plates P, P, and spiked to the studs O, O. A board on each side may be nailed to this truss and to the top of the middle studs O, O, as a tie to the upper, or roof plates S, S.

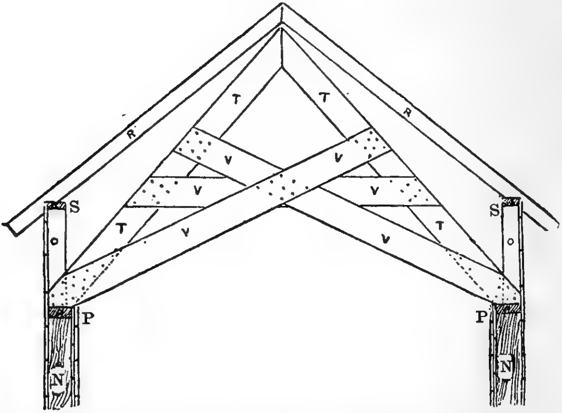

Fig. 7. **Form of truss to prevent spreading of the walls, with relations to roof. T, T, T, T, 2x10 scantling; V, V, V, V, V, 1x12 boards, forming the truss; N, N, studs of silo proper; P, P, main plates; O, O, studs for roof; S, S, upper plates; R, R, rafters.**

The bottom of the silo, seen in outline section in Fig. 5, may be finished by firmly packing the earth, E, E, and covering with a few inches of concrete, C, C.

The concrete is not absolutely necessary and is often omitted when the bottom is clay that can be puddled and packed. A pitched plank floor would have advantages as a non-conductor of heat, and it can readily be laid water tight in a thin bed of cement mortar, and spiked to ribs of 2x4 scantling bedded in the concrete.

The general plan of the doors is indicated in the diagram, Fig. 8. The large door, B, in the gable to receive the carrier from the cutting machine in filling, needs no description. Similar doors on each side, above the walls of the silo proper, will be found convenient for admitting light when filling the silo, and at other times as required. They may be hinged at the top and fastened at the bottom with a hook and staple.

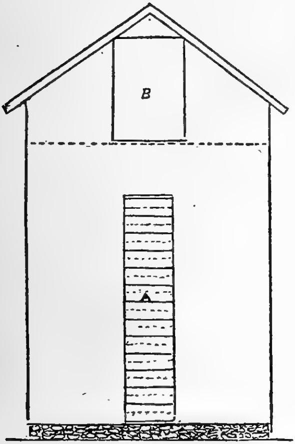

Fig. 8. Diagram of end elevation, showing plan of doors.

The long door, A, in the wall of the silo, to give access to the silage in feeding out, should be wide enough to admit a truck (in the form of an oblong box on three wheels, two of them under one end and one at the other), and it should extend from the sill to within two and one half or three feet of the top of the silo.

This door is, in effect, but a section of the inside sheathing, with its middle layer of tarred roofing paper, that can be removed in pieces, but which, when in place, protects the silage as completely from atmospheric contaminations as any other portion of the walls.

When setting the studs for the frame, place two of the end studs the proper distance apart to form the jambs of the doorway. On the outer side of each spike a 2x4 inch scantling flush with the inner edge, to form a wide bearing for the laps of the inside sheathing, and the pieces cut from it to form the door. When putting on the inside sheathing, cut from each board of the first layer, and opposite the doorway, a piece three inches longer than the distance between the studs forming the door jambs, and number and set them aside to form part of the door.

From the inner layer of sheathing cut out in like manner pieces for the door, but two inches longer than were cut from the first layer. When filling the silo, the door can be laid in sections, three or four feet high at a time, as needed, by beginning at the bottom and putting each board into the space from which it was cut, with horizontal sheets of tarred roofing paper between the two layers of boards, to completely cover all joints and make a practically airtight surface.

As the door boards are put in they may be held in place, until the silage is banked against them, by a small wedge at one end. When ready to begin feeding the silage, the top of the door can be readily reached from the inside, and the boards removed in sections and laid aside, with the roofing paper, for future use. As the silage is fed out additional boards can be taken out until the bottom of the silo is reached. This form of door will be found convenient in feeding from the entire top surface of the silage, or, still better, if the silo is longer than broad, the feeding may be from the end in oblique sections, and the covering will then be removed from the top as required.

