Feeds and Feeding

A Hand-Book for the
Student and Stockman

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FOR THE

STUDENT AND STOCKMAN

BY

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"The eye of the master fattens his cattle."
—*German adage.*

ELEVENTH EDITION,
Revised and Entirely Rewritten

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PREFACE.

The widespread favor with which *Feeds and Feeding*, first published in 1898, was received is indicated by the fact that nine editions have since followed. The plates used by the printer having become worn and new ones being necessary, the opportunity has been used to revise, bring down to date, and entirely rewrite the book.

In Part I the description of the processes of digestion have been amplified, and the studies of Pawlow on the work of the digestive glands touched upon; the far-reaching findings of Kellner and Armsby on the energy value of food are summarized; the importance of the mineral matter in food has been duly recognized; Jordan's ingenious study is recited, settling at last the long debated question of the carbohydrates as a possible source of fat in the milk of the cow; the Wolff feeding standards are retained because of their great help to the student of both the old and the new in feeding problems; Haecker's modifications of these standards for the dairy cow are presented; the advanced feeding standards proposed by Kellner and Armsby in substitution for those of Wolff are briefly presented; also the helpful Scandinavian feed-unit system. For help in this part and elsewhere Kellner's recent work, *Die Ernährung der landwirtschaftlichen Nutztiere*, has been heavily drawn upon.

In Part II the various new feeding stuffs are considered along with the old. The supreme importance of combining the legume roughages with Indian corn for the economical feeding of farm animals is duly emphasized, also the economical importance of soilage and silage; and finally the vital relation of animal husbandry and the manurial residue of feeding stuffs to the economical maintenance of soil fertility.

In Part III all the important findings of the experiment stations, to date, on the value of feeding stuffs, obtained thru feeding trials, are recorded. All tabular matter of feeding trials, both old and new, is presented in an entirely new form, greatly simplified. The studies of Zuntz on the relation of feed to the work performed by the horse, and rations for horses as gathered by Langworthy, are presented. The findings of Skinner, Mumford, and Waters on the feed requirements in beef production and the importance of the legume roughages in the rations of fattening cattle are given merited prominence.

Finally, the Appendix Tables, giving the composition and fertilizing value of the various feeding stuffs, a marked feature of the old work, have been extended and brought down to date.

Those familiar with the earlier editions may observe that some of the experiments reported and other matter given in the old book have been supplanted by later and better material. The reader who notes that much is still lacking in this book is reminded that the subject of animal nutrition and the rational feeding of animals is one of great complexity, and that it is only about seventy years since trained men began to search out and put into form the matter here reported.

Thruout the book the object has been to present the findings of the laboratory, the feed lot, and the stable bearing on the problems of stock feeding in simple language and few words. The scientific terms necessarily used have been plainly defined, and thru constant repetition should almost unconsciously become a part of the vocabulary of all who use the book. The observant reader will discern that the results of the investigations as set forth in this work do not tend to render the great art of stock feeding complex and abstruse, but rather to greatly simplify it. In evidence of this, note the smaller allowances of expensive concentrates recommended in the rations for dairy cows and for fattening cattle when corn silage and the legume forages are rightly used to supply the roughage; also that grinding and cooking feed is, for the most part, discouraged, in opposition to the theories and teachings of earlier times. Those who may be rather surprised that the ways marked out in this book are after all so simple and plain should remember that knowledge and wisdom are always kind in leading us along easy paths.

While the number of pages in the new *Feeds and Feeding* is somewhat less than before, the total matter contained has been materially increased thru enlarging the printed page, changing the style of type, simplifying the tables, avoiding repetitions, etc.

Acknowledgment is due my co-workers, Professors Woll, Hart, and McCollum, for appreciated assistance on Part I; to Messrs. A. D. Faville, O. Lloyd-Jones, and E. P. Smith for help in collating and arranging the tables of feeding trials; and especially to Mr. F. B. Morrison for faithful assistance covering the whole range of the book.

October, 1910. W. A. HENRY.

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INFORMATION TO THE READER

When seeking information on any subject presented in this book, the reader should first consult the copious index, the figures of which refer to the *page* on which the topic is presented. Additional information bearing on the subject given at other places may be found by following up the numerous references set in black-face figures in parentheses occurring in the body of the text. These figures refer to the numbered *black-face* side-heads, and *not to the pages.*

FEEDS AND FEEDING.

Part I.

PLANT GROWTH AND ANIMAL NUTRITION.

CHAPTER I.

THE PLANT; HOW IT GROWS AND ELABORATES FOOD FOR ANIMALS.

I. Plant Growth.

Aside from air, water, and salt, plants either directly or indirectly supply all food for animals; it is therefore proper in beginning these studies to briefly consider how plants grow and elaborate this food.

1. The food of plants.—Of the 80 or more elements known to the chemist, only 13 are essential to plants, viz.: carbon, hydrogen, oxygen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, sodium, silicon, and chlorin. Iodine and manganese are present in some plants, and while not regarded as vitally necessary may be more or less useful. With the limited exceptions noted further on, plants cannot make use of the elements, as such, for food, but are nourished and supported by chemical combinations of the elements.

Water is the largest single component of the plant, that not held in chemical combination constituting from 75 to 90 per ct. of its fresh weight. The plant obtains practically all its water from the soil thru its roots, only a small amount being taken from the air by the leaves. Soil water, absorbed by the roots, enters the cells of which the plant is composed and passes onward and upward thru the stem, moved by capillarity and sap currents, eventually reaching every portion of the structure, being especially abundant in the leaves and growing parts. Thruout its existence the plant takes great quantities of water from the soil, giving most of it off again to the air thru its leaves and green parts. Lawes and Gilbert of England found that wheat and clover plants take from the soil by their roots and give to the air thru their leaves about 200 lbs. of water for each lb. of dry matter they produce.

Next to water, carbon dioxid or carbonic acid gas is the great food material of plants. Ten thousand parts of air contain about 4 parts of carbon dioxid, and about 28 tons of this gas rests over each acre of the earth's surface. The supply of carbon dioxid is never exhausted from the air because thru the decay and dissolution of plant and animal matter it is being constantly returned thereto. On the under surface of plant leaves are innumerable minute openings or pores, leading inward among the cells of the leaf structure. The air, penetrating these pores, supplies carbon dioxid which is absorbed into the cells and thus enters the plant proper.

Nitrogen abounds in the living, growing parts of plants. Despite the fact that about three-fourths of the air is nitrogen gas, with the exception noted farther on, plants cannot take it up as such, but obtain their supply from the soil by means of their roots, either in the form of nitrates or as ammonia, chiefly the former.

The mineral substances required by plants are taken from the soil thru the roots. They may be grouped as follows:

Sulfates		potassium.
Phosphates		calcium.
Nitrates	of	magnesium.
Chlorids		iron.
Silicates		sodium.
Carbonates		ammonium.

Sulfur, in small amount, is a component of plant proteins. Phosphorus, likewise in small amount, is present in the life-holding protoplasmic protein of the leaf cells and also abounds in the protein of seeds. Potassium, vital to the formation of plant protoplasm, is probably one of its components. Iron also seems to have a specific function to perform in the growth of the plant. It is universally found in plant tissues. Calcium and magnesium are vital to plants, tho their uses are not well understood. Silicon and sodium, tho always present, are regarded by some authorities as not essential to plant life.

Free oxygen gas is absorbed by seeds during germination, and a small amount is being constantly absorbed by the leaves and fruits of plants. Bacteria inhabiting nodular growths on the roots of leguminous plants, such as clover, alfalfa, and peas, take nitrogen gas from the air and pass it on in combined form to the host plant, thus indirectly supplying this important element. With these exceptions, the elements, as such, are never used in uncombined form by plants, but serve them only when in chemical combination.

2. Plant building.—Living matter is distinguished from non-living matter by its power to grow, to repair its own waste, and to reproduce itself. In plants the life principle is most in evidence in the transparent, viscous protoplasmic masses found within the cells of the green parts, principally the leaves; and because of inherent differences therein, each plant possesses an individuality and is able to grow and reproduce itself after its own manner.

The interior of the plant is everywhere bathed with juice or sap, which is the great fluid medium for conveying the chemical compounds, gathered by leaf and root, to the place where they are formed into organized plant substances or building materials proper, and, in turn, for transporting the materials thus elaborated to all parts where needed. By means of this sap, the green-colored protoplasm in the leaf cells is supplied with carbon dioxid taken from the air by the leaves, and water, nitrates, and other soluble mineral salts taken by the roots from the soil. The carbon dioxid, salts, and water, commingling in the protoplasmic masses, are there decomposed, and their atoms rearranged to form the various primary plant compounds. The first definite result of such union may be some form of sugar or starch, with the excess oxygen given back to the air as a free gas. It is thru the chlorophyll-containing protoplasm of their leaves that plants are able, under the influence of sunlight, to decompose carbon dioxid and water and to recast their elements into such basal plant substances as sugar and starch. Sugar and starch contain much energy which may be set free as heat when these substances are burned or otherwise broken up. Carbon dioxid and water have little internal energy, and so on being decomposed do not liberate heat. Energy must therefore be supplied whenever sugar and starch are formed out of the elements contained in these two energy-poor bodies. This energy comes from the sun and is seized and used by the active life-holding protoplasm in building carbon dioxid and water into energy-holding sugar and starch.

3. The carbohydrates.—Sugar and starch are the two great common elementary structural substances of plants. With their secondary products, the celluloses and pentosans, they constitute the major portion of all dry plant substance. They are grouped under the term *carbohydrates,* meaning formed of carbon and the elements hydrogen and oxygen in the proportion existing in water, the chemical formula for which is H_2O. The molecular composition of the leading carbohydrates is shown in the following formulæ:

Glucose Levulose	$C_6H_{12}O_6$
Cane sugar Maltose	$C_{12}H_{22}O_{11}$
Starch Cellulose	$(C_6H_{10}O_5)x$
Pentosan	$(C_5H_8O_4)x$
Pentose	$C_5H_{10}O_5$

Chemists hold that the molecules in the bracketed groups are in reality far more complex than the formulæ indicate, the actual molecule being many multiples of the group here given. The formulæ not bracketed are held to express the actual atomic composition of the molecule.

All sugars—*sucrose, glucose, maltose, levulose,* etc.—are soluble in the juices of the plant and constitute the common, portable carbohydrate building material of plants, capable, by diffusion and sap currents, of passing to all parts of the structure as needed. Some plants, the beet and the sugar cane for example, store their carbon reserve as sugar. *Starch,* however, is the common intermediate carbohydrate reserve of the plant world. It is insoluble in the juices of the plant and so cannot be directly transported as can the sugars. Starch abounds in most seeds, closely packed about the germs, as in the kernels of wheat, Indian corn, etc. Often it is stored in the underground parts of plants, as in potato tubers. When the starch thus stored is needed in other parts of the plant, it is changed by a ferment called diastase, thru the addition of water, to maltose, a soluble sugar, which can be further changed to glucose by the addition of more water. The sugars so formed can then be passed from cell to cell until their destination is reached, where they may be again changed to starch, pentosans, or cellulose, as required.

Plants are primarily composed of minute cells, variously grouped and modified, the walls of these cells being formed of cellulose. Cellulose is the great permanent, insoluble structural substance of the vegetable world, constituting as it does almost the whole of the skeleton or framework of plants. As before shown, cellulose is similar to starch and sugar in general composition and originates from them. In the dense wood of trees the cell walls are thick, in some cases nearly filling the entire cell. In the more tender twigs and leaves they are less dense, while in the still softer portions, such as fruits and seeds, they are thin and delicate. More or less mineral matter or ash is built into the cell walls of plants, being especially abundant in the bark of trees, as is shown when such material is burned.

The *pentoses* and *pentosans* are carbohydrates with 5 atoms of carbon in the molecule, in place of 6 as in the sugars and starches. The pentoses correspond to sugars, and the pentosans to starches and cellulose. The pentosans are largely associated with cellulose in the more woody portions of the plant, being abundant, for example, in wheat bran and corn cobs.

4. Vegetable fats and oils.—In some cases the plant stores carbon in the form of *fat*, which is solid at ordinary temperatures, or of *oil*, which is liquid. Such storage is entirely possible since fats and oils are formed from the same elements that exist in the carbohydrates. In vegetable fats and oils the molecules are composed of a larger number of atoms than are those of the sugars, and the proportion of carbon is greater, as the following formulæ of three common vegetable oils or fats show:

Stearin	$C_{57}H_{110}O_6$
Palmitin	$C_{51}H_{98}O_6$
Olein	$C_{57}H_{104}O_6$

Vegetable oils and fats give off more heat on burning than do the carbohydrates, because they contain relatively more carbon. Oils and fats most abound in the seeds of plants and represent carbon energy stored in condensed form. When seeds containing oil, as the flax seed for example, begin to grow, the oil is changed over into products which nourish the growing plantlet the same as do the products of starch in ordinary seeds.

5. Nitrogenous compounds.—We have learned how in the life-holding protoplasmic masses of the green parts of plants, especially their leaves, the carbohydrates and fats are formed from the elements of carbon dioxid and water by the energy of the sun. To these life centers of protoplasm, with their green coloring matter, holding sugar and starch, the sap brings nitrates and other mineral salts gathered by the roots from the soil. Thru the union of the elements of the nitrates and other salts with those of the starches and sugars there is formed a new group of complex compounds called *crude proteins*, which, in addition to carbon, hydrogen, and oxygen, found in the carbohydrates, contain nitrogen, sulfur, and sometimes phosphorus. The nitrogenous compounds are the most complex of all plant substances. Osborne of the Connecticut Station gives the following as the probable molecular composition of legumin, a protein found in the seed of the field pea, and hordein, found in the barley grain:

Legumin	$C_{718}H_{1158}O_{238}N_{214}S_2$
Hordein	$C_{675}H_{1014}O_{194}N_{181}S_4$

Because of their great variety and complexity, the nitrogenous compounds are the most difficult of all plant substances for study and classification. Able organic chemists are attacking these intricate problems with great energy and patience, and important discoveries are being made. While it is certain that the old classification of these compounds must be superseded, it is too early to present any satisfactory substitute. Since this work sets forth only the briefest and most informal consideration of the matter, it seems best to adopt the following grouping of the nitrogenous compounds of plants, in so doing holding to what has been found in the past and helping toward what is to come.

Crude protein is the term employed to designate all the nitrogenous compounds of the plant. The chemist finds that about 16 per ct. of the plant proteins is nitrogen. Accordingly, he multiplies the nitrogen found in any given plant substance by 6.25 ($^{100}/_{16}$=6.25) and calls the product crude protein. Crude protein embraces two groups of nitrogenous plant compounds, proteins and amids.

Proteins are the more highly organized forms of crude protein. They are not always soluble and therefore not transportable in the juices of the plant. The life of the plant centers in its protein-containing parts, such as the active leaf cells and the germs of seeds.

Amids are the nitrogenous, portable building compounds of the plant. They are soluble in its juices and are the common vehicle for conveying nitrogen to needed points thruout the plant structure. Out of the soluble amids the plant constructs its still more highly organized protein compounds. During the active period of the plant's life, amids are constantly being formed out of the elements composing sugar or starch and the nitrates and other mineral salts. These amids are transported to needed points and there changed into the proteins. As a consequence the amids do not usually continue to accumulate in the plant. Just as starch and sugar may be changed one into the other in the plant, so the proteins and amids may be changed one into the other as plant necessity may require. When germination starts in a seed, an enzyme or ferment contained therein acts upon the insoluble proteins stored in and about the germ and changes them to soluble amids, so that the nitrogen may be transported to the newly forming parts of the plantlet. When corn forage is placed in the silo, much of the proteins it then contains is changed back to amids thru the fermentations which occur.

Very little crude protein is found in the older woody parts of plants, the greater portion always being concentrated at the point of growth, or in the leaves, seeds, and reproductive parts. The germ of seeds is largely protein, and the rich nutritive substances in the grain close about it usually hold much protein. It is in the life-holding protoplasm in the green parts of plants, principally in their leaves, that all the crude inorganic compounds taken up by the plant from air and soil are elaborated into true plant substances by sun power. The life processes of the plant are maintained and all changes are wrought thru its nitrogenous or protein compounds, and a knowledge of such fact is not only of interest, but has many practical bearings for the farmer and stockman.

6. Mineral compounds.—The elaboration of food materials in the protoplasmic masses, as well as the development of young plants from the seed, requires the presence of mineral matter, or ash, which is found in relatively small amount everywhere thruout the plant. The leaves contain more ash than do the other parts, due to the life processes within the leaf cells and the constant evaporation of water from their surfaces by which the ash in solution is left behind. The ash content of the bark of trees and stems of plants is also often high.

7. The end of plant effort.—If we study the life history of a plant, we observe that its first effort is toward self-establishment and enlargement. At such time all the elaborated material, as fast as formed, is transferred to the growing parts that the plant may be built up and established. As the plant approaches maturity, its energies are changed from growth to reproduction, or the perpetuation of its kind. The nutrients in the juices, which were formerly directed to the growing portions, are now turned toward the reproductive parts. First come the blossoms, then the young enlarging fruits. Into these the sugars, amids, and mineral substances, all elaborated and worked over by the plant in its leaves, are poured in a steady current. The wheat plant resulting from a single kernel bears a hundred fruits in the shape of seed grains, while the Indian corn plant may produce a thousand-fold. In each of these grains is a miniature plant, the germ, composed largely of protein, about which is stored a generous supply of rich nutriment—proteins, starch, sugar, oil, and mineral matter—all in compact, concentrated form, awaiting the time when the germ shall begin life on its own account. In the tuber of the potato the cells are packed with starch, while in the beet root the stored material is largely in the form of cane sugar. Each germ, or reproductive part, is surrounded with food nutrients stored after Nature's choicest plan to aid the new life which is to follow.

8. Plants support animal life.—Nature has decreed that it is the function of plants to build inorganic matter taken from earth and air into organic compounds, in which operation the sun energy employed becomes latent. Thru the life processes the various plant compounds used as food by animals are, after more or less change, built into the animal body, or are broken down within it to give heat and energy. In this change and dissolution the sun energy which became latent or was hidden in the growing plant is again revealed in all the manifestations of animal life. In the coal burning in the grate we observe the reappearance of the energy of the sun which was stored in the plants of ages ago. In the stalks and ears of corn which we feed our cattle we are furnishing energy received from the sun and rendered latent by the corn plant during the previous summer. Thus it is that the stockman, when supplying plants and seeds to the animals under his care, observes in their growing bodies, warmed by internal fires, the energy of the sun transmitted by the plant to the animal. To the plants of the farm the stockman turns for the nourishment and support of his animals. A general knowledge and full realization of how plants live and grow is therefore not only of interest, but also may be helpful in a thousand ways.

II. How the Chemist Groups Plant Substances.

In the following table, taken from Table I of the Appendix, the composition of a few common feeding stuffs is arranged after the manner adopted by agricultural chemists. The first column gives the name of the feeding stuff, followed by the number of analyses from which the average composition is derived. The remaining columns give the average percentage composition of the several nutrients.

Sample table showing the percentage composition of plants.
(For full table consult Table I of Appendix.)

Feeding stuff	No. of analyses	Inorganic matter		Organic matter			
					Carbohydrates		
		Water	Ash	Crude protein	Fiber	N-free extract	Fat
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Pasture grass	--	80.0	2.0	3.5	4.0	9.7	0.8
Mangels	9	90.9	1.1	1.4	0.9	5.5	0.2
Dent corn	86	10.6	1.5	10.3	2.2	70.4	5.0
Red clover hay	38	15.3	6.2	12.3	24.8	38.1	3.3

9. Water.—To determine the amount of water in a fodder the chemist places a small quantity of the material, finely divided, in a dish and ascertains its weight. It is then dried in an oven at a temperature of 212° F. for several hours and again weighed. The difference between the first and last weights represents the amount of water in the sample. From the third column of the table we learn that fresh pasture grass is about 80 per ct. or four-fifths water, while dent corn contains 10.6 per ct. and red clover hay 15.3 per ct. of water.

10. Ash.—The chemist next burns the sample, weighing as before, to ascertain its ash or mineral content. From the next column of the table we learn that 100 lbs. of fresh pasture grass has 2 lbs. of ash, which is about twice that in mangels. Red clover hay has 6.2 lbs. of ash per 100 lbs. This large amount is due to the accumulation of mineral matter in the clover leaves during growth, to earthy matter washed upon the growing plants by rain, and to dust settling on the hay before it is housed. The foreign material is not really plant ash, but of necessity is reported as such. The ash and water of plants constitute the so-called *inorganic matter;* the other components combined are termed the *organic matter.*

11. Crude protein.—The process of determining the nitrogenous constituents of feeding stuffs is too complicated for presentation here. Suffice it to say that the nitrogen content is found and the result multiplied by 6.25 to give the crude protein, since about 16 per ct. of plant protein is nitrogen ($^{100}/_{16}$=6.25). From the table we learn that pasture grass contains 3.5 lbs. of crude protein per 100 lbs., while dent corn contains over 10 lbs., and red clover hay still more.

12. Fiber.—The woody portion of a feeding stuff is determined by boiling a sample thereof successively in weak acid and alkali and washing out the dissolved matter. That which remains is termed *fiber.* Fiber consists mostly of cellulose and is the woody portion of feeds. The grains of Indian corn contain only 2.2 per ct. of fiber, while clover hay yields nearly 25 per ct.

13. Fat.—A sample of the pulverized dried fodder is treated with ether, which dissolves the fats, waxes, resins, chlorophyll or green coloring matter, and similar substances. This, most properly called *ether extract* in works on plant analysis, is for convenience termed *fat* in this work. The ether extract of seeds is nearly all true fat or oil, while that of the leaves and stems contains chlorophyll, wax, etc. By the table, mangels are shown to yield only 0.2 lb. of fat per 100 lbs., while corn carries 5 lbs., the extract in this case being true fat.

14. Nitrogen-free extract.—The *nitrogen-free extract,* expressed in the tables in this book as *N-free extract,* embraces the substances that are extracted from the dry matter of plants by treatment with weak acids and alkalies under standard conditions, less the crude protein, fat, and ash. It is determined by difference and not by direct analysis. The total dry matter in a feeding stuff minus the sum of the ash, crude protein, fiber, and fat, equals the nitrogen-free extract. It embraces the sugars, starches, pentoses, non-nitrogenous organic acids, etc., of the plant.

15. Carbohydrates.—The nitrogen-free extract and fiber together constitute the *carbohydrates.*

The methods of analyzing and grouping plant substances now employed by chemists are, in many particulars, unsatisfactory. In time they will work out a more rational classification of the food substances of plants, but for the present we have nothing better than what is here given.

In discussing feeding stuffs it is often desirable to differentiate between those of coarse, bulky nature and others more condensed and usually more nutritious. Accordingly the terms "concentrate" and "roughage" employed in the first edition of the work are retained since they are now widely recognized and used.

Concentrates are feeding stuffs of condensed nature and usually highly nutritious character, such as the various grains, milling by-products, etc. Indian corn, oats, bran, and oil meal are examples. *Roughages* are the coarser feeding stuffs, such as hay, corn forage, straw, silage, roots, etc.

III. The Study of an Acre of Corn.

To illustrate and fix more clearly in mind the great basic facts in plant life as briefly told in the preceding pages, there is here presented the classic study of Ladd of the New York (Geneva) Station[1] on the development of the nutrients in a measured acre of that greatest of all agricultural plants, Indian corn.

16. Changes in a maturing corn crop.—Beginning his studies July 30, at which time the plants were fully tasseled, and repeating the examination at periods until September 23, when the crop was mature, Ladd secured the following data:

Composition of an acre of Indian corn at different stages.

	Tasseled, July 30	Silked, Aug. 9	Milk, Aug. 21	Glazed, Sept. 7	Ripe, Sept. 23
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weight of green crop	18,045	25,745	32,600	32,295	28,460
Water in same	16,426	22,666	27,957	25,093	20,540
Dry matter in same	1,619	3,078	4,643	7,202	7,918
Nutrients in same:					
Ash, or mineral matter	139	201	232	302	364
Crude protein	240	437	479	644	678
Fiber (Carbohydrates)	514	873	1,262	1,756	1,734
N-free extract (Carbohydrates)	654	1,399	2,441	4,240	4,828
Fat, or ether extract	72	168	229	260	314

The table shows that this acre of corn increased over 14,000 lbs. in weight between July 30, when tasseled, and August 21, when the grains were in the milk stage. After the latter date the gross weight decreased nearly 4000 lbs. because of the water lost by the maturing plants. The plants increased continuously in dry matter from tasseling to full ripeness, the gain being strikingly rapid between the silking and glazing stages. In less than a month following August 9, this acre of corn stored over 2 tons of dry matter! At tasseling, on July 30, the crop was nearly 90 per ct. water and only about 10 per ct. dry matter, while at ripening, September 23, there were nearly 28 per ct. dry matter. The mineral matter and crude protein increased rapidly at first and more slowly thereafter.

[1] Rpt. 1899.

The stalk of corn must be strong and sturdy to carry the heavy ear. Hence until the glazing stage there was an increase in fiber which forms the woody plant framework. The nitrogen-free extract increased more than 2 tons between tasseling and ripening. Most of this increase was stored in the kernels as starch. The crude protein and so-called fat increased thruout the whole period under study, most of these nutrients being likewise stored in the corn kernels. (**211**)

17. Changes in crude protein.—Ladd's study further shows most important and interesting changes in the nitrogenous constituents of the maturing crop, as the following table sets forth:

Changes in the crude protein of the ripening corn crop.

Date	Stage of maturity	Crude protein	
		Amids	Proteins
		Lbs.	Lbs.
July 30	Tasseled	69	171
August 9	Silked	158	279
August 21	Kernels in milk	102	377
September 7	Glazed	152	491
September 23	Ripe	109	569

During the development of the plants there was a steady formation of the soluble, circulating amids, which in turn were constantly being changed to the more highly organized proteins. As a result there was no increase of the amids after the silking stage, while there was a steady and marked increase in the proteins up to maturity. Much of the protein formed was stored in the kernels, especially in and about the germ, to there aid in carrying on the vital functions whenever the grains might find lodgment in the soil and begin growth to form new corn plants.

18. The nitrogen-free extract.—The development of the principal carbohydrates in this acre of corn is presented in the following table:

Changes in the glucose, sucrose, and starch of the ripening corn crop.

Date	Stage of maturity	Glucose	Sucrose	Starch
		Lbs.	Lbs.	Lbs.
July 30	Tasseled	58	9	122
August 9	Silked	300	111	491
August 21	In milk	665	129	707
September 7	Glazed	720	95	1,735
September 23	Ripe	538	149	2,853

On August 21, at the milk stage, the glucose and sucrose together amounted to nearly 800 lbs., which is more than the total weight of the starch stored at that period. After the milk stage was reached, the glucose and sucrose did not increase, while there was a continuous and rapid increase in starch, of which there was nearly a ton and a half when this acre of corn was ripe. During all the periods, glucose and sucrose were being steadily formed in the leaves of the plants and transferred from them thru the sap to the swelling kernels of the ear. Here these sugars were changed to insoluble starch, which was compactly stored about the germs in the corn kernels.

Adding together the glucose, sucrose, and starch and subtracting this sum from the total nitrogen-free extract found at the same period, as reported in the first table, there is a remainder of nearly 1300 lbs. This excess must have been largely pentosans and the soluble celluloses.

As the sugars were built, a portion was changed into cellulose, forming the woody framework of the plant structure—the roots, stems, tassels, leaves, husks, cobs, etc. A second and larger portion was changed to starch and stored in the kernels. The elements of a third portion must have been combined with nitrates and other mineral matter taken from the soil to form the nitrogenous compounds—the amids and proteins.

In reviewing the tables so graphically setting forth the development of America's greatest agricultural plant, the reader is reminded that, in producing this acre of corn, probably not over 10 lbs. of seed was placed in the ground in the spring time. From this insignificant beginning, by the following October, about 120 days later, the resultant plants had gathered inorganic matter—carbon dioxid from the air, and water, nitrogen, and mineral matter from the soil—and built all these, first into primary organic forms, and finally into complex organic parts of their structure. The product of such building amounted to over 14 tons of green or 4 tons of dry matter, all largely available for nourishing the animals of the farm and, thru them, man. This is a forceful illustration of Nature's wonderful processes of food production occurring all about us under the guiding mind of man.

The reader who will thoroly familiarize himself with this study of the growing corn plant can readily extend his acquirement to all the other crops of the farm. Thus equipped he is in position to study the composition of the bodies of farm animals and consider how they are built up and maintained by food derived from plants, as later presented.

CHAPTER II.

COMPOSITION OF THE ANIMAL BODY—DIGESTION—METABOLISM.

I. Composition of the Animal Body.

Division III of the preceding chapter sets forth the yield and composition of an acre of Indian corn, thereby showing the manner in which the several nutrients of feeding stuffs are elaborated by the plants of the farm. We will next consider the nature and composition of the bodies of farm animals, which are built up and nourished by plants.

19. The animal body.—The unit of the animal body is the protoplasmic life-holding cell, which, associated with myriads of others and modified in innumerable ways, makes up the body structure. Both the cell envelop and its contents are of nitrogenous material in most complex combination.

In studying the higher animals we may regard their bodies as consisting of a bony skeleton of mineral character surrounded by an elaborate muscular system. Fatty tissue permeates the bones and muscles, filling in and rounding out the body form, and around all is the enveloping skin. Within the body cavity are the various special organs, such as the heart, stomach, etc., designed for dissolving, assorting, distributing, and utilizing the nutritive matters of the food and for conveying and disposing of the waste. Finally there are the nerves, which control and direct all body actions.

20. Composition of animal bodies.—To aid in a study of the composition of the bodies of farm animals we have the following invaluable data gathered by those greatest of agricultural students, Lawes and Gilbert[1] of the Rothamsted (England) Experiment Station, whose classic investigations stand as models in agricultural research.

21. Mineral matter.—The first division of the table shows the composition of the entire body (fasted weight) of the animal. Referring to the first column we learn that in each 100 lbs. of the body of the fat calf there are 3.80 lbs. of mineral matter, or ash. That is, if the body of the calf were burned, there would remain that

[1] Jour. Roy. Agr. Soc. Eng., 1898; U. S. Dept. Agr., Office Expt. Sta., Bul. 22.

amount of ash for each 100 lbs. of body weight. With the half-fat ox the ash amounts to 4.66 lbs., while for the fat ox it falls to 3.92

Composition of the entire bodies, carcasses, and offal of farm animals.

Description of animal	Mineral matter (ash)	Protein	Fat	Total dry substance	Water	Contents of stomach and intestines in moist state
Division I. Per cent in the entire animal (fasted live weight).						
Fat calf	3.80	15.2	14.8	33.8	63.0	3.17
Half-fat ox	4.66	16.6	19.1	40.3	51.5	8.19
Fat ox	3.92	14.5	30.1	48.5	45.5	5.98
Fat lamb	2.94	12.3	28.5	43.7	47.8	8.54
Store sheep	3.16	14.8	18.7	36.7	57.3	6.00
Half-fat old sheep	3.17	14.0	23.5	40.7	50.2	9.05
Fat sheep	2.81	12.2	35.6	50.6	43.4	6.02
Extra-fat sheep	2.90	10.9	45.8	59.6	35.2	5.18
Store pig	2.67	13.7	23.3	39.7	55.1	5.22
Fat pig	1.65	10.9	42.2	54.7	41.3	3.97
Means of all	3.17	13.5	28.2	44.9	49.0	6.13
Division II. Per cent in carcass.						
Fat calf	4.48	16.6	16.6	37.7	62.3	--------
Half-fat ox	5.56	17.8	22.6	46.0	54.0	--------
Fat ox	4.56	15.0	34.8	54.4	45.6	--------
Fat lamb	3.63	10.9	36.9	51.4	48.6	--------
Store sheep	4.36	14.5	23.8	42.7	57.3	--------
Half-fat old sheep	4.13	14.9	31.3	50.3	49.7	--------
Fat sheep	3.45	11.5	45.4	60.3	39.7	--------
Extra-fat sheep	2.77	9.1	55.1	67.0	33.0	--------
Store pig	2.57	14.0	28.1	44.7	55.3	--------
Fat pig	1.40	10.5	49.5	61.4	38.6	--------
Means of all	3.69	13.5	34.4	51.6	48.4	--------
Division III. Per cent in offal (excluding contents of stomach and intestines).						
Fat calf	3.41	17.1	14.6	35.1	64.9	--------
Half-fat ox	4.05	20.6	15.7	40.4	59.6	--------
Fat ox	3.40	17.5	26.3	47.2	52.8	--------
Fat lamb	2.45	18.9	20.1	41.5	58.5	--------
Store sheep	2.19	18.0	16.1	36.3	63.7	--------
Half-fat old sheep	2.72	17.7	18.5	38.9	61.1	--------
Fat sheep	2.32	16.1	26.4	44.8	55.2	--------
Extra-fat sheep	3.64	16.8	34.5	54.9	45.1	--------
Store pig	3.07	14.0	15.0	32.1	67.9	--------
Fat pig	2.97	14.8	22.8	40.6	59.4	--------
Means of all	3.02	17.2	21.0	41.2	58.8	--------

lbs. In 100 lbs. of live lean pig there are but 2.67 lbs. of ash. The pig has the least mineral matter in its body of any of the farm animals.