There is no apparent advantage to be derived from partitions in silos, and they are objectionable on many accounts. If they are made they should be permanent and made as tight as the side walls.

Planks will spring if used for partitions, and a studded wall, sheathed on both sides, will alone be found satisfactory. A door through the partition may be made on the same plan as at the end described above.

In building a silo on the plan here presented, skilled labor is not required, as anyone who understands the use of the square and saw can do the work, if he has clear ideas of what he wishes to accomplish and works on a definite plan. The aim should be to build a tight box, or chamber, open at the top, with double walls that are proof against vermin, and the whole made durable by the liberal application of the coal tar compounds.

CHAPTER VII.

FODDER CROPS FOR ENSILAGE.

All green crops like clover, lucerne, rye-grass, etc., etc., may be preserved in the silo, but the American cereal, Indian corn, has many advantages in this climate that will undoubtedly make it the staple crop for ensilage throughout the United States. From the large yield per acre under favorable conditions, and its value as cattle food when properly grown and managed, it can have no successful competitor as a green forage crop, on a large majority of the farms in this country.

As the principles involved in the ensilage of all fodder crops are the same, we will confine our attention to the ensilage of maize, without stopping to notice the details of special treatment required in the ensilage of crops of subordinate interest. Too often mistakes are made in the cultivation of fodder corn which seriously detract from its feeding value.

The conflicting opinions expressed in the agricultural papers in regard to the value of fodder corn as feed for cows giving milk, furnish an illustration of the importance of directing our attention to methods of cultivation, and conditions of growth, as factors that may determine its value as cattle food. It has been asserted by some farmers that a diminished flow of milk followed the full feeding of fodder corn, while others consistently claim that it is one of the best feeds for dairy stock. The obvious explanation of these conflicting statements should be of interest to every farmer.

THICK SEEDING.

From its peculiar habits of growth Indian corn, as a fodder crop, must vary in feeding quality with the conditions that prevail in its cultivation. When too thickly planted the stalks are bleached and slender, and the leaves are pale and lacking in vigor, and although a considerable yield in gross weight may be obtained under such conditions, water forms too large a proportion of the constituents of the crop, and there is consequently a corresponding deficiency in nutritive materials. The general sickly habit of growth is an indication of defective nutrition and a suppression of the processes of assimilation.

Some of the leading facts in vegetable physiology have a practical significance in this connection, which should not be disregarded. The green coloring matter of plants (chlorophyll) is the active and essential agent in the assimilation of carbon, and the formation of starch, and the reserve materials that are stored up in the body of the plant. Carbon, which usually constitutes about one-half of the weight of the dry substance of most plants, is derived from the carbonic acid of the atmosphere, and can only be assimilated by the chloryphyll *in the presence of light.* "When the amount of light is small, even these assimilating organs which contain chlorophyll lose the power of producing organic substances out of water and carbon dioxide with the assistance of other food materials."

The effect of what physiologists call assimilation is to increase the dry substance of the plant, and consequently its feeding value. Defective assimilation, then, means deficiency in dry substance and diminished value as food. Indian corn, a semi-tropical plant, with its wealth of foliage needs an abundance of sunlight and air for its vigorous growth and development. When crowded in dense masses, as we see it in thickly planted fodder corn, the upper leaves only receive sufficient light to enable them to carry on the active assimilation of carbon, while the pale lower leaves and stalks are thickly shaded and unable to perform their share of the work in the constructive processes of the plant.

The yellow leaves and delicate, spindling stalks, without a rudiment of ears, furnish conclusive evidence that the plants are suffering from inanition, and that insufficient supplies of nutritive materials, in proper form and under proper conditions, have been provided for their perfect development and maturity.

Dr. E. H Jenkins, in a table on the "Composition of American Feeding Stuffs," * gives the results of seventy-five American analyses of maize fodder, the dry matter of which varies from 7.1 to 48.5 per cent; and in fifty-nine analyses of maize fodder ensilaged, the dry substance ranges from 13.0 to 35.6 per cent.