22. Protein.—The muscles, tendons, ligaments, hide, hair, horns, blood, nerves, all internal organs, and a part of the organic portion of the bones are nitrogenous or protein in character. Most of the protein is in the muscular tissues or lean flesh. The fat calf has 15.2 lbs. of dry nitrogenous substance, or protein, for each 100 lbs. of fasted body weight. This proportion is slightly increased in the half-fat ox, but reduced in the fat one. There is less protein in the lean sheep and pig than in the fat calf, while in the extra-fat sheep and fat pig there are but 10.9 lbs., mostly lean meat, in each 100 lbs. of body.

23. Fat.—In the fat calf there are 14.8 lbs. of fat for each 100 lbs. of fasted body weight. This is increased to 19.1 lbs. in the half-fat ox, and 30.1 lbs. in the fat ox. Lean sheep show 18.7 lbs. of fat, while extra fat ones run up to 45.8 lbs. per 100 lbs. The lean pig shows 23.3 per ct. and the fat pig 42.2 per ct. of fat.

It is interesting to observe that the body of the fat calf contains almost as much fat as dry lean meat, and that of the fat ox more than twice as much. Even in the lean sheep or the store pig there is much more fat than lean meat, while the sheep or the pig, when extra fat, has 4 times as much dry fat as lean meat, their carcasses often being nearly one-half fat.

24. Water and dry substance.—The next two columns show the dry substance and water in the animal body. We learn that 63 out of every 100 lbs. live weight of the fat calf's body is water. With the half-fat ox the water is materially reduced, and in the fat one it amounts to only 45.5 per ct. Considerably more than half the body weight of the calf, and nearly half that of the fat ox, is water. In extra fat sheep the water falls to 35.2 lbs., the lowest for any farm animal, while for the fat pig it is 41.3 lbs. for each 100 lbs. of body. For all the animals studied, 49 lbs. in every 100 of the body weight, or nearly 50 per ct., is water. The supreme importance of water in the animal body is strikingly brought out by these figures.

25. Nitrogen and ash.—The following table shows the nitrogen and the principal ash constituents in the fasted live weight of the animals analyzed at Rothamsted, and also in milk and unwashed wool:

Ash and nitrogen in 1000 lbs. of farm animals (fasted live weight), milk, and unwashed wool.

	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)	Lime (CaO)	Magnesia (MgO)
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Fat calf	24.64	15.35	2.06	16.46	0.79
Half-fat ox	27.45	18.39	2.05	21.11	0.85
Fat ox	23.26	15.51	1.76	17.92	0.61
Fat lamb	19.71	11.26	1.66	12.81	0.52
Store sheep	23.77	11.88	1.74	13.21	0.56
Fat sheep	19.76	10.40	1.48	11.84	0.48
Store pig	22.08	10.66	1.96	10.79	0.53
Fat pig	17.65	6.54	1.38	6.36	0.32
Milk	5.76	2.00	1.70	1.70	0.20
Unwashed wool	54.00	0.70	56.20	1.80	0.40

The table shows that the nitrogen in each 1000 lbs. (fasted live weight) of the bodies of farm animals varies from about 17 to 27 lbs., being least in the fat pig and greatest in the half-fat ox. Lime, the largest mineral constituent of the bones, ranges from about 6 lbs. per 1000 lbs. of carcass in the fat pig to over 21 lbs. in the ox. Phosphoric acid almost equals lime in quantity, while potash runs from 1 to 2 lbs. only per 1000 lbs. of animal, and magnesia still less. Soda, silica, iron, etc., are found in small quantities.

26. Plants and animals compared.—One of the great distinguishing differences between plants and animals is that in plants the walls of the cells of which they are composed are of carbohydrate material, while in animals the walls of the body cells are of protein substance. Thus plants are on a carbon and animals on a nitrogen foundation. The higher plants are nourished by inorganic matter, while animals live upon both organic and inorganic substances, principally the former. Plants absorb thru their leaves great quantities of carbonic acid gas, composed of carbon and oxygen, retaining the carbon and giving off the oxygen as waste. Animals take free oxygen thru their lungs and combine it with carbon to form carbonic acid gas, which is thrown off as waste in the breath. Thus the two great classes of living objects are interdependent.

In the animal body the organic material derived from plants may be built into still other highly organized compounds, usually protein in character. Thus built, matter has reached its last high stage of organized existence, but its fall or descent soon occurs. In the daily waste of the body or upon the withdrawal of life, this highly endowed organic matter is quickly broken down into inorganic compounds, to begin again the eternal round of Nature.

II. Digestion.

27. Digestion.—The changes which food undergoes within the digestive tract of the animal to prepare it for absorption and ultimate use in building new tissues, repairing body waste, and as a source of energy are collectively known as *digestion.* Digestion is effected by enzymes or ferments elaborated by glands of the mouth, stomach, pancreas, and small intestines. Bacteria inhabiting certain parts of the digestive tract attack the woody cellulose of the food, breaking it down and thereby freeing nutrients. In addition to the action of the secretions and bacteria, the food in its course thru the digestive tract is subjected to mechanical processes which tend to reduce it to a fine state of division, the object of the whole process being to separate from the useless matter those constituents which are to nourish the body.

28. The alimentary tract.—The digestive tract is a long, tortuous tube passing thru the animal from mouth to vent, enlarged in places for the storage of food or waste. Within its linings are secretory organs furnishing various fluids of digestion, and into it, from other specific secretory organs located near by, pour still other digestive fluids. Within its walls are nerves controlling its action, arteries which nourish it with fresh blood, and veins and lymphatics which absorb and carry from its interior the products of digestion, as well as water, mineral matter, and gases. It should be borne in mind that the contents of the stomach and intestines are really outside the body proper. Only when a substance has passed into or thru the walls of the digestive tract has it actually entered the body of the animal.

In young ruminants, or animals which chew the cud, the first 3 stomachs are less developed than in grown animals. Colin found that the first stomach, or rumen, of a calf held 2.6 lbs. of water; the second stomach, or reticulum, 0.22 lb.; the third stomach, or manyplies, 0.35 lb.; and the true stomach, or abomasum, 7.7 lbs. As the diet of the growing calf changes to more solid food, such as grass, hay, and grains, the rumen or paunch gradually increases in size, until in the grown ox it holds 9 times as much as the other 3 stomachs combined.

The length and capacity of the intestines and the capacity of the stomachs of different farm animals are as follows:

Capacity and length of intestines and capacity of stomachs of farm animals.

Animal	Capacity of stomach and intestine		Average length of intestine	Ratio between length of —	
	Quarts	Relative capacity		Large and small intestine	Body and small intestine
		Per cent	Feet		
Horse					
Stomach*	19.0	8.5			
Small intestine	67.4	30.2	73.6	1:3	1:12
Large intestine	137.4	61.3	24.5		
Total	223.8	100.0	98.1		
Ox					
All 4 stomachs	266.9	70.8			
Small intestine	69.7	18.5	150.9	1:4.1	1:20
Large intestine	40.1	10.7	36.3		
Total	376.7	100.0	187.2		
Sheep					
Rumen	24.7	52.9			
Reticulum	2.1	4.5			
Manyplies	1.0	2.0			
Abomasum	3.5	7.5			
All 4 stomachs	31.3	66.9			
Small intestine	9.5	20.4	85.9	1:4	1:27
Large intestine	5.9	12.7	21.4		
Total	46.7	100.0	107.3		
Hog					
Stomach	8.5	29.2		1:3.5	1:14
Small intestine	9.7	33.5	60.0		
Large intestine	10.8	37.3	17.1		
Total	29.0	100.0	77.1		

*Chauveau, Comparative Anatomy of the Domestic Animals, places the capacity at 3 to 3.5 gallons.

29. Insalivation.—In the mouth of the animal the food is crushed and ground by the teeth, and at the same time is moistened with the alkaline saliva, forming a pasty mass. Colin[1] found that a horse fed on hay secreted 11 to 13 lbs. of saliva per hour. Oats require a little more than their own weight, green fodders half, and dry fodders 4 times their weight of saliva during mastication. If the ration of a horse for one day amounts to 11 lbs. of hay and 11 lbs. of other dry fodder, this will require 4 times its weight of

[1] Smith, Physiol. Dom. Anim.

saliva, or 88 lbs., to which must be added 4.4 lbs. secreted during rest, making 92.4 lbs. in all. The mingling of saliva with the food aids the sense of taste by dissolving small quantities of food which affect the nerve ends of the tongue. In this moist condition the food is more easily swallowed. The most important property of the saliva is due to the enzyme, called ptyalin, which it contains.

Enzymes are mysterious organic compounds which are able to change or break down other organic compounds without themselves being broken down.

30. Ptyalin.—The first enzyme of digestion, *ptyalin*, converts the insoluble starches of food into a sugar called maltose. The proteins and fats of food are not changed by the action of the saliva.

Since most of the changes which food substances undergo during digestion are effected thru enzymes, their general nature should be early understood by the student, and ptyalin action serves as an example. If a quantity of starch, placed in a dish, is treated with saliva and the whole kept at body temperature, the starch so treated will gradually dissolve, and after a time malt sugar will be found in its stead. The complex starch molecule has been cleaved or split into simpler ones by the action of the ptyalin. The enzyme causing this change is itself not altered in character or function, however, or seemingly exhausted in energy thereby, but is still capable of changing more starch into sugar. So far as known, there is no limit to the amount of sugar which a given quantity of ptyalin will produce if the supply of starch is maintained and the resultant sugar is continuously removed from the solution. If the saliva is heated above 176° F., it will no longer possess this power. At the temperature of ice water its action ceases, altho the enzyme is not destroyed, for on warming it becomes active again. Acids destroy ptyalin if added much beyond the point of neutrality. Each of the several enzymes of digestion is capable of acting on only one of the groups of nutritive substances—on either proteins, carbohydrates, or fats. Some act only in the presence of acids, and others only in neutral or faintly alkaline solutions. All are most active at about the temperature of the body.

31. Digestion in the stomach.—The food remains but a comparatively short time in the mouth, and is then passed on thru the gullet to the stomach, where it is acted on by the *gastric juice*. This consists of water containing the enzymes, pepsin and rennin, and also from 0.2 to 0.5 per ct. of hydrochloric acid, the gastric juice of carnivora, or flesh-eating animals, being more acid than that of others

Pepsin acts only in weak acid solutions, converting the very complex proteins into soluble and simpler, tho still complex, products known as proteoses and peptones. *Proteoses* and *peptones* are soluble nitrogenous compounds, simpler than the proteins from which they originate. They are the result of the partial cleavage of proteins with the addition of water.

Rennin is the enzyme which curdles milk. The membranous lining of the stomachs of calves yields the rennet of commerce, which contains this enzyme. One part of rennin will coagulate 400,000 parts of milk. This enzyme is an interesting provision of nature for conserving milk so the animal may get the full value from it. Altho liquid, milk is not in condition to be taken directly into the animal system, but, like solid foods, must first undergo digestion. Milk being liquid, the stomach would naturally pass it quickly on to the small intestine, and if this occurred it would not be sufficiently acted on by the pepsin. Rennin quickly converts the milk into a solid curd which is easily retained by the stomach until dissolved by the action of the digestive juice.

Acid destroys the power of ptyalin to convert starch into sugar. The construction of the stomach, however, is such that the action of ptyalin on the food after it reaches that organ, following mastication, is not too promptly checked. The first portion of the stomach, into which the gullet directly leads, secretes pepsin but no acid. The action of ptyalin on the starches of the foods continues, therefore, in this part of the stomach. The intestinal or rear end of the stomach, on the other hand, secretes little pepsin but much hydrochloric acid. Here the conversion of the starches into malt sugar by the pytalin ceases, and pepsin digestion becomes active. Only the preliminary steps of digestion are accomplished in the stomach, and relatively little absorption of the digested nutrients takes place from it. Sugars may be absorbed to some extent, but the proteoses and peptones produced from the breaking up of protein, and also the fats, are mostly carried into the small intestine along with the other matter.

Soon after the food reaches the stomach that organ begins a series of orderly movements for the delivery of its contents into the small intestine. In this delivery the stomach contracts at the middle region, and the wave of contraction proceeds slowly and regularly toward the intestinal end, one wave following another. Every time the contraction reaches the rear end of the stomach, the ring of muscles which keeps the stomach shut off from the small intestine relaxes and allows a small quantity of the semi-liquid contents of the stomach to spurt thru into the intestine. After this the ring of muscles again contracts, thereby closing the entrance. The stomach in turn slowly relaxes, and after a certain length of time, varying in different animals, the process is repeated. By this means the fluid portions of the mixed contents of the stomach are squeezed out and carried into the small intestine, while the more solid portions remain behind for further action by the gastric juice.

32. The stomach of ruminants.—In such animals as the horse the gullet is a simple muscular tube passing from the mouth to the stomach. In ruminants, or animals which chew the cud, as the cow, sheep, etc., it is expanded into three compartments of great aggregate capacity, called the paunch, the honeycomb, and the manyplies, before the true stomach is reached. They secrete water but no enzymes, and merely serve as pouches for the storage of food and the better preparation of it for digestion. With ruminants the food is swallowed after partial mastication and passes to the paunch, from which it can be returned to the mouth in small portions to be again chewed. While the food is in any of the first compartments the action of the ptyalin of the saliva continues.

The nutritive substances within the cells of plants are enclosed within the cellulose cell walls. Where these cell walls are formed of hard, thickened cellulose, the nutritive substances contained within the cells are not readily reached by the fluids of digestion. In the first stomachs of ruminants, especially in the paunch, the fermentation of cellulose by bacteria takes place, the walls of the cells being thereby more or less broken down and their contents set free, thus becoming available for digestion. In the partial destruction of the woody cellulose in the paunch there regularly occurs the evolution of gases, which may be very considerable when fresh, easily fermentable forage, such as green clover or alfalfa, is eaten. Ordinarily these gases are absorbed by the blood, but in some cases the gas is evolved so rapidly that the blood circulation cannot absorb it as fast as formed, and hoven or bloat occurs.

33. The small intestine.—In the small intestine the work of digestion is carried on even more vigorously than in the stomach. All classes of nutrients are attacked by the fluids it holds, and in it the digestive processes come to a close. The contents of the stomach, when received into the small intestine, consist of a semi-liquid mixture of undigested proteins, partially digested nutrients—proteoses and peptones, fats, sugars, starches, and celluloses—and waste matter. The small intestine first receives digestive fluids from two outside organs, the liver and the pancreas, whose functions in nutrition are of the highest importance, while farther on the food is mixed with a secretion containing several enzymes which are produced by the intestine itself. Immediately on entering the small intestine the inpouring material is changed from an acid to an alkaline character thru rapid addition of the bile and pancreatic juice, both alkaline.