As these differences evidently exceed any reasonable margin of error in analysis, they must be attributed to differences in varieties; to the stage of maturity at time of harvest; or, to methods of cultivation; but unfortunately we have not the data for determining the influence of each of these factors on the results obtained.

It is evident, however, that fodder corn varies widely in the amount of dry substance it contains, and that silage must vary in value with the quality of the crops ensilaged, so that no definite statements can be predi-

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* Connecticut Agr'l Ex. St. Rep't 1880, p. 40.

cated in regard to average nutritive values. Some of the objections to the thick seeding of fodder corn have apparently been observed by farmers, as instead of the one, two or three bushels of seed per acre of a few years ago, we now oftener see recommendations of the more consistent and rational quantities of but eight to ten quarts per acre. This is progress in the right direction and in harmony with the well-known laws of vegetable nutrition and growth.

As seen from the published analysis quoted above, the amount of water in fodder corn is liable to wide variations, and in all experiments with maize as a field crop, *the amount of dry substance obtained per acre*, in connection with the variety and quantity of the seed planted, and the conditions under which the crop is raised, should be clearly and fully stated, as they are matters of the first importance in the interpretation of results. In a succulent, large-stalked plant, like maize, a statement of gross weights only may be misleading in discussing nutritive values.

When immature fodder corn is ensilaged, whether from thick seeding or premature harvesting, the excess of water it contains is a real source of annoyance and probable loss. From the weight of the superincumbent mass the juice is pressed out of the silage in the lower half of the silo, and there is towards the bottom an accumulation of liquid containing more or less of the food constituents of the silage, which cannot be disposed of to advantage.

In a number of cases of this kind, to which my attention has been called, the accumulation of liquids in the bottom of the silo has been attributed to the soaking in of water from the outside, and the real cause of the difficulty was not suspected. The crops ensilaged should contain no more water than can be retained in the cells of the plant under the conditions in which they are placed, and this means that a certain stage of maturity should be reached before the crop is harvested. It is true that immature fodder corn may be partly dried in the field after it is cut up, before putting it into the silo, but this obviates but part of the difficulty; the deficiency in dry substance still remains. The excess of water in the immature plant is exhaled from the leaves in the process of maturation as the chlorophyll of the leaves assimilates carbon, and reserve materials, like starch and its allies, are stored up to increase the percentage of dry substance. Nature's method of drying immature succulent vegetation will be found the most profitable, and we need only aid her by furnishing suitable conditions for the performance of her work.

The reported yields of fodder corn, under good management, vary from about 15 to 30 tons per acre, and if yields of less than ten tons are mentioned, some excuse is presented of unfavorable conditions for the crop, or, the effects of a bad season. Claims of 40 to 50 tons per acre are frequently made, and yields of even 80 to 90 tons have been reported, but these exceptional yields are evidently enthusiastic estimates that need verification. There can be no doubt that Indian corn will yield a greater aggregate of valuable cattle-food per acre, under good conditions of farm management, than any other crop, and exaggerated claims are not needed to lead to its general recognition as the King of the cereals.

VARIETIES OF MAIZE FOR ENSILAGE.

A great number of varieties of maize have been recommended as the best for a fodder crop, but allowance must be made, in many cases, for a bias of judgment, where the sale of seed is the object.

From the wide geographical range of the crop in America, and the different climatic conditions under which it is successfully cultivated, it will be seen that the best variety in one locality may not succeed in a large proportion of cases in other localities. It has been the fashion to grow Southern varieties at the North for fodder corn, from the imposing appearance of the crop, and the large gross weights, in yield, that are obtained.

To what extent this practice is desirable we have not as yet the data to determine, as quality is quite as important as quantity, and the real value of the crop will largely depend on the amount of dry substance obtained on a given area, and the labor required in its production and management.

Any increase in the gross weight of the crop that arises from a larger proportion of water, without any marked increase of dry substance, adds to the cost of labor in harvesting and storing it, without any real compensating advantages. Among the varieties frequently mentioned in the current agricultural papers, Southern white and yellow dent; Southern sweet; and the B. and W. have perhaps been the most popular, and in many localities, it is possible that either one of them may be better, on the whole, than some of the smaller sorts, but it will not be safe to urge their exclusive use throughout the range in which fodder corn may be profitably raised.