34. The pancreas.—The pancreas is a slender gland lying just beyond the stomach and connected with the small intestine by a duct. Its secretion, the *pancreatic juice*, varies in different animals, being thin, clear, and watery in some, and thick, viscous, and slimy in others. The pancreatic juice bears three enzymes—trypsin, amylopsin, and steapsin.

Trypsin is an enzyme which, like pepsin, converts protein into proteoses and peptones. It has the power of further cleaving these two partially digested substances into *amino acids*, which constitute the ultimate useful nutrients which come from the cleavage of all the proteins of food stuffs thru digestion. The digestion of protein goes on much more thoroly in the small intestine under the influence of trypsin than it does in the stomach with pepsin.

Amylopsin is a pancreatic enzyme which converts starch into glucose-like sugars.

Steapsin is a pancreatic enzyme which splits fats into fatty acids and glycerin.

Ordinarily, when digestion is not going on there is no secretion by the pancreas. It has been found that if the mucous lining of the first part of the small intestine is treated with dilute hydrochloric acid, the pancreas at once pours out its secretion. It will be remembered that the contents of the stomach, at the time of their ejection from that organ into the small intestine, are strongly acid because of the hydrochloric acid of the gastric juice. This acid when it pours into the small intestine, acting on the lining of the latter, produces something which, when absorbed into the blood, calls forth the pancreatic secretion just when needed—a forceful illustration of how all the organs of the complicated digestive tract work in harmony.

35. The liver.—The liver, the largest organ in the body, has numerous duties in the digestion and metabolism of nutrients. While some of its functions will be dealt with in a later chapter, attention is here directed to its function in the digestion and absorption of the fats of foods.

Bile, the product of the liver, is a clear, greenish or golden colored fluid, alkaline in reaction, and extremely bitter in taste. The bile furnishes the alkalies which are necessary for the conversion of the fats of the food into soaps, that is, for changing them from an unabsorbable into a readily absorbable condition. It is of such nature that it readily forms an emulsion with fats, and in this form the latter present a very large surface for the action of the steapsin of the pancreatic juice. The process of the decomposition of the fats into fatty acids and glycerin is greatly hastened by this means. In the presence of bile the fatty acids take on alkali and form soaps, which are soluble in water and can be absorbed into the walls of the intestine. After performing this important function the bile is not wholly excreted with the contents of the intestine, but is in part taken up by the circulation and again utilized. According to Colin, the liver of the horse secretes over 13 lbs., of the ox 5.7 lbs., and of the sheep 0.75 lb. of bile during each 24 hours.

36. The intestinal secretion.—The first portion of the small intestine secretes no fluids except possibly water, but into it are poured the pancreatic juice and the bile, as already described. Further on, the small intestine secretes its own digestive fluid containing several enzymes, the most important of which are erepsin and the invertases.

Erepsin is an enzyme of great digesting power which attacks and still further splits or cleaves those proteoses and peptones which have escaped such action by trypsin, likewise converting them into amino acids, the ultimate digestion products of the proteins.

The invertases, *sucrase, maltase,* and *lactase,* are enzymes which convert cane-, malt-, and milk-sugars into the more simple glucose-like sugars.

Thus into the small intestine are poured the complex bile; the three digestive enzymes from the pancreas—trypsin, amylopsin, and steapsin; and finally erepsin and the invertases from its own walls. Water is also freely poured into the small intestine from its walls.

While in the small intestine, the food, which has been masticated in the mouth and partially digested in the stomach, is acted on by all the various fluids above described. That part of the food which thus far has escaped digestion is now vigorously and variously attacked, so that under ordinary conditions little that is useful is lost. The larger portion of all the digested material is absorbed from the intestine into its walls, and thus enters the body proper, as will be shown in the next chapter. The waste, along with some digested matter and much of the digestive fluids, passes from the small into the large intestine.

37. Special provision for the horse.—The horse, tho eating coarse food like the ox, has a small stomach and no paunch for specially preparing such food for digestion. In partial compensation it has the caecum, which is a greatly enlarged portion of the alimentary tract, linking the small and large intestines. Into the caecum is passed much of the undigested matter, together with the enzymes of the small intestine. Here the digestive processes of the small intestine are prolonged, thus making up for his small stomach and lack of a paunch.

Since the steps by which the food is prepared thru digestion for final use by the body are so numerous and complicated, it is well to now review the subject, dealing with the nutrients and what occurs with them, rather than considering the organs and solvents employed.

38. Digestion of fat.—As has been stated, the fats of foods, no matter how finely divided, cannot directly enter the circulation, but must be changed in the following manner: One of the enzymes produced by the pancreas is the fat-splitting steapsin, which breaks some of the fats in the food into glycerin and fatty acids. The bile is largely made up of alkaline salts, and with these the fatty acids react and form soaps. These soaps in turn form an emulsion with the unchanged fats, the emulsified fats presenting a large surface on which the steapsin may act. Thus it is believed that the fat which is finally absorbed is split into glycerin and fatty acids, the latter and the alkali of the bile forming soaps. These soaps and the glycerin are absorbed by the intestinal wall, in the cells of which they are reunited into fats and are contributed as such to the circulation. Some authorities hold, however, that a part of the fatty acids and glycerin formed by the splitting of neutral fats by steapsin may be absorbed as such, without being first changed to soaps.

39. Carbohydrate digestion.—The purpose of the animal in digesting either starch, or sugars other than those of glucose-like form, is to convert them into glucose or glucose-like sugars, which are the only forms of carbohydrates that can be used in the body.

Since the carbohydrates constitute a large portion of the food of animals, nature provides for their digestion in several parts of the alimentary tract. Carbohydrate digestion begins with the action of ptyalin on the starches of foods in the mouth, whereby they are converted into maltose. Ptyalin action continues in the first portion of the stomach, but ceases in the latter part of that organ. Sugars of glucose form may be absorbed from the stomach. Even the compound cane-, malt-, and milk-sugars may without change be absorbed from the alimentary canal in small amounts. If these compound sugars remain in the digestive tract an appreciable time, as usually happens, they are changed to glucose and glucose-like sugars. Thus most of the carbohydrates are absorbed from the alimentary tract in the form of glucose. Nearly all the carbohydrates are carried on from the stomach into the small intestine, which is the principal organ concerned in their final digestion. Here the starches which have escaped digestion in the mouth and stomach are acted upon by amylopsin, and the compound cane-, malt-, and milk-sugars are converted by the invertases into simpler glucose-like sugars.

When a human eats bread, or an animal consumes hay or corn, the starch of such food must all be changed to sugars before it can enter the body proper. With trifling exceptions all compound sugars are converted into glucose-like sugars. It is even held that milk sugar has no food value with birds, because their digestive tract provides no enzyme for breaking it up into glucose-like sugars which may be absorbed.

In the digestive tract no enzyme has been found which acts on cellulose. Bacteria inhabiting the alimentary canal, however, attack cellulose, especially in the paunch of ruminants and the caecum of the horse. Among the products of such bacterial decomposition of cellulose are organic compounds, such as acetic and lactic acid, besides gases—marsh gas, carbon dioxid, and hydrogen. While these gases are of no value to the animal, there is little doubt that the other cleavage products are absorbed from the digestive tract and serve as nutrients. Smith[1] suggests that cellulose digestion may be brought about by ferments contained in the food itself. When artificially digested with strong sulphuric acid, cellulose is converted into a gummy product and finally into glucose. Because the goat and the ox can subsist for long periods on coarse straw, which is largely cellulose, it is reasonable to hold that this sub-

[1] Manual of Vet. Physiol., 1908.

stance has considerable nutritive value, tho the manner of its digestion is not yet understood.

40. Protein digestion.—In the process of digestion the protein compounds in the food are attacked first by pepsin in the stomach, and later by trypsin and erepsin in the small intestine. The action of these enzymes is to cleave the very complex protein molecules into simpler ones, during which process the split molecules take up water and become soluble. Proteoses and peptones are products of the cleavage of proteins, an example of which may be seen in the following experiment: If a fragment of the white part of a hard-boiled egg, which is a protein substance, is placed in a dish with dilute hydrochloric acid, a little pepsin added, and the whole kept at body temperature, in a short time the edges of the opaque egg mass will become swollen and transparent, the change gradually extending thru the whole fragment. After a time the mass will have entirely disappeared, and in its stead there will remain a clear solution. If this peptone solution is evaporated to dryness there will be left a yellowish, transparent mass resembling the dried white of an unboiled egg. This dry digested material, now a mixture of proteoses and peptones, is soluble in water the same as the white of egg; but if dissolved in water it will not solidify on heating, as does ordinary white of egg. This shows that the substance has been changed to something other than protein, which always coagulates or solidifies on heating. These proteoses and peptones have resulted from the cleavage or splitting of the very complex egg protein into simpler molecules, which upon such cleavage have taken up chemically a large amount of water and become soluble. When a piece of lean meat or hard-boiled egg is taken into the human stomach, the pepsin, acting in the presence of hydrochloric acid, gradually dissolves such meat or egg, changing it to soluble peptones and proteoses. If it escapes solution in the stomach, it is usually dissolved later in the small intestine.

The soluble proteoses and peptones are not yet in suitable form for use in the body of the animal, and so are not absorbed, but are retained in the small intestine until they have undergone further enzyme action. This is effected by trypsin, which can not only attack protein directly and convert it into proteoses and peptones. as does pepsin in the stomach, but can also attack the peptones and proteoses and cleave them further. Erepsin, an enzyme of the small intestine, is of powerful action. It attacks nitrogenous substances after they have become proteoses and peptones. By the action of these last two enzymes the proteoses and peptones have their molecules further cleaved into simpler but still complex molecules, water being again taken up as in the first cleavage. The simplest products of such cleavage of the proteins of food substances are the amino acids.

The *amino acids* are the common final nitrogenous nutritive materials of the digestive tract, resulting from the cleavage of the complex molecules of the food proteins. They are soluble in the juices of the small intestine and are ready for transference thru the intestinal walls into the body proper. These acids are still relatively complex in structure, but are much simpler than the proteoses and peptones from which they are derived. The amino acids, derived from the nitrogenous portion of foods, constitute the great primary nitrogenous building material out of which the protein tissues of the animal body are built. So far as known, protein compounds taken as food cannot be broken apart further than into amino acids and remain useful in body building. The amino acids are now obtained by the physiological chemist as a laboratory product. The mixture of amino acids secured by completely digesting a protein and then evaporating the water is a syrup-like substance.

41. Tissue building.—The process of protein digestion is the breaking down of complex nitrogenous bodies into simpler ones. A good picture of what takes place can be had by likening the protein molecule to a house being taken down by a builder in order that he may construct another from the materials. An animal eating protein compounds cannot use the protein molecules in the form in which the plant has built them up into its own substance, but must first take them apart to a greater or less extent, and from the parts reconstruct another kind of protein molecule suitable for its own use. In other words, its protein molecules must have a different architecture from those of the plants which serve as its food. The proteoses and peptones may be likened to the roof and walls of the house. These walls and the roof can be broken down into bricks and tiles, which are represented by the amino acids; and from these the animal, beginning anew, can construct new proteins of the specific architecture its body may require.

It is possible that in certain cases portions of the protein molecule which are more complex than the amino acids may be of such structure that they can be directly utilized in the reconstruction of body protein, without first being broken down into amino acids.

While most of the nitrogen from the food protein is absorbed as amino acids, it is possible that some of it is taken up as proteoses or peptones. It is certain that in artificial digestion of proteins in the laboratory, if sufficient time is given the enzyme to act, the proteoses and peptones are completely broken down into amino acids or similar bodies. Very probably this takes place normally in the digestive tract.

42. The large intestine.—The large intestine receives the contents of the small intestine after the latter organ has ceased further effort at digestion. These contents consist of undigested matter, bits of indigestible substances of all kinds taken in with the food, bile salts which have escaped resorption, water, mineral salts, and fragments of the mucous lining of the small intestine. Mixed with these are some of the digestive juices of the small intestine. The large intestine does not elaborate any digestive fluids, but its walls contribute water and certain metabolic waste products, especially certain inorganic salts common to the tract. It is possible that some digestion may occur in the large intestine owing to traces of digestive enzymes coming from the small intestine, but such digestion is insignificant in amount. There is a constant interchange of water between the contents of the large intestine and the blood circulation, which results in the absorption of any soluble products, nutritive or otherwise, which may be formed in the large intestine either by digestion or bacterial action.

43. Bacteria.—In the stomach bacteria find unfavorable conditions for growth because of the free acid of the gastric juice, and in the small intestine the presence of bile rapidly causes the death of bacteria. Consequently bacteria play little or no part in digestion in either the acid stomach or the alkaline small intestine. They do act, however, on the woody fiber or cellulose in the first three stomachs of ruminants and in the caecum of the horse. In the large intestine there develops a profuse bacterial flora of various forms which thrive in the absence of air. The presence of more or less undigested food, together with moisture, warmth, and the faint alkaline reaction, furnishes ideal conditions for bacterial growth. Some cellulose is decomposed by the bacteria with the liberation of carbon dioxid, marsh gas, and hydrogen. Sulfureted hydrogen is also produced thru putrefaction of protein substances. Some nitrogen is found, but this has its source in the air taken in with the food. Much of the gas is doubtless absorbed into the circulation and eliminated from the lungs. Products other than gas which are mostly toxic or poisonous to the animal result in small quantity from bacterial growth in the large intestine. To these substances the odor of the feces is largely due. If the functions of the bowels are impaired, the contents may remain for an undue length of time, in which case excessive putrefaction may cause the animal to suffer from poisoning due to the absorption of the products formed.

44. Feces.—The solid excrement, or dung, of farm animals is that waste which finally escapes from the large intestine, the solids of which, for the most part, have never been within the body proper. It is composed principally of cellulose, or woody fiber, from the undigested portions of straw, hay, and grasses; and also of seeds, grains, or parts of the food that have escaped proper mastication and digestion. Matter not properly food, such as hair and dirt of various kinds taken into the alimentary tract, escapes thru this exit. Finally there are cast away traces of bile salts and some mucus from the lining of the intestines, together with much water.

45. Amid digestion.—The nitrogenous bodies of plants which are known collectively as "amids" are, as before stated, simpler nitrogenous compounds than proteins. They are either on their way to be built into proteins, or result from the cleavage of proteins in the plant for the purposes of transportation, or are formed in the partial breaking down and decay of protein. Very little is actually known of their chemical nature, but they are probably similar in character, in many instances at least, to certain intermediary products of digestion in the animal body. Since amids may result from enzyme action in the plant, their digestion in the animal may be looked upon as similar to that of proteins.

46. Mineral matter.—So far as known, the mineral matter, or ash, in foods is absorbed principally from the small intestine and is usually unchanged in chemical composition. Changes which occur in the different inorganic salts, or mineral matter, are entirely due to such chemical reactions as would have taken place outside the intestine under the same conditions. Insoluble mineral matter in food may become soluble because of the hydrochloric acid in the gastric juice of the stomach, but this is hardly to be regarded as digestion.

47. The work of the digestive glands.—The brilliant studies of the Russian physiologist, Pawlow,[1] and his associates, working with dogs, have thrown much light upon the subjects of digestion, appe-

[1] The Work of the Digestive Glands.

tite, and palatability. Pawlow and his associates performed the following surgical operations on dogs: (1) The ducts or tubes which deliver the saliva into the mouth were cut, turned outward, and healed into the cut edges of the skin, so that when saliva was secreted it poured out thru the opening and could be caught in glass tubes attached to the dog's head. (2) The gullet, which carries food from the mouth to the stomach, was cut across, led outward, and healed in the skin at the throat, so that when food was swallowed it would pass out at the severed end and fall back into the dish out of which he was feeding. Food so eaten was called a "false meal." In many cases a dog with a gullet thus severed would chew and swallow the "false meal" again and again with apparent satisfaction. (3) An opening was made thru the side of a dog and into his stomach. On the healing of the stomach wall with the cut in the skin, the investigator was enabled to pass food directly into the stomach and study the processes of digestion occurring within that organ. (4) A portion of the stomach was constricted and made into a small separate chamber, which likewise opened out thru the side of the dog. Here the flow of juices could be studied independent of admixture with food placed in the other portion of the stomach. (5) The small intestine was drawn to the side of the dog, and an opening made in it the same as in the stomach. (6) The pancreatic duct was cut and led outward, so that its secretion could likewise be studied.

Many persons assisted in these operations, and many dogs were used in the various studies. The animals usually yielded readily to the operations and lived comfortable lives, so that the results were normal.

It was found that the character, composition, and quantity of saliva secreted varied greatly according to the composition, quality, and other characteristics of the food rather than according to either appetite and hunger, or to the palatability of any particular food.

It was found that when food was placed directly in the stomach it did not necessarily call forth the gastric secretions from the walls of the stomach. On the other hand, the sight, smell, or taste of food not only started the flow of saliva in the mouth, but the gastric juices also began to pour from the walls of the stomach even when there was no food in that organ. Neither chemical nor mechanical stimulation of the mucous membrane of the mouth was capable of reflexly starting a flow of the juices of the stomach. The gastric secretions which are brought forth by the sight, taste, or smell of food are designated by Pawlow as "psychic secretions." For example, when a dog was given a false meal, and the swallowed food fell out of the fistula or opening in the throat and back into the dish out of which the dog was eating, the stomach would nevertheless pour forth its fluids (psychic secretions), as tho the food had reached it. The more eagerly the dog ate his false meal the greater was the amount of gastric secretions, and the richer they were in both acid and pepsin. The gastric secretions were freest and strongest with that food which was liked best, and food given in small portions called forth stronger juices than when the whole ration was given at one time.

It was found that in character and proportion the digestive ferments adapt themselves to the nature of the food. When the meat diet of a dog was changed to one of milk and bran, the protein-digesting enzymes of the pancreatic juices diminished, while the ferments which act on starch were increased. Pawlow's studies lead to the conclusion that the gastric and pancreatic glands are guided by a form of instinct, so that they pour out their juices in a manner which corresponds quantitatively and qualitatively, in a measure, to the amount and kind of food consumed. He believes that in time it will be found that there are specific stimuli or excitants in the food itself, possibly produced after it has entered the alimentary tract, the purpose of which is to excite and draw forth that form of secretion which is best suited to digest the particular kind of food then in the stomach.

The studies of Pawlow, here barely touched upon, point plainly to the great basic fact that digestion, appetite, and palatability are associated with each other, and should be studied together and not separately. With palatability, appetite, and digestion inter-related and resting on so fundamental and profound a basis, the prudent stockman will always give due heed to the preferences of his animals as to kind and quality of food, as well as to its preparation and administration.

48. Palatability.—So vague and illusive is the subject of the palatability of food that it would be a waste of space to discuss it at any length in this work. "What is one man's meat is another man's poison" is an old saying, to which might be added, "and what is one man's meat today may be his poison tomorrow;" for desire, appetite, and digestion are not the same with any given individual at all times and under all circumstances. Even with farm animals palatability is greatly influenced and controlled by familiarity and habit or custom. When corn silage is first placed before cows, not infrequently, after sniffing it, they will let it alone for a time. They then usually begin nibbling at it, and later will gorge themselves thereon if permitted. In such cases food that at first seems unpalatable suddenly becomes palatable.

In his early experience the author was feeding two lots of fattening steers, one on shelled corn and wheat bran, the other on wheat bran and shelled corn ground to a meal. After some weeks of successful feeding, the rations for the two lots were reversed. The steers changed from corn meal to whole corn showed a strong dislike for the new ration, eating so little at first that they shrank materially in weight. From this the general conclusion might have been drawn that shelled corn is less palatable than corn meal for fattening steers. But the steers given corn meal in place of shelled corn were equally dissatisfied. No conclusion is possible from this experiment except that custom and habit—something entirely extraneous to the food—are possible factors in palatability.

While palatability has a bearing on digestibility, the reverse is not necessarily true, for humans and animals often show fondness for kinds of food that are indigestible or worse. Even poisonous substances may be palatable, and, *per contra*, food which the human or animal does not relish or even dislikes may have high nutritive value provided the repugnance is overcome.

Despite the complexities of the subject, every practical stockman knows that to get the best results he must at all times provide feed for his animals which is palatable and altogether acceptable. This may be accomplished in considerable degree by steadily using the same feeds and feed combinations, and in always avoiding sudden and violent changes in their character and in the manner of feeding.

III. Metabolism.

In the preceding division we learned how digestion prepares the nutrients of feeding stuffs for the nurture of the animal body. In what follows there is briefly set forth how the digested materials are brought into the body proper and what becomes of them. Chemists and physiologists, working together with skill and great patience, have been able quite fully to set forth and explain the processes of digestion. When the nutrients leave the alimentary tract and enter the body, the difficulties of following them and learning what becomes of them have in a large measure thus far exceeded the powers of man. As inert matter takes on the hidden properties of life in plant or animal the problem seems to grow too deep for solution by finite man. Many of the changes that occur in the body are known and can be described; concerning others, but little of a definite nature can be told.

49. Metabolism.—The processes by which the digested nutrients of the food are utilized for the production of heat and work, or built up into the living matter of the body, in turn being broken down and once more becoming non-living matter, are termed *metabolism.* Constructive metabolism, or the building-up processes, is termed *anabolism,* while the breaking-down and wasting processes are styled *catabolism.*

50. The circulative canals of the body.—The body of the animal is made up of innumerable cells, which, grouped and modified in myriads of ways, ultimately form all its organs and parts. Everywhere among the cells are minute spaces called *lymph spaces,* which are connected with the *lymphatics,* a set of vessels which permeate most parts of the body. In some respects the lymphatics resemble the veins, but they are thinner and more transparent and drain in only one direction—toward the heart. Within these vessels is a clear fluid called *lymph.* These vessels unite with one another, forming a network in many places. Here and there a trunk subdivides into five or six smaller vessels, and the latter enter a nodule-like body called a *lymphatic gland.* From this gland come several small vessels, which, after a short space, again unite to form a trunk. Gradually these trunks unite, forming larger trunks until two large ducts are formed which enter a vein in the neck.

The other set of canals is the arteries and veins, which permeate every portion of the body, the former carrying the blood away from the heart, and the latter carrying it to the heart. At the extremities of the arteries are still more minute tubes, called *capillaries,* which connect them with the veins. If one extends his arms in front of him with his finger tips touching, his body will represent the heart, while one arm will represent an artery carrying blood from the heart, and the other a vein conveying blood to the heart. The touching fingers will correspond to the capillaries connecting the arteries with the veins, and the space all about the fingers will represent the surrounding body tissues. In general, neither the veins nor the arteries allow any substance within them to escape thru their walls proper. It is thru the capillaries that the nutritive matter carried by the blood finds its way into the body tissues for their nourishment, and thru the capillaries and the lymphatics, in turn, the waste of the body drains back into the blood circulation. The cellular tissues of which the body is composed are thus everywhere permeated by the ducts of the lymphatic system and the capillaries of the blood system. The cells of the body are bathed by lymph, which is the fluid that receives and temporarily holds all the nutritive substances and the body waste. The mucous membrane lining the small intestine has a velvety appearance, caused by innumerable minute cone-like projections or tongues, called *villi*, which project into the interior of the intestinal tube, thereby coming into contact with its fluid contents. Within each villus are *lacteals*, or drainage tubes of the lymphatic system, and capillaries of the blood system.

51. Absorption of fat.—As before told, in the small intestine a part of the fat of the food is split into fatty acids and glycerin by the action of steapsin. These acids and the alkalies in bile combine to form soaps which aid in emulsifying the remaining fat, so that it also is rapidly acted on by the steapsin and changed into fatty acids and glycerin. Modern investigation supports the view that the fats are absorbed as soaps and glycerin. In the intestinal wall these are reconverted into neutral fats which enter the lacteals, forming with the lymph a milky substance called *chyle*. This is carried in the lymphatics and poured into a vein near the shoulder, thus entering the blood circulation.

52. Absorption of carbohydrates; formation of glycogen.—The glucose and glucose-like sugars taken up from the intestinal contents by the capillaries pass into the veins, and thence by way of the portal vein into the liver. Here they are for the most part withdrawn from the blood and temporarily stored in this organ as *glycogen*, a carbohydrate which is closely related to starch and, having the same percentage composition, is sometimes called animal starch. Normally from 1.5 to 4.0 per ct. of the weight of the liver consists of glycogen. The glycogen stored in the liver is gradually changed back into glucose, and then doled out to the system as required. The property of converting glucose into glycogen is not possessed by the liver alone, but by the tissues of the body generally, especially the muscles. When work is being done the glycogen in the muscles is first drawn upon to furnish glucose, and after this store has been exhausted, the glycogen in the liver furnishes the needed glucose. Under normal conditions some glucose is found in the blood and a trace in the muscles.

53. Absorption of proteins.—The amino acids and other products of protein digestion are likewise absorbed from the small intestine thru the villi. While still within the intestinal walls these relatively simple products are joined together, thereby forming the extremely complex molecules of the two proteins, *serum albumin* and *serum globulin.* These newly formed proteins, which are the common nitrogenous structural material of the body tissues, pass on into the capillaries and enter the blood circulation along with the glucoses.

Mineral matter is taken up from the small intestines, and water is absorbed all along the alimentary tract, from the stomach to the large intestines.

54. Distribution of absorbed nutrients.—We have seen that the digested fats which are to nourish the body are poured into the blood current by way of the lymphatics, while the glucoses, as such, and the amino acids and other nitrogenous products of digestion, changed to serum globulin and serum albumin, enter the blood directly thru the capillaries and veins. The veins from the small intestine unite and become the portal vein, which passes the blood thru the liver and on into the heart. The various nutrient materials, having been mingled with the blood, are carried thru the circulation to the capillaries.

These are so constructed that, when the blood finally reaches them, the nutritive substances it carries pass thru their walls and are mingled with lymph that bathes the myriad body cells. In this manner all the nutrients, having been especially prepared and transported, are available for the nourishment of every portion of the body. Oxygen is taken into the blood thru the lungs, and water and mineral matters are absorbed from the digestive tract. All are carried by the arteries and pass thru the capillaries into the lymph bathing the body cells.

55. Use of the absorbed nutrients.—The absorbed nutrients, thus transferred to all the tissues of the body, may be oxidized or burned to warm the body, or to produce energy to carry on the vital processes and to perform work, as shown in the following chapters. In case more nutrients are supplied than are required for these purposes, the excess may be transformed into body tissue proper, as shown in Chapter V. The glucoses may be converted into fats and stored as body fat, as may also the fats derived directly from the food fats. It is probable that the proteins of the food, changed to serum globulin and serum albumin, may be broken up and a portion of their carbon, hydrogen, and oxygen turned into fat, while the nitrogen is wasted as urea. The highest and most general use of the proteins, however, is the formation of nitrogenous tissues—the muscles, nerves, skin, hair, and various organs of the body.

56. Disposal of body waste.—In breaking up the food nutrients within the body proper for the production of heat, and in the changes which occur in building them into body tissues, carbon dioxid is evolved. Most of this escapes into the capillaries and is carried in the blood by the veins to the lungs, where it is eliminated in breathing, a portion, however, escaping by way of the skin. Some of the marsh gas produced by fermentations in the stomach of herbivora is absorbed into the blood and thrown out by the lungs.

Nearly all of the nitrogenous waste, representing the breaking down of protein material in the body, is excreted in the urine thru the kidneys, tho a trace is given off in the sweat and a more appreciable amount in the feces. In mammals this waste takes the form principally of urea. In calculating the total amount of protein metabolism it is customary to determine the total nitrogen in the urine and multiply this by 6.25. This gives the amount of protein broken down, since it is assumed that, on the average, nitrogen forms 16 per ct. of the total weight of the protein molecule.

A great variety of other end-products of metabolism are likewise eliminated by the kidneys thru the urine. The inorganic salts, such as common salt, also escape from the body principally in the urine. Small amounts of most of the substances eliminated in the urine are also excreted by the skin thru the sweat glands. A considerable portion of certain inorganic salts containing calcium, magnesium, and phosphorus are eliminated by way of the intestines.

57. Summary.—In Chapter I we learned how the various inorganic compounds taken by plants from earth, air, and water are built into organic plant compounds, and how in such building the energy of the sun becomes latent or hidden in the substance of the plant. In this chapter we have learned how the animal, feeding on plants, separates the useful from the waste by mastication and digestion, and how the digested nutrients, after undergoing more or less change, are conveyed from the alimentary tract to the body tissues and used for building the body, for warming it, or in performing work. All the energy manifested by living animals and the heat evolved in their bodies represent the energy of the sun originally stored in food substances by plants. With the breaking down of the nutrient matters in the bodies of animals, and in the decay of the animal substance itself, the organic matter loses the condition of life and falls back to the inorganic condition, once more becoming a part of the earth, air, and water as inert matter. After this degradation it is again gathered up by the plants and once more starts on the upward path. Such is the eternal round of Nature, in which plants, animals, the energy of the sun, and the mysterious guiding principle of life all play their parts.

CHAPTER III.

DIGESTIBILITY—RESPIRATION—CALORIMETRY—ENERGY.

I. Digestibility.

The method of determining the digestibility of feeding stuffs is based on the fact that the undigested portion of food passes from the body in the so-called solid excrement. In studying the digestibility of a given feed the chemist first determines by analysis the percentage of each nutrient it contains. Weighed quantities of the feed are then given to the animal, and the solid excrement voided during a stated period is saved, weighed, and samples analyzed. The difference between the amount of each nutrient fed and that found in the solid excrement resulting therefrom represents the digested portion.

58. A digestion trial with sheep.—The following description covers an actual digestion trial conducted by Armsby at the Wisconsin Station.[1] Desiring to ascertain the digestibility of clover hay and malt sprouts, 2 wethers weighing 87 lbs. each were confined in specially constructed apartments and fed from zinc-lined boxes to prevent waste. Each day's allowance was weighed and samples analyzed. The solid excrement passed by the wethers was collected in rubber-lined bags attached to their hind quarters by a light harness. These bags were emptied each 24 hours, and the contents weighed and analyzed. Feeding progressed 6 days before the trial proper began, in order that all residues of previous feed might have passed from the alimentary tract. During the first period each sheep, as shown in the table, was fed 700 grams (about 1.5 lbs.) of clover hay daily, which was consumed without waste.

Digestion trial with sheep fed clover hay; average for 1 day.

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Grams	Grams	Grams	Grams	Grams
Fed 700 grams hay, containing	586.1	77.7	191.5	276.7	10.7
Excreted 610.6 grams dung, containing	288.6	40.4	101.5	119.4	7.9
Digested	297.5	37.3	90.0	157.3	2.8
Per cent digested	50.8	48.0	47.1	56.8	26.2

[1] Rept. 1884.

The table shows that the 700 grams of hay fed contained 586.1 grams of dry matter, and that the solid excrement for 1 day, which represented the undigested portion of the ration, contained 288.6 grams. The difference, 297.5 grams, or 50.8 per ct., is held to be the dry matter digested. The average dry matter digested in 2 such trials was 51.2 per ct. Of the 77.7 grams of crude protein supplied, 40.4 grams appeared in the solid excrement. The difference, 37.3 grams, or 48 per ct., represents the digested crude protein. In like manner the percentage of the other nutrients digested was determined.

The average percentage of each nutrient digested in a feeding stuff is termed the *coefficient of digestibility* for that nutrient in the feed.

59. Digestibility of malt sprouts.—The sheep were next fed the following ration of 600 grams of clover hay and 175 grams of malt sprouts.

Trial with sheep to ascertain the digestibility of malt sprouts.