Some general propositions may be of assistance in making a choice of a variety for fodder corn. In the first place it will be generally admitted that it should be so well adapted to the locality that it will be likely to mature before it is threatened with early frosts. In the absence of other defects, an exuberant leafy growth with stalks of small or medium size may be desirable. A variety that is prolific in grain formation may likewise have advantages in feeding quality. At the extreme North, the medium, or smaller varieties will, undoubtedly, give better results, on the whole, than the larger Southern varieties that require a long season to mature.

It seems to be generally admitted that the sweet varieties have no marked advantages, as the yield is usually less than that of other sorts, and there is no evidence that they have a decidedly higher nutritive value. The system of cultivation practiced is probably of greater importance, in most cases, than the selection of the variety to be grown, provided it is adapted to the locality.

Fodder corn should never be sowed broadcast, but planted in drills, or hills, at such a distance apart as will admit of convenient cultivation.

The soil should be in high condition and carefully prepared for seeding. The smoothing harrow may be profitably used, to check the growth of weeds, until the plants are several inches high, and thorough after-cultivation should follow. As to the distance between the rows, no definite rule can be prescribed, as the larger varieties require more room than the smaller sorts, but all need nearly as much space as when grown as a field crop with grain as the leading object. One of the most satisfactory crops I have raised was of medium Western dent corn, in drills four feet apart, and yielding, in gross weight, but twenty tons per acre, but this included eighty bushels of well matured shelled corn that gave the crop a high feeding value.

It appears to me to be decidedly the best practice to plant corn for a fodder crop, and for ensilage, so that it will have abundant room and light for the vigorous growth of the lower leaves and the development and approximate maturity of the ears. The ensilage of such a crop, under proper conditions, cannot fail to give satisfaction as to the quantity and quality of the feed obtained from a given area.

The importance of maturity, or a close approximation to maturity, in the plants fed to animals, will be best seen by some practical applications of the principles of physiological science to the intimate relations of plant and animal life. From the farmer's standpoint his field crops may be looked upon as machines for making food for animals from inorganic materials which the animals could not otherwise make use of in their nutritive processes.

In order to obtain the largest possible returns from these living plant machines, they must be made to work to their full capacity, under conditions that are the most favorable for the exercise of their special endowments. They must have an abundant supply of the raw materials required in making organic substances, and of energy, in the form of light, and heat from the sun, to be expended in the work of construction they have to perform. Any deficiency in either of these essentials (inorganic raw materials, and energy) must detract from their efficiency as machines in the work they have to do.

The resulting products of these plant machines, which we call organic substances, as starch, sugar, fat, proteids, etc., are not only food for animals in the sense that they furnish materials for building animal tissues, but, what is quite as important, they are also stores of potential energy that is liberated and made active in doing work in the constructive processes of the animal economy.

One of the indications that these plant machines have performed the full measure of useful work they are capable of doing, is the store of reserve materials provided for future seed formation, as in the bulbs of our root crops, or the actual formation of seeds, as in the cereals, to provide for the future reproduction of similar machines. In other words, seed formation, or provisions for seed formation, marks the summit or limits of the profitable work which plants can do in the manufacture of food for animals; and the farmer will find his interests are best subserved by keeping up, or allowing these activities to continue, until the limit is at least nearly reached. Immaturity in plants, therefore, implies unfinished, imperfect work in the construction of organic substances, and in the storing up of energy, and a corresponding deficiency in the supplies of nutritive materials furnished for the food of animals.

CHAPTER VIII.

FILLING THE SILO.

When the crop has reached the proper stage of maturity for harvesting, the work of filling the silo may begin. As green fodder is heavy to handle, strict economy should be practiced in the labor expended in harvesting the crop and filling the silo, to reduce the cost of the silage to a minimum. Reaping machines have been successfully used in harvesting, and it is claimed that they can be made to do the work well, by cutting but one row at a time, even when the crop is a heavy one. Taking the wear and tear of the machine into account, and especially with the larger varieties of fodder corn, cutting by hand will, perhaps, be found quite as economical in the long run, particularly if the crop is a reasonably heavy one. In hauling from the field to the silo, two or three wagons, and one or two teams, according to the distance of the haul, will be found convenient, but no arbitrary rule can be laid down in regard to the details of such work, on account of differences in the conditions, in each particular case, and the farmer must plan the work for himself to make every step count as far as possible.

The wilting, and partial drying, or curing of the fodder, in the field before hauling to the silo, is frequently recommended. As a saving in the weight of the fodder in the subsequent handling, this may be a decided advantage, but the utilities of the practice must depend largely on the condition of the crop as to maturity, and the amount of water it contains, and it will hardly be safe to formulate any definite method of procedure, where good judgment is required in deciding upon the best course under the special conditions presented in each case. The fact that the fodder is not necessarily injured by leaving it in the field, in bunches as cut up, for a short time, or even several days in favorable weather, is, however, of some practical importance, as considerable latitude may be admissible in economizing labor, in adjusting the relations of the cutting and hauling gangs of workmen.

The fodder may be preserved by packing it in the silo as it comes from the field, but the practice is not to be recommended, as the whole stalks are not conveniently handled, or packed, in the silo. It will be far better to cut the fodder in about half-inch lengths with a suitable machine, rigged with a carrier to deliver the cut fodder over the top of the silo. On the whole, this will be found a labor-saving operation, and, moreover, the cut fodder will pack to better advantage in completely filling the silo, and it is also more conveniently fed out. The fodder cutter should be sufficiently strong to cut the large stalks with their attached ears without danger of getting out of repair, and the carrier should deliver the cut fodder, as near as may be, at the top and middle of the silo.

Some differences of opinion have been expressed as to the length of cut that is most desirable, but in a large proportion of cases, the range of variation reported is from three-eighths to three-fourths of an inch, and very few longer cuts are mentioned. The size of the stalks may be taken into account in deciding upon the length of cut it will be desirable to make. With small stalks a longer cut may be admissible, but there appears to be no good reason for making a shorter cut than one-half inch, under any conditions. It is perhaps not necessary to cut the fodder for ensilage as short as may be advisable with dry fodder.

Until within a few years past there has been a prevailing notion that a silo must be rapidly filled, in a single day if possible, and that a large expenditure of labor was required in treading and packing the fodder as it was put in, and to make assurance doubly sure, even horses and mules have been used to tramp down the fodder as the silo was being filled. The next assumed element of success was to put on a tight cover of planks as soon as the silo was full, and load it with heavy weights at the rate of from 100 to 200 or more pounds per square foot.

A better system now prevails, and these expensive details which were believed to be of paramount importance in the ensilage of green fodder, are known to be useless expenditures of labor.

Several years ago, after making a series of experiments on the thermal death-point* of the bacteria of fermentation, I ventured to make the suggestion that the rapid filling and packing of the silo was unnecessary, and that with slow filling, without treading down the fodder, the temperature of the mass would rise to a point that is fatal to the bacteria that cause the acid fermentations, and that "sweet ensilage" might thus be made. These statements were made in lectures at several different places, and I was informed by a number of persons, that they could now understand the results of their experience the preceding year, as they had unintentionally made sweet ensilage of superior quality, as the result of acci-

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* For the relations of temperature to the activities of bacteria see pp. 60-61.

dental and unavoidable delays, of several days, in the filling of their silos, so that the silage became "quite hot" before it was covered and weighted. Their fears that the silage was entirely spoiled were not realized, as it proved to be the best they had ever made. Soon afterwards I learned that Mr. George Fry, Chobham, England, had made sweet ensilage by the process of slow filling, when the temperature in the silo exceeded 122°. In the ensilage of clover and rye-grass, he observed temperatures of 135° to 158°.

On the publication of these suggestions, with the corroborative evidence I had collected in regard to the practicability of the method, I was assailed on all sides, in the agricultural papers of the day, and many theoretical objections were urged that were assumed to conclusively disprove the data on which this new departure in ensilage was founded. At the present time, however, my method of filling the silo, to avoid objectionable acidity, has been quite generally adopted, and the favorable reports received in regard to the practice, are the best answer to former criticisms.