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Grams	Grams	Grams	Grams	Grams
Fed 600 grams hay	500.9	67.4	163.3	236.3	9.4
Fed 175 grams malt sprouts	154.1	36.8	21.0	87.5	2.2
Total	655.0	104.2	184.3	323.8	11.6
In 681.1 grams solid excrement	295.2	41.5	100.6	129.0	5.5
Digested, total	359.8	62.7	83.7	194.8	6.1
Digested from hay	256.4	33.2	76.8	135.2	3.8
Digested from malt sprouts	103.4	29.5	6.9	59.6	2.3
Per cent digested	67.1	80.2	32.9	68.1	104.5

The digestibility of malt sprouts was determined indirectly in the following manner: The dry matter of the clover hay and malt sprouts together equaled 655 grams. The excreted dry matter from this equaled 295.2 grams, so that the total quantity digested was the difference, or 359.8 grams. In the previous trial it was found as the average of 2 periods that 51.2 per ct. of the dry matter in clover hay was digestible. Taking 51.2 per ct. of 500.9 grams gives 256.4 grams, which is the probable quantity of dry matter that was digested from the hay. Subtracting 256.4 from 359.8 grams, there is left 103.4 grams, or 67.1 per ct., which is taken as the per cent of dry matter digested from the malt sprouts. In a similar manner the other digestion coefficients for malt sprouts are determined. The table reports 104.6 per ct. of the fat of malt sprouts digested—an absurdity. The total quantity of fat in the feeds used in this trial was so small that an error like this could easily occur.

Table II of the Appendix shows the coefficients of digestibility of American feeding stuffs so far as they have been ascertained.

60. Concerning digestibility.—In digestion trials it is assumed that all matter appearing in the so-called solid excrement has escaped the action of the digestive ferments, and so represents the indigestible part of the food. Tho correct in general, there are exceptions to this assumption. Solid excrement contains some waste from the body itself, such as bile residues and matter which sloughs off from the walls of the alimentary tract. Since these wastes cannot be wholly separated and determined, they tend to vitiate the accuracy of digestion studies.

Armsby has shown[1] that ruminants feeding on coarse forage convert much of the fiber into marsh gas, or methane, which has no nutritive value. In such cases digestion trials will show too high a value for the fiber.

In digestion studies the so-called fat is determined by the use of ether, which not only dissolves the true fat, but also chlorophyll, wax, bile residues, and other substances which are not true fat. Due to this, and because the fats in feeding stuffs are usually in relatively small amount, errors are liable to occur in their determination. The true fats are highly digestible.

Table II of the Appendix shows that feeds low in fiber and rich in nitrogen-free extract usually have a high factor of digestibility; for example, corn, barley, linseed meal, etc., are better digested than straw, chaff, etc. The percentage of digestibility of the grasses decreases as they approach maturity. However, the large accumulation of starch which occurs in the corn plant, a grass, as it ripens gives the more mature form a greater total feeding value. (**18**) It seems reasonable that palatability should stimulate the supply of digestive fluids, as it must likewise stimulate the action of the digestive tract itself.

Grinding grain to meal may or may not increase its digestibility. Jordan[2] states that crushing or grinding grain for horses may increase its digestibility as much as 14 per ct. Cooking food usually

[1] Cyclopedia Am. Agr., III, p. 65. [2] The Feeding of Animals, p. 133.

lowers the digestibility of the crude protein. At the Oregon Station[1] Withycombe and Bradley found that steaming both vetch and corn silage materially decreased the digestibility of the crude protein and other nutrients. In general, cooking, steaming, or fermenting food, while often improving its palatability, generally lowers its digestibility, tho potatoes and possibly other starchy tubers are improved thereby.

When nitrogenous feeds, such as oil meal, oats, etc., are added to roughages—hay, straw, etc.—the digestibility of the roughage is not thereby increased. The addition of a large quantity of digestible carbohydrates, such as sugar and starch, to a ration containing much roughage may reduce the digestibility of its crude protein and fiber. If pure carbohydrates, such as starch and sugar, form more than 10 per ct., or roots and potatoes furnish more than 15 per ct., of the dry matter in the ration, its digestibility is diminished thereby. At the Weende Station, in a trial with sheep, the addition of 0.5 lb. of starch to a ration containing 1.75 lbs. of hay reduced the digestibility of the crude protein from 54 per ct. to 32 per ct. and of the fiber from 60 per ct. to 54 per ct. This depression does not occur when nitrogenous feeds, such as oil meal, supplement the starch or sugar. Adding fat to a ration does not increase the digestibility of the other constituents. Salt does not affect digestion, tho it may increase the quantity of food eaten and improve nutrition.

If green forage is cured without waste and in a manner to prevent fermentation, the mere drying does not lower its digestibility. Ordinarily, however, in curing forage much of the finer and more nutritious parts is wasted, and dews, rain, and fermentations effect changes which lower digestibility. The large amount of work done in masticating dry forage and passing it thru the alimentary tract explains why green forage may give better results and hence appears more digestible than dry forage. The long storage of fodders, even under favorable conditions, decreases both their digestibility and palatability. Hay browned by heating shows increased digestibility of fiber but decreased digestibility of crude protein and carbohydrates.

Ruminants—the ox, cow, sheep—digest the same kind of forage about equally well. Kellner,[2] however, shows that the ox is able to digest as much as 11 per ct. more of the less digestible roughages, such as straw, than is the sheep. He ascribes this difference to the

[1] Bul. 102.

[2] Land. Vers. Stat., 63, 1906, p. 313.

fact that the content of the last part of the intestine of the ox remains more watery and hence is subject to more complete fermentation. The more easily digested a feeding stuff is, the less difference will there be in its digestion by these various animals. For the great majority of feeding stuffs the same digestion coefficients may be used for the sheep and ox.

The horse and pig digest less fiber than the ruminant, in whose paunch the coarse feeds undergo special preparation and digestion. The richer the feed the more nearly do the digestive powers of the horse approach those of other farm animals. Swine digest the concentrates fully as well as do the ruminants, but make only small use of the fiber. Age and breed do not affect digestion, tho individuals show considerable variations one from another. The species, breed, or age of animals does not ordinarily cause variations of more than 5 per ct. in digestibility.

Neither the frequency of feeding, the time of watering, nor the amount of water drank appears to influence digestibility. Within reasonable limits the quantity of food the animal eats does not affect its digestibility. Jordan[1] found that sheep digested 4.7 per ct. more of the dry matter when given a half ration than when fed a full ration. Warington[2] states that an animal does not digest its food any better during partial starvation, tho when an abundance of rich food is fed its digestibility may be lowered. Healthy animals usually eat no more forage than they can properly digest, and the digestive fluids are no more active on small than on large quantities of food. Grandeau and Leclerc[3] found that Paris cab horses digested their rations best when given walking exercise or worked at walking gait. When trotting or at hard work their digestion was lowered. Kindness should favorably influence digestion. On the other hand, the flow of saliva and the other digestive juices is checked by fright. Under skillful care animals show remarkable relish for their food, and it is reasonable to conclude that better digestion ensues, tho no confirmatory data can be given.

The digestibility of a feed should not be confused with its availability. **(69)**

II. Respiration Studies.

The *respiration apparatus* is an air-tight chamber, arranged in such manner and with such devices that all that goes into and comes from the body of an animal within it can be accurately measured

[1] N. Y. (Geneva) Expt. Sta., Bul. 141.
[2] Chem. of the Farm, p. 150.
[3] Ann. Sci. Agr., II, 1884, p. 325.

and studied. In some cases mechanical work is performed, while in others the subject is at rest. Everything which passes into the animal—air, food, and water—is carefully measured and analyzed so that the exact intake of the body is known. The air is in turn drawn from the chamber, and the solid and liquid excrements passed by the animal are all likewise weighed and analyzed. If the intake is larger than the outgo, the animal has increased in body substance; if less, it has lost. The respiration apparatus has been used for studying the production of work and the formation of the tissues of the body, both the lean flesh and the body fat. Thru this means scientists have, in some measure, been able to determine what becomes of the food of animals.

61. A respiration study.—The following example from Henneberg[1] of the Weende Station, Germany, illustrates the use of the respiration apparatus. A full-grown ox weighing 1570 lbs. was placed in the respiration chamber. During one day of the trial it was fed 11 lbs. of clover hay, 13.2 lbs. of oat straw, 8.2 lbs. of bean meal, and 2.13 oz. of salt, and drank 123.7 lbs. of water. The intake and outgo of the body for the day are shown in the table on the opposite page.

62. Intake of the body.—The table shows that during the 24 hours of the trial the intake of nourishment by the ox was as follows:

	Grams	Pounds
Oxygen taken by way of the lungs	7,255	16.0
Dry matter taken into the alimentary tract	12,675	27.8
Water drank and in food	58,200	128.0
Total intake of the body for 1 day	78,130	171.8

From these data we learn that during the 24 hours of study the ox breathed in 16 lbs. of oxygen, ate 27.8 lbs. of dry matter, and took 128 lbs. of water in food and drink, a total for the day of 171.8 lbs.

63. Waste products.—Division B of the table records the losses from the body as follows:

	Grams	Pounds
Passed off as so-called solid excrement	40,645	89.4
Passed off as urine	13,900	30.6
Respiration products from lungs and skin	22,550	49.5
Total waste from body during 24 hours	77,095	169.5

Thus during the day of the trial there passed from the ox 89.4 lbs. of the so-called solid droppings and 30.6 lbs. of urine, while the

[1] Neue Beitrage, Göttigen, I, 1870, p. XIX; Kraft, Lehrb. Landw., III, p. 17.

One day's study with a 1570-lb. ox in a respiration apparatus.

1 gram=1-28 oz. 1000 grams=2.2 pounds.

	Mineral matter	Carbon	Hydrogen	Nitrogen	Oxygen
A. *Intake of body.*	Grams	Grams	Grams	Grams	Grams
70,875 grams feed and water, containing 12,675 grams dry matter and 58,200 grams water	890	5,825	7,215	310	56,635
7,255 grams oxygen from air	--------	--------	--------	--------	7,255
78,130 grams, total intake	890	5,825	7,215	310	63,890
B. *Outgo from body.*					
54,545 grams excrements, consisting of:					
40,645 gms. solid excrement	575	2,585	4,205	105	33,175
13,900 gms. urine	305	220	1,480	170	11,725
22,550 grams respiration products, consisting of:					
9,800 grams carb. acid	--------	2,670	--------	--------	7,130
30 grams methane gas	--------	20	10	--------	--------
12,720 grams water	--------	--------	1,410	--------	11,310
77,095 grams, total outgo	880	5,495	7,105	275	63,340
C. *Production in body.*					
219 grams dry lean meat	--------	114	15	35	55
281 grams fat	--------	216	35	--------	30
10 grams mineral matter	10	--------	--------	--------	--------
525 grams water in flesh and fat	--------	--------	60	--------	465
1,035 grams remaining in body	10	330	110	35	550
78,130 grams in B and C to balance A	890	5,825	7,215	310	63,890

lungs and skin exhaled 49.5 lbs. of gas and vapor, a little over half of which was water and a little less than half carbonic acid gas. The total outgo for 24 hours was 169.5 lbs.

A considerable part of the food was not digested, but passed off as the so-called solid excrement and so was useless. The larger part, however, entered the body proper from the stomach and intestines, and was used to carry on the life functions, repair the wasting tissues, etc., and passed off as waste after being so used. A small portion only was stored as body substance, as we shall see later.

64. Nitrogenous waste in the urine.—During the day the ox gave off 30.6 lbs. of urine which contained 170 grams of nitrogen. We can determine the amount of nitrogenous substance which was broken down to produce this waste in the following manner: About 16 per ct. of such nitrogenous substance as was in the food of the ox or composed its body tissues was nitrogen. Multiplying 170 grams by 100/16, or 6.25, gives 1,062 grams, or 2.33 lbs., which represents the amount of nitrogenous substance that was broken down and passed away in the urine. This nitrogenous waste came either from the food which the ox had consumed during the day, or resulted from the breaking down of the lean-meat tissues of the body which lost the condition of life and passed away as dead matter.

65. Dry lean meat.—Division C of the table shows that during the day of the study the body weight of the ox was increased by 1,035 grams as follows:

	Grams	Pounds
Total substance passed into the body	78,130	171.8
Total waste leaving the body	77,095	169.5
Amount remaining in the body for the day	1,035	2.3

Let us now direct our attention to the 2.3 lbs. of income which really became a part of the body. We learn from the table that during the day of this study the ox stored up 35 grams of nitrogen in its body. Sixteen per ct. of the nitrogenous substance or proteins of the body, such as dry lean meat, is nitrogen. Accordingly the 35 grams of nitrogen retained in the body represents about 219 grams of dry lean meat. The table shows that 330 grams of carbon were retained by the ox. As dry lean meat is a little over half carbon, about 115 grams of carbon were built into the 219 grams of dry lean-meat proteins.

66. Dry fat.—Since the lean meat took up 115 grams of carbon there remains 215 grams of carbon out of the total of 330 grams. This must have gone into the fatty matter stored during the day. Pure fat is about three-fourths carbon. Hence the 215 grams of carbon represents about 281 grams of dry body fat. From this we learn that about 281 grams of dry fat were stored in the body during the day of trial.

67. Summary.—From all this we learn that during the 24 hours spent by the ox in the respiration chamber, out of a total intake of 171.8 lbs. of food, water, and oxygen it stored up matter as follows:

	Grams	Pounds
Proteins or dry lean meat	219	0.48
Fat	281	0.61
Mineral matter	10	0.02
Water	525	1.17
Total	1,035	2.28

It has been shown that the intake of the body of the ox during the day of the trial exceeded the outgo by 2.30 lbs. The table accounts for practically all of this in the 2.28 lbs. of increase here reported.

The 0.02 lb. of mineral matter must have largely gone to increase the bony structure. Fresh lean meat is nearly two-thirds water, therefore the 0.48 lb. of dry lean meat equaled about 1.25 lbs. of fresh lean meat. The fatty tissues of the fattening ox are about two-thirds fat, hence the ox put on slightly less than 1 lb. of body fat during the day.

Thus we are shown that a 1570-lb. ox confined in a respiration chamber for 24 hours consumed during that time 11 lbs. of clover hay, 13.2 lbs. of oat straw, 8.2 lbs. of bean meal, and 2.13 oz. of salt; drank 123.7 lbs. of water; and breathed in 16 lbs. of oxygen gas. From all this it gained 2.28 lbs. of body weight, of which about 1.11 lbs. was dry lean meat, fat, and mineral matter, and 1.17 lbs., or over one-half, was water.

III. Calorimetry.

In nutrition studies it is helpful to consider food according to its power to produce heat. Such studies fall under the head of *calorimetry.*

68. Calorimetry.—The *calorimeter* is an apparatus in which a given quantity of material is burned with pure oxygen gas under pressure, the heat evolved being taken up by water and measured with a thermometer.

A *Calorie* is the amount of heat required to raise 1 kilogram of water 1° C., or 1 lb. of water 4° F.

A *therm* is 1000 Calories, or the amount of heat required to raise 1000 lbs. of water 4° F.

The heat or chemical energy evolved on burning 100 lbs. of various substances is as follows:

	Therms.
Anthracite coal	358.3
Timothy hay, containing 15 per ct. moisture	175.1
Oat straw, containing 15 per ct. moisture	171.0
Corn meal, containing 15 per ct. moisture	170.9
Linseed meal, containing 15 per ct. moisture	196.7
Pure digestible protein	186.0
Pure digestible carbohydrates	186.0
Pure digestible fat	422.0

The table shows that, on burning, 100 lbs. of anthracite coal yields 358.3 therms, or enough heat to raise the temperature of 358,300 lbs. of water 4° F., or about 8000 lbs. of water from 32° F., or freezing, to 212° F., or boiling temperature. One hundred pounds of timothy hay likewise burned would yield 175.1 therms, or about half that of coal. Linseed meal has a higher fuel value than corn meal because it contains more oil. Digestible protein yields about the same amount of heat as the carbohydrates and fat more than twice as much. In comparing feeding stuffs the digestible fat is regarded as having 2.25 times the fuel value of the digestible carbohydrates. (**131**)

The energy evolved on burning a substance may be expressed by the work it will do in lifting a weight, the foot-ton being the unit of such measurement. A *Calorie* will furnish the energy required to raise a weight of 1.53 tons 1 foot. A *therm* is the energy required to raise a weight of 1530 tons 1 ft., or 1 ton 1530 feet.

IV. The Energy of Food.

69. Available energy.—The fuel value of any food does not necessarily measure its nutritive value to the animal, because foods containing the same heat units may vary in the amount of available energy which they can furnish to the body. This is because:

1. A part of the food passes thru the alimentary tract undigested.

2. The carbohydrates, especially the woody fiber, undergo fermentations in the intestines and paunch, gases being evolved which are without fuel value to the animal.

3. When the protein substances in the body are broken down they form urea, a nitrogenous compound which escapes thru the kidneys. Urea has fuel value which is lost to the body.

The fuel value of any food which remains after deducting these three losses represents the *available energy* of the food, or that portion which the animal can use for body purposes.

70. Net energy.—The available energy of the food measures its value for heat production, but, as will be shown in the next article, does not represent its true value to the animal for other purposes. A portion of the total available energy of any food must be expended in the work of masticating and digesting it and of assimilating the digested nutrients. The energy so expended finally takes the form of heat, but is not available for other purposes in the body, since the animal has no power to convert heat into other forms of energy. That portion of the energy which remains after masticating, digesting, and assimilating the food is termed the *net energy* of the food. This net energy is used by the animal in the work of the heart, lungs, and other internal organs, and in case a surplus of net energy remains after satisfying the maintenance requirement of the animal, such surplus may be used for producing fat, growth, milk, or wool, or in the performance of external work, etc.

71. Available and net energy.—There has already been given a brief description of the respiration apparatus, with an example study by Henneberg of the intake and outgo of an ox confined therein. In recent years the respiration apparatus of the earlier times has been improved by adding thereto means for accurately measuring the heat given off by the animal while under study. The new apparatus is styled the *respiration calorimeter.* The first respiration calorimeter in the United States was constructed by Atwater with the aid of the United States Department of Agriculture, at Middletown, Connecticut. It was for human nutrition studies only. The first and only respiration calorimeter for animals in this country was erected some years since in a special building at the Pennsylvania State College by Armsby, thru the joint efforts of the United States Department of Agriculture and the Pennsylvania Station.[1]

For many years Kellner[2] of the Möckern Station, Germany, has been using the respiration chamber in animal studies. His studies and those of Armsby[3] with the respiration calorimeter have been for the most part with the mature ox. In these investigations not

[1] For a popular description of these calorimeters, see Century Magazine, July, 1887, and the Experiment Station Record, July, 1904.
[2] Land. Vers. Stat., 53, 1900, pp. 440–468.
[3] U. S. Dept. Agr., Bur. Anim. Ind., Bul. 101.

only was a record kept of all the feed consumed and water drank, but of everything that passed from the animal, including the so-called solid excrement, urine, carbonic acid gas, and water, and in the case of Armsby's experiments all the heat given off by the body. While the work of Kellner and Armsby has really only begun, they have already brought out facts of great interest and importance. The following table sets forth some of their findings with reference to what becomes of the pure nutrients and three common feeding stuffs when fed to the ox.

Net energy from 100 lbs. of pure nutrients and common feeding stuffs.

Nutrients or feeding stuffs	Total energy	Energy lost					Net energy remaining
		In feces	In methane gas	In urine	In production process's	Total loss	
	Therms	Therms	Therms	Therms	Therms	Therms	Therms
Pure nutrients							
Peanut oil (fat)	399.2	0.0	0.0	0.0	174.4	174.4	224.8
Wheat gluten (protein)	263.1	0.0	0.0	49.2	118.3	167.5	95.6
Starch (carbohydrate)	186.0	0.0	18.8	0.0	68.7	87.5	98.5
Common feeding stuffs							
Corn meal	170.9	15.7	15.9	6.6	62.0	100.2	70.7
Timothy hay	179.3	87.7	6.8	5.5	52.9	152.9	26.4
Wheat straw	171.4	93.9	15.5	4.3	47.4	161.1	10.3
Expressed in per cent.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Corn meal	100	9.2	9.3	3.9	36.3	58.7	41.3
Timothy hay	100	48.9	3.8	3.1	29.5	85.3	14.7
Wheat straw	100	54.8	9.0	2.5	27.7	94.0	6.0

This table sets forth some of the highest and most instructive attainments of the scientists working on animal nutrition. It shows, first of all, that when 100 lbs. of pure peanut oil, a true fat, is burned it will yield 399.2 therms. When fed, none of this oil passed into the solid excrement or feces as waste, all being absorbed out of the small intestine and going into the body proper. This oil contained no nitrogen, and so no nitrogenous waste from it appeared in the urine, nor did any of it form methane gas in the intestines. To digest and assimilate this 100 lbs. of oil required 174.4 therms of energy, leaving 224.8 therms which might be stored in the body, either temporarily in the lymph bathing the tissue cells, or more permanently as body fat.

When 100 lbs. or 263.1 therms of wheat gluten, which is principally protein, was fed, no part passed away in the solid droppings, but the very large amount of 49.2 therms was carried away by the urine, this loss coming from the breaking down of this protein nutrient within the body, or from the breaking down of body tissue which was replaced by new protein from this source. In all, 167.5 out of 263.1 therms in 100 lbs. of gluten were lost either in the urine or in carrying on the work of mastication, digestion, and assimilation, leaving 95.6 therms which might be temporarily or permanently stored in the body. This amount of protein was available for building protein tissues or lean meat, which would be its highest use, or it could serve for the production of body fat, etc.

72. Losses in undigested matter, methane, and urine.—Studying the lower division of the table we observe that if the total energy of corn meal is placed at 100, then 9.2 per ct. of its heat value passed from the ox in the undigested matter of the solid excrement. This loss we may compare to bits of coal passing unburned thru the grate bars of a furnace. While undergoing digestion, large quantities of gas, called methane, were formed. This gas was taken from the intestines by the blood and given off thru the lungs and skin, a loss of 9.3 per ct. resulting. There was a further loss of 3.9 per ct. in the urea which left the body in the urine by way of the kidneys. The sum of these three losses is 22.4 per ct., which measures that portion of the total fuel value of the corn meal which was of no value to the ox, but really worse than useless, because work was required in passing it thru the alimentary tract. The remaining 77.6 per ct. represents the available energy of the corn.

73. Losses due to mastication, digestion, and assimilation.—From this 77.6 per ct. of available energy must be deducted the energy expended in the work of mastication, digestion, and assimilation, amounting to 36.3 per ct. of the total fuel value of the corn. Subtracting this last sum and the previous losses from 100, there remains 41.3 per ct. as the net energy value of the corn, or the amount which the animal may use for repairing body tissue, for growth, for the laying on of fat, or for the production of external work. In the case of timothy hay only 14.7 per ct., and with wheat straw but 6 per ct., of its original fuel value remains as finally available for such purposes. About one-half of the total fuel value of these two feeds passed off as undigested matter, this portion never having been inside the body proper.

In noting the heavy losses shown under the column headed "Production processes," the following points are of interest: Zuntz found that the work of the horse in chewing hay and preparing it for swallowing required 4.5 per ct. of the total energy in the hay, oats only a little over 1 per ct., and corn but one-third of 1 per ct. He estimates that with the horse the work of digestion calls for about 9 per ct. of all the energy in the digestible portion of the food. He further found that each 100 lbs. of fiber, or the woody part of feeding stuffs, in passing thru the animal, whether digested or not, required about 118 therms for the work of disposing of it.

The digestive processes call for a large amount of work, and this means an evolution of heat. Such roughages as straw, hay, and corn stover, because of their coarse, woody character due to the fiber they contain, place much work on the animal in digesting them and passing the waste out of the body. Where the animal, such as an idle horse in winter, is doing no work, living on coarse food may bring no harm but rather economy in cost of keep, because the large amount of heat necessarily evolved in the digestion and passage of such food helps to keep the animal warm. On the other hand animals at hard work and those producing milk or being fattened cannot profitably utilize large amounts of coarse forage.

The data of the table we have been studying are as a whole correct, interesting, and helpful in extending our knowledge of a difficult, tho most important, subject of animal nutrition. In details the data are more or less imperfect. It is hardly probable, for example, that corn evolves as much methane gas during digestion as does straw, and more than timothy hay. The student should not regard the figures in each division of the table as exact and final, but rather as approximate to the facts. Taken in the right spirit, these data are of the highest value in setting forth what portions of the food consumed by the animal are lost at each step in their progress thru the body, and how a considerable part of the value of the food is required to carry on the work of mastication, digestion, and metabolism, leaving a relatively small portion ultimately available for building the body or for external work. The marvel is that the scientists have been able to go so far in solving these most complicated problems, and that their zeal is still unabated.

CHAPTER IV.

NUTRITION STUDIES—THE FUNCTIONS OF PROTEIN, CARBOHYDRATES, AND FAT.

In this chapter there will be considered the effects of withholding all food from the animal and of feeding the three basic nutrients—proteins, carbohydrates, and fat—separately and in combination.

74. Starvation.—At all times there is a loss of nitrogen from the animal body by way of the urine, since all the tissues are steadily breaking down and wasting away. The nitrogen excretion from the body of a well-nourished animal is relatively large, keeping pace with the amount of nitrogen supplied in the food. If food is withheld from such an animal the nitrogen excretion decreases rapidly at first, many holding that the losses at this time fall chiefly upon the circulating protein, or protein which is not a part of the tissues of the body. If starvation continues, this loss falls upon both the circulating protein and on the muscles and other nitrogenous tissues of the body. At the same time the fats of the body are also being gradually oxidized or burned in the effort to sustain life. The nitrogen waste in the urine now slowly decreases until it reaches a minimum, which remains quite constant so long as there is available fatty matter to furnish energy. When the supply of body fat begins to fail, however, the muscles and other protein tissues waste more rapidly, and the animal finally perishes thru the impairment of its organs and the lack of the food fuel required to carry on the functions of life.

A rise in temperature occurs at the beginning of starvation, followed by a general fall until death takes place. Carnivora or flesh-eating animals can withstand hunger longer than herbivora. While dogs and cats have lived until their weights were decreased 33 to 40 per ct., horses and ruminants will die when their weight has been reduced 20 to 25 per ct.[1] The age of the animal also influences the time at which death occurs from starvation, old animals withstanding the effects of hunger better than young ones, the latter losing weight more rapidly and dying after a smaller loss of weight than old ones.[2]

[1] M. Wilckens in v. d. Goltz, Hand. d. ges. Landw., III, p. 88.
[2] Halliburton, Chem. Physiol., p. 834.

75. Feeding protein only.—We have seen that during starvation there is a small but steady waste of the protein tissues of the body, both thru natural wear and the heavier loss due to the effort to support life by using the energy these tissues furnish on being oxidized.

On the basis of the theory of circulating protein, it is assumed that the protein of the body tissues, such as the muscles, is normally subject to only slow oxidation. On the other hand, the circulating protein, which is relatively large in the well nourished body, but which rapidly disappears during starvation, is easily and quickly decomposed, and furnishes by far the larger part of the nitrogen waste of the liberally fed animal. If a mature starving animal is fed a limited amount of practically pure protein substance, such as washed lean meat, the circulating protein in the body will be increased, with a proportionately greater nitrogen waste. Even tho the food consumed contains more protein than balances the daily waste from the tissues, there will be no storage of nitrogen during the feeding of this one-sided ration.

When protein is fed far in excess of the waste of the starving body, nitrogen equilibrium may be established; that is, the amount of nitrogen excreted will equal but not exceed that consumed in the food. If the supply of protein given to a mature animal be still further increased after nitrogen equilibrium is reached, the excess of protein fed will not be stored in the body as protein, thereby increasing the muscular tissues, but will still be decomposed, and the nitrogen excreted in the urine. Thus the nitrogen waste keeps pace with the supply of nitrogen in the food. This does not mean, however, that the food value of the protein so decomposed has been entirely lost to the animal. After the splitting off of the nitrogen from the protein molecules the non-nitrogenous residue which remains may be converted into glucose and finally into glycogen or fats.

Supplying a heavy exclusive protein ration not only tends to check the waste of the fat already stored in the body, but probably with flesh-eating animals at least, fat may be formed from the protein of the food and stored as body fat during such exclusive protein feeding. (**83**) It is probable, then, that the carnivora or flesh-eating animals can live on pure protein food alone, providing it is supplied in abundance. Whether the herbivora, or plant-eating animals, can live on protein alone has not been settled, and altho of scientific interest the subject has no practical importance.

76. Feeding fats and carbohydrates only.—Kellner[1] points out that when animals are fed exclusively on nitrogen-free nutrients, such as the sugars, starches, fats, etc., the waste of fat from the body is materially lessened, and the waste of the nitrogenous tissues of the body, such as the muscles, is somewhat reduced, tho not entirely stopped. On account of this sparing of the body substances, animals forced to live on such diet survive longer than those wholly deprived of food. Yet because of the continuous small waste of protein from the tissues of the body, animals nourished solely on fats and carbohydrates cannot long survive.

77. Feeding fats and carbohydrates with protein.—Experiments by Voit[2] with dogs, and Kellner[3] with oxen, show that when animals are fed fats or carbohydrates in addition to protein, the nitrogen waste depends in some measure upon, but does not necessarily keep pace with, the amount of nitrogen supplied in the food, since the fats and carbohydrates protect the protein in the body from oxidation, or spare it, to some extent. The digestible portion of the crude fiber, and likewise in all probability the pentosans, decrease the waste of nitrogen in some degree, as do the more easily digested sugars and starches.

When an excess of protein is supplied an animal, the nitrogen waste is greatly increased, as the following experiment by Lawes and Gilbert[4] shows. One of 2 pigs which were similar in weight and appearance was given all it would consume of lentil meal, which contains about 25 per ct. of crude protein. The other was fed an unlimited ration of barley meal, containing about 12 per ct. of crude protein. The nitrogen consumed in the food and excreted as urea was as follows:

Effect of an excess of protein on the nitrogen excretion.

Periods	Food	Nitrogen in food	Urea-nitrogen
Days		Grams	Grams
3	No. 1, Lentil meal	123.0	62.6
3	No. 2, Barley meal	58.9	28.7
10	No. 1, Lentil meal	120.6	65.8
10	No. 2, Barley meal	51.2	24.3

The table shows that the pig receiving lentil meal consumed more than twice as much nitrogen as the one fed barley meal. It also

[1] Ernähr. landw. Nutztiere, 1907, p. 125.
[2] Ztschr. Biol., 5, 1869, pp. 352, 431.
[3] Landw. Vers. Stat., 53, 1900, pp. 124, 210, 316.
[4] Jour. Roy. Agr. Soc., 1895; U. S. Dept. Agr., Office Expt. Sta., Bul. 22.

excreted more than twice as much nitrogen as urea as did the other pig, the nitrogen waste thus depending on the nitrogen intake.

Experiments show that a pound of carbohydrates has somewhat greater protein-sparing action than a pound of fat, a surprising fact when we remember that, on burning, fat produces over twice as much energy as do carbohydrates. Evidently there is no relation between the fuel values of these nutrients and their protein-sparing power. Landegren[1] explains this superiority of carbohydrates over fat as follows: For the carrying on of their normal functions, living cells need a certain minimum not only of protein but also of carbohydrates, especially glucose. When carbohydrates are not supplied, the body forms the necessary glucose by decomposing protein. So long, however, as there is an ample supply of carbohydrates in the food, protein is not used for this purpose. As the body can form carbohydrates from fat only with great difficulty, if at all, the fats are less potent than the carbohydrates in checking the protein wastes in the body.

78. Amids.—Some scientists hold that the amids do not serve to form the protein tissues in the body of farm animals. Numerous experiments have shown that asparagin, a pure amid, cannot spare protein or take its place in the bodies of the carnivora and omnivora. It is quite generally agreed, however, that the amids furnish energy to the body and may in some cases prevent the waste of the protein tissues. Nearly half the nitrogen in corn silage, and not over 15 per ct. of that in dried corn forage, is in amid form. Yet, based on dry matter, corn silage is somewhat more valuable than corn forage as a feed for dairy cows, which require a liberal supply of crude protein. The amids are abundant in grass, roots, and silage, all of which feeding stuffs are especially useful to growing or pregnant animals and to those producing milk and wool. Kellner[2] and Strusiewicz[3] have shown that sheep given protein-poor rations gained in weight when asparagin was added. In view of such facts it is reasonable to hold that at least some of the amids can be built up into the protein tissues of the bodies of farm animals.