Quite recently it has been discovered that the weights, and even the tight plank covers that were formerly considered of prime importance, can be dispensed with to advantage. In a recent communication from Mr. John Gould of Ohio, who has made extended observations among the silos at the West, he informs me that weights are now seldom used, and that but about one-half of the silos are covered with boards or planks, and that the number of these is rapidly diminishing. Tarred roofing paper covered with a layer of straw or coarse hay from twelve to sixteen inches in depth is frequently the only protection to the top of the silo, while many omit the paper altogether and only rely upon the simple covering of straw or marsh hay, which, they claim, from their experience, is quite as efficient in protecting and preserving the silage as the more expensive methods.

In the evolution of the silo, and the practice of ensilage, remarkable progress has been made, and the evident tendency is towards simplicity in all directions, and a consequent saving of labor, which of course diminishes the cost of silage.

The filling of the silo is no longer a task that must be hurried to completion in one or two days, at any cost, and at the sacrifice of all other interests, but it comes in as part of the regular routine of farm work, and requires no extraordinary addition to the usual working force of the farm.

The usual practice, in filling the silo to avoid acid fermentation, is to put in but two and one-half or three feet in depth of the fodder in a single day, and this is allowed to heat until a temperature of about 125° is secured. Another similar layer is then added and left to heat in the same manner, and this process is repeated until the silo is full. From one to three days, or even more, may intervene between the filling in of any two contiguous layers, according to the condition of the fodder and the progress of the heating process. Each layer is carefully packed at the edges and corners to completely fill all of the space, but any tramping beyond what is required for this purpose is avoided.

When there are two or more silos, the filling may alternate from one to the other, a layer of fodder being put into one while the others are heating, and with a single long silo, without a partition, the two ends may be treated as separate silos and alternately filled in the same way.

As the heat developed in the silage may be lost by conduction and radiation, it is found that a temperature of from 122° to 125° is not as readily obtained at the bottom and corners of the silo, and along the walls, especially if they are of masonry or concrete.

This difficulty is obviated, to some extent, by care in the management of the fodder as the silo is filled. The fodder put in the first day is not leveled at once, but allowed to remain in a loose pile in the middle of the silo until it is well heated and the fodder for the next layer is ready to put in. The hot silage is then leveled and packed at the corners and *immediately* covered with the fresh fodder of the next layer. With a similar purpose in view, the last load or two of the fodder of each layer is left in a pile in the middle of the silo to heat until ready to fill in the next layer. In this way hot silage is provided in the middle of the silo, to fill the corners where the heat is likely to be deficient. When the silo is full the last layer is treated in the same way, and when the desired temperature is developed the surface is leveled and a cover of tarred paper and cut straw or coarse hay, as described above, is finally added. This cover should be well packed at the sides and corners, and a few loose boards may be laid on, to keep it in place.

This simple method of covering was naturally suggested by the well-known fact that a few inches in depth of the surface of the silage was often moldy and spoiled, and the obvious remedy for this difficulty was the addition of a stratum of straw or other coarse materials for the molds to grow on, and thus protect the layer of silage beneath from their action. This covering of straw is soon saturated with moisture from the heated mass under it, and is thus made more compact and impervious to atmospheric influences.

Aside from the check given to the acid ferments, the slow method of filling the silo has advantages which commend it to popular favor. The work can be carried on leisurely and economically with the ordinary farm force, and the entire storage capacity of the silo can be utilized. Under the old method of rapid filling, thorough packing and heavy weights, the space left at the top of the silo from the settling of the silage could not be filled with fresh fodder without taking off, and replacing, the heavily weighted cover, which involved a considerable expenditure of labor. In the improved method of filling, the settling of the silage, favored by the high temperature, goes on gradually and continuously, as the fodder is put in, and there is nothing to prevent successive additions of fresh fodder until the silo is completely filled.

It will be seen that all details of the slow filling process are managed to favor the development of a temperature of at least 122° in all parts of the silo, to keep in check, or diminish, the activity of the bacteria of the acid fermentations.

The cause of the temperature developed in the silage has not been definitely ascertained, but from the facts presented in the chapter on Fermentation, it may, with apparent good reasons, be attributed to the normal activities of the living plant cells in the maturation of their contents. There is, at least, no evidence that it is caused by a true fermentation, or by any direct process of oxidation. There is, likewise, no evidence to warrant the assumption that the high temperature involves a direct loss of nutritive materials, as it is well known that heat is evolved in the normal metabolism of plant cells in the elaboration of organic substances. That the metabolism of the cells of maize goes on after the plant is cut up, is shown in the maturation of the grain in the ear while attached to the stalks that are cut up before the ears are glazed, and we cannot doubt that heat is liberated in this process. This metabolism of the cells must continue, in the presence of sufficient moisture, as long as they retain their vitality.

It must be admitted that the chemical changes taking place in the ensilage of green fodder have not, as yet, been determined, and we have much to learn in regard to the real transformations of matter and energy involved in the process, under different conditions. In investigations relating to the chemistry of the silo, the biological factors concerned in the metamorphoses of matter and energy cannot be ignored, and any generalizations that are based on inferences from Liebig's obsolete theories of fermentation can only mislead, by obscuring the fundamental elements of the problems it is proposed to solve. The uniformly favorable reports that have been made by those who have tried the new method of filling the silo, both as to the quality of the silage and the certainty and uniformity of the results obtained, show that the process has merits that are recognized by practical men as a decided improvement on former methods.

It has been proposed to revive the practice of M. Reihlen, of harvesting the ears of corn when the crop is sufficiently matured, and let them cure in the husks, while the fodder is ensilaged by itself. There may be advantages in particular cases that might justify the expenditure of the additional labor required in this plan, but as a rule it will probably be better economy to run the stalks and ears together through the feed cutter and ensilage the crop as a whole.

CHAPTER IX.

ENSILAGE AND FARM ECONOMY.

The advantages that may be derived from the ensilage of green fodder have, undoubtedly, been exaggerated by its enthusiastic advocates, and on the other hand, the opponents of the practice have failed to recognize its intrinsic merits in their efforts to show that it involves needless expense and a loss of nutritive materials.

Notwithstanding the reaction from over-estimates of its value, and the many objections that have been urged against it, the ensilage of fodder corn is rapidly extending, and as the economies of the system come to be better appreciated, the indications are that it will be quite generally adopted on farms where the feeding of live stock is made a prominent interest.

The silo cannot be looked upon as the only essential element of success in farm practice, or as an inexhaustible mine of wealth that may be drawn upon at pleasure, without an equivalent rendered. The farmer can only take from it the food constituents he has put in, and the benefits he may derive from the ensilage of the fodder will largely depend on other considerations than the one of mere nutritive values. Experiments have been made to test the relative feeding value of dry fodder corn and the same fodder ensilaged, with results that are not decisive, as the problem is an exceedingly complex one that cannot be solved by a few simple tests with a small number of animals. Such investigations have a theoretical interest, and should be encouraged, but from the very limits of their scope they cannot settle the practical economy of ensilaged fodder. The form in which a given food is supplied to animals, and even its palatableness, may have a more decided influence in determining its nutritive value, than slight differences in chemical composition. The same food may give different results when fed to different animals, and the benefit derived from it by the same animal may vary widely at different times, so that extreme caution should be exercised in interpreting the results of feeding experiments, and in the generalizations based upon them.

From a chemical point of view, there is, beyond question, a loss of nutritive materials in curing corn fodder by the ordinary process of drying, and there is also a similar loss in the ensilage of the same fodder, but the differences in these losses are comparatively unimportant in deciding upon the relative practical economy of the two methods.

The demand for a supply of succulent food in the system of feeding, the labor involved in harvesting, storing and feeding out of the crop, and the waste of the fodder in feeding under ordinary conditions of management, must all be taken into the account in striking a balance to determine the best paying method.