79. Origin of body fat.—The exact source of the fat which animals store in their bodies has been the subject of much controversy. Kellner, Armsby, Hagemann, and other modern authorities agree that the body fat of animals may originate either from fat or carbo-

[1] Skand. Archiv. Physiol., 14, 1903, p. 112.
[2] Ztschr. Biol., 39, 1900, p. 313.
[3] Ztschr. Biol., 47, p. 143.

hydrates. Scientists still disagree upon the possibility of animal fat being formed thru the decomposition of protein. The preponderance of evidence favors such conclusion, as is later shown. (**83**)

80. Body fat from food fat.—Many experiments have conclusively shown that the fat in food, which has been acted on by the digestive fluids in the intestines, may be directly stored in the body tissues when supplied in large quantity.

Hofmann[1] allowed a dog to starve until its weight had decreased from 26.5 to 16 kilograms and the supply of fat in its body had entirely disappeared, as shown by the increased decomposition of the protein tissues at that time. For 5 days this dog was fed large quantities of fat and only a little fat-free meat, during which time it gained 4.2 kgms. in weight. When slaughtered its body contained 1353 grams of fat, only 131 of which could possibly have come from the protein fed. Hence much of the fat formed during this time must have come from the fat of the food.

Henriques and Hansel[2] fed 2 three-months-old pigs barley meal together with oil. The first pig received linseed and the second cocoanut oil. Samples of the body fat were removed from the back of each pig thru incisions, and analyzed. The fat which had formed during the feeding resembled in odor, consistency, and composition the vegetable fat which had been fed. Later, when the feeds were reversed with the 2 pigs, the body fat then formed showed a corresponding change in properties.

All the digested fat taken into the body of the animal beyond that required for maintenance cannot, however, be deposited as body fat, since considerable losses always occur thru the energy expended in digestion and metabolism. Kellner[3] states that in the case of carnivora, or flesh-eating animals, such as the dog, not more than 87.3 lbs. of body fat can be formed from 100 lbs. of pure fat supplied in the food. With herbivora, or animals which consume coarse forage, such as the horse, ox, etc., considerable losses are caused by fermentations which take place in the digestive organs. The work of moving the food thru the digestive tract, digesting it, and disposing of the waste is also relatively large. Hence the amount of body fat which may be formed by these animals from 100 lbs. of digestible fat in the food consumed is much lower than with the carnivora, varying from 64.4 lbs. in the case of pure fats to 47.4 lbs. in the fats of roughages.

[1] Ztschr. Biol., 8, 1872, p. 153.
[2] Centbl. Agr. Chem., 29, 1900, p. 529.
[3] Ernähr. landw. Nutztiere, 1907, p. 143.

81. Fat from carbohydrates.—Scientists agree that the fat in the body of animals can be formed from carbohydrates. As early as 1842 Liebig maintained that animal fat was formed mainly from the carbohydrates, tho it might also originate from the protein of the food. The extensive experiments of Lawes and Gilbert of the Rothamsted Station,[1] conducted from 1848–1853 with more than 400 animals, clearly showed that much more fat was stored than could be derived from the fatty matter and protein of the food.

Soxhlet[2] fed 2 full-grown pigs a daily ration of 4.4 lbs. of rice meal for 5 days. One pig was then killed and its body analyzed, while the other was fed 4.4 lbs. of rice, daily, and later a ration of 3.3 lbs. of rice with some meat extract, both foods which are almost free from fat. After 82 days this pig was also killed and its body analyzed. Assuming that the bodies of both pigs were of similar composition when the first was killed, Soxhlet found the quantity of fat formed in the body of the second pig and its source to be as follows:

	Grams
Maximum fat possible from fat in food	340
Maximum fat possible from protein in food	2,488
Maximum fat that must have been formed from carbohydrates in food	19,352
Total fat from 3 sources	22,180

It is shown that during the trial 22,180 grams of fat were formed. Deducting from this the sum of the maximum amounts of fat which could have been derived from the fat and the protein supplied in the food, there remains 19,352 grams of fat as the minimum which must have been formed from the carbohydrates in the food. Hence at least 87 per ct. of the fat formed by this pig during the trial was derived from the carbohydrates in the food.

The formation of fat by ruminants from the carbohydrates was first demonstrated by Kühn[3] with the aid of a respiration apparatus. Oxen were fed for long periods on meadow hay and starch, which provided a ration low in protein and fat. Kühn shows that even if all the carbon resulting from the digestion of the protein and fat in the food went to form fat in the body, there still remained a large amount of deposited fat which could only have come from the carbohydrates of the food. These conclusions are confirmed by later experiments by Kellner,[4] also with oxen. In

[1] Jour. Roy. Agr. Soc. VI, Pt. 1, 1895; Bul. 22, Office of Expt. Sta.
[2] Jahresber. Agr.Chem., 1881, p. 434.
[3] Landw. Vers. Stat., 44, 1894, pp. 1–581.
[4] Land. Vers. Stat., 53, 1900, pp. 1–450.

these later trials it is shown that 100 lbs. of digested starch or digested fiber yielded about 24.8 lbs., and 100 lbs. of digested cane sugar only 18.8 lbs., of body fat.

82. Fat from pentosans.—Tho no experiments have yet been carried on to show that body fat may be formed from pure pentosans, it is certain that these carbohydrates aid in its formation. Kellner[1] fed oxen straw in which pentosans furnished 33 per ct. of the energy. The large deposits of fat which followed must have come in part from the pentosans of the food.

83. Fat from protein.—When a liberal protein diet supplies the animal with more energy than is necessary for its maintenance, not only may a part of the excess protein be deposited in the body as flesh, but the non-nitrogenous portion resulting from the cleavage of protein may be converted into body fat or glycogen. Since body fat may be derived from the carbohydrates, and since glucose and glycogen may be formed from the proteins, it is reasonable to hold that body fat may be formed from the protein of the food. Demonstration of the direct formation of body fat from food protein is difficult, however, as it is almost impossible to induce animals to consume any large quantity of pure protein food. The consumption of protein must be relatively large to maintain the nitrogen equilibrium of the body, and so usually but a small excess available for the formation of fat remains above body requirements.

Investigations by Cramer[2] with cats, and by Voit[3] and Gruber[4] with dogs which were fed large amounts of lean meat, show that the protein it contained must have been the source of the fat which was stored in their bodies during the trials. Henneberg,[5] working with dogs, concluded that 100 lbs. of protein may, upon decomposition, yield 51.4 lbs. of fat. Rubner,[6] likewise experimenting with dogs, has shown that owing to the losses of energy which occur in the decomposition of protein not more than 34.7 lbs. of fat can be formed from 100 lbs. of protein in the food.

Herbivora—the ox, horse, sheep, etc.—cannot be fed exclusively on protein, since such feeding causes intestinal disorders. Kellner,[7] experimenting with steers, added wheat gluten, which is principally composed of vegetable proteins, to a ration which was already causing a considerable deposition of fat. The feeding of 100 lbs. of gluten caused the deposition of only 23.5 lbs. of fat

[1] Loc. cit.
[2] Ztschr. Biol., 38, 1899, p. 307.
[3] Jahresber. Tier-Chem., 22, 1892, p. 34.
[4] Ztschr. Biol., 42, 1901, p. 407.
[5] Landw. Vers. Sta., 20, 1877, p. 394.
[6] Ztschr. Biol., 21, 1885, p 250.
[7] Landw. Vers. Sta., 53, 1900, p. 452.

above the amount due to the basal ration. Kellner maintains that this additional deposit was derived from the protein fed in the wheat gluten. Less body fat was formed by the steers from 100 lbs. of protein than would have been formed by dogs, on account of the large losses which occur thru fermentations in the digestive organs of ruminants. As above shown, Kellner found that because of the large losses which occur thru fermentations in the digestive organs of herbivora, only 23.5 lbs. of fat can be formed by these animals from 100 lbs. of protein in the food.

84. The source of fat in milk.—By an ingenious experiment Jordan and Jenter of the New York (Geneva) Station[1] proved that the cow can form the fat of milk from substances other than the fat in her food. A thousand lbs. of hay and 1500 lbs. each of corn meal and ground oats were sent to a new-process oil-meal factory, where nearly all the fat was extracted from these feeds with naphtha in the percolators employed for extracting the oil from crushed flax seed. The almost fat-free feeds were returned to the Station and afterwards fed to a cow which had freshened about 4 months before. For 95 days the cow lived on these nearly fat-free feeds, yet during this period she gave 62.9 lbs. of fat in her milk. The food she consumed contained but 11.6 lbs. of fat, of which only 5.7 lbs. was digested. Hence at least 57.2 lbs. of the fat found in the milk must have been derived from some other source than the fat in the food. This fat could not have come from the body of the cow, for Jordan writes: "The cow's body could have contained scarcely more than 60 lbs. of fat at the beginning of the experiment; she gained 47 lbs. in weight during this period with no increase of body nitrogen, and was judged to be a much fatter cow at the end; the formation of this quantity of milk fat from the body fat would have caused a marked condition of emaciation, which, because of an increase in the body weight, would have required the improbable increase in the body of 104 lbs. of water and intestinal contents."

Jordan concludes that not over 17 lbs. of the fat produced during the trial could possibly have been produced from the protein supplied in the food. It is most evident that a large part of all the fat produced by this cow must have come from the carbohydrates in her feed, and so a long disputed question is at length settled.

[1] Bul. 132.

85. Body fat from nutrients.—The following table from Kellner[1] summarizes his studies on the amount of fat which may possibly be formed in the body of the growing ox from 100 lbs. of digestible matter of the several nutrients fed in combination with a basal ration already exceeding the maintenance requirements of the animal:

	Energy available for fat formation Therms	Possible fat Lbs.
Fat	204–259	47.4–59.8
Protein	102	23.5
Starch and fiber	107	24.8
Cane sugar	81	18.8

The table shows that if an ox is getting enough food for maintenance, supplying 100 lbs. of fat in addition may result in the storage of from 47.4 to 59.8 lbs. of body fat. For the other nutrients there is a smaller deposit, cane sugar forming only 18.8 lbs.

[1] Ernähr. landw. Nutztiere, 1907, p. 158.

CHAPTER V.

NUTRITION STUDIES CONTINUED.

I. Additional Requirements of the Animal.

86. Air.—The first and most vital requirement of animals is air. The amount of air breathed by farm animals, as given by King,[1] is placed in the first division of the table below. The second division shows the quantity of fresh air that must pour into a room where animals are confined, in order to provide substantially pure air, or that which does not contain over 3.3 per ct. of air that has been previously breathed.

Air breathed by animals, and air required for good ventilation.

Animal	Air breathed			Ventilation requirement per animal	
	Hourly	Per 24 hrs.		Hourly	Per 24 hrs.
	Cu. ft.	Cu. ft.	Lbs.	Cu. ft.	Cu. ft.
Horse	142	3,401	272	4,296	103,104
Cow	117	2,804	224	3,542	85,008
Pig	46	1,103	89	1,392	33,408
Sheep	30	726	58	917	22,008

The table shows that the horse breathes hourly 142 cu. ft. of air, and daily about 3,400 cu. ft., which weighs about 272 lbs. To provide the horse in confinement with air not more than 3.3 per ct. of which has been previously breathed, there must hourly pass into the room not less than 4,296 cu. ft., or over 103,000 cu. ft. each 24 hours.

The cow gives off about 19 therms of heat each 24 hours, or enough to raise 79,603 cu. ft. of dry air from 0° F. to 50° F. As shown in the preceding table, proper ventilation for the cow requires that about 85,000 cu. ft. of air be brought into the stable each 24 hours. This is only a little more air than the natural heat from her body will raise from 0° F. to 50° F., which is a desirable winter temperature for cow stables in cold climates.

87. Water.—Animals can live much longer without solid food than without water, and an insufficiency of water in the body causes serious disturbances. The processes of mastication, digestion, ab-

[1] Ventilation for Dwellings, Rural Schools and Stables.

sorption, and assimilation are hindered; the intestines are not properly flushed, and waste matter remains too long therein; the blood thickens; and the body temperature is increased. Thru these complications death may result. Animals partially deprived of water for a long period lose their appetite for solid food, and vomiting and diarrhea may occur, the latter also often taking place when water is again supplied.

Under normal conditions animals consume a fairly uniform quantity of water for each pound of dry matter eaten; Kellner places the amount at 4 to 6 lbs. for milch cows, 4 to 5 lbs. for oxen, 2 to 3 lbs. for horses and sheep, and for swine 7 to 8 lbs., which seems excessive. Possibly due to their laxative nature, feeds rich in crude protein—bran, linseed meal, peas, etc.—cause a greater demand for water than starchy feeds. Kellner[1] found that for each 100 lbs. of water drank and in the food, the stabled ox passed 46.3 lbs. in the solid excrement, 29.2 in the urine, and 24.5 in the breath and perspiration. Water is an important regulator of the temperature of the animal body. A large amount of heat is absorbed in converting water into the vapor given off by the lungs and skin, and when sweat evaporates it carries much heat from the body. **(105)**

The free drinking of water does not diminish the gains of animals nor increase the breaking down of protein in the body, tho flushing the intestines with much water may at first cause a more complete removal of the nitrogenous waste therefrom. With animals which continue to drink freely, the nitrogenous waste soon becomes normal again. Scientists now agree that farm animals should have all the water they will drink, for they do not take it in excess unless they are forced to live on watery foods or are given salt irregularly. The excess of water taken into the body is discharged thru the urine.

Water taken into the body must be raised to the temperature of the body. Warington[2] points out that during winter sheep in the turnip fields of England consume about 20 lbs. of roots daily, containing over 18 lbs. of water, or about 15 lbs. more than is needed. To raise 15 lbs. of water from near the freezing point to the body temperature requires the heat evolved in the body by burning nutrients found in the turnips, equivalent to 3 oz. of glucose, or about 11 per ct. of their total food value. In addition the equiva-

[1] Landw. Vers. Stat., 53, 1900, p. 404.
[2] Chemistry of the Farm.

lent of more than 2 oz. of glucose must be burned for each lb. of water vapor given off from the lungs and skin. Warming cold water taken into the body does not necessarily mean that more food must be burned, for animals evolve a large amount of heat in the work of digesting food and converting the digested matter into body products or work. (**104**) Due to this, many animals have an excess of body heat. Comfortably-housed and well-fed steers and dairy cows burn more food than is needed to keep their bodies warm, and such excess may go to warm the water they drink, so that no food is directly burned for that purpose.

Armsby[1] points out that in winter farm animals, watered but once daily, then drink freely. The sudden demand for heat caused by taking into the body this large quantity of cold water may exceed the available supply, with the result that some of the food nutrients or body tissues are burned to meet it. Animals unduly exposed to cold and those sparingly fed or with scant coats may be directly helped by watering frequently or by warming their drinking water. In cold regions in order to induce animals, especially cows, to drink freely in winter, it is usually best to warm the water, which should be comfortably accessible.

When entirely oxidized in the body, 100 lbs. of starch or cellulose will yield 55.5 lbs. of water and 163 lbs. of carbon dioxid, and fats over twice as much water as starch. The nitrogenous compounds yield a little less than the carbohydrates because they are not entirely oxidized in the body. This shows that a very considerable amount of water comes to the animal body from the dry matter of the food they consume. It is probable that the water which results from the breaking down of the food is used in the anabolism, or building processes, of the body, rather than that water which the animal drinks, tho this is not definitely known.

88. Mineral matter.—The ash of feeding stuffs is of the greatest importance to animals. This is shown by feeding them rations freed as far as possible from mineral matter, in which case they sooner or later die of mineral starvation. During mineral starvation the nervous system first suffers in a perceptible manner; marked weakness of the limbs, trembling of the muscles, convulsions, and great excitability result; and the animal generally dies sooner than when no food is given.[2]

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[1] Principles of Animal Nutrition, p. 439.
[2] Kellner, Ernähr. landw. Nutztiere, 1907, p. 169.

Howell[1] states that the mineral salts