It is generally admitted that some form of succulent food is a desirable addition to the ordinary winter rations of live stock, and the question arises as to the best and cheapest method of providing it. The English farmer looks upon his root crop as an indispensable adjunct of his food supply for farm stock, but in this country, for many reasons that need not be stated, the raising of root crops will not, in all probability, be extensively practiced. The steaming of feed of all kinds has been urged as the true solution of the problem, but this method has failed to gain the approval of a large majority of farmers, and where it has been tried on a considerable scale, it is apparently on the decline.

The ensilage of fodder corn has been found a convenient and economical method of providing a supply of succulent food during the winter months, or in seasons of drought, and when properly conducted, as a part of a consistent system of farm management, it has given the most satisfactory results, and, in American farm practice, at least, it must almost entirely supersede the raising of root crops, or the steaming of fodder. Maize, from its many valuable qualities, is conceded to be the most important farm crop in the United States, and its preservation in the form of green winter food will tend to add to the deservedly high estimation in which it is held as the main stay of American agriculture.

The necessary expense involved in the ensilage of fodder corn has been very much overrated by those who have not made a trial of it. With the comparatively cheap silos of wood, and discarding the heavy weights that were formerly used, it is believed that fodder corn can be put in the silo, and finally fed out, at less expense than it can be cured in stooks in the field, hauled to the barn and run through the feed cutter, and fed to animals, and in the winter management of stock the ensilaged fodder has the advantage of convenience, and decidedly less waste in feeding. Hon. Hiram Smith of Wisconsin makes the statement that, by actual trial, he found that a load of fodder corn could be run through the feed cutter, elevated more than twenty feet, and deposited in the silo, in seven to eight minutes' less time than was required to set it up in stooks in the field.

There is, however, another consideration that must have weight in estimating the economy of the silo. Fodder corn is rapidly growing in popular favor for summer feed, and it would be more extensively cultivated for winter feeding were it not for the difficulty of curing it, particularly in wet seasons, and its liability to injury when stored in the barn or in stack, from the readiness with which it absorbs moisture. Ensilaged fodder, on the other hand, is exempt from the influence of the atmospheric conditions that are so annoying in the management of dry fodder, and it is always ready for use when wanted. The relations of the silo to the general system of management suggest many questions of practical interest that the farmer must carefully consider. Every interest of the farm has its influence, for good or ill, on every other interest, and the aim should be to make each supplement the others and thus aid in increasing the aggregate of profits. In a large proportion of cases the net proceeds of the farm will depend more upon the harmonious adjustment of many details than on the disproportionate development of any special interest.

Animal husbandry, in one form or another, must become a prominent feature of American farming, under existing conditions of production, to secure the largest immediate profits, and at the same time conserve the elements of fertility as a resource for the crops of the future. In the feeding of animals the direct returns in animal products should not be the only consideration, as the value of the residues in the form of manure must have an important influence on the ultimate sum of the results of the system of management.

The ensilage of green fodder may be practiced with advantage if it is made to supplement other interests of the farm, and is not allowed to become the sole reliance, or the dominant factor in production. To successfully meet the world-wide competition in agricultural products that is forced upon the farmer by the rapid development of the means of transportation, and cannot be evaded, every resource must be utilized, under a well-planned system, and the economies of the farm must be studied from every standpoint.

With the introduction of the silo should come a systematic readjustment and modification of many details of the ordinary routine of practice, and the adoption of improved methods in every department and interest of the farm. No arbitrary, empirical rules can be formulated in regard to the minutiæ of farm management, but good judgment and a thorough knowledge of practical farm economy will be required in adjusting the various interests to the prescribed conditions of the locality, in order to realize the largest net returns from the aggregate results.

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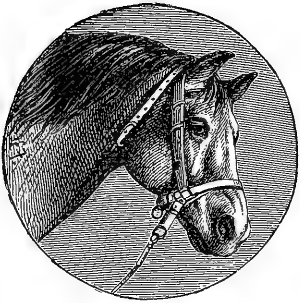

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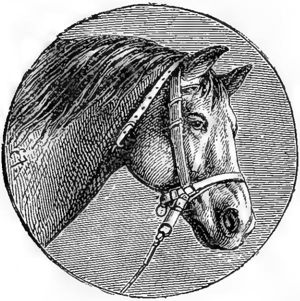

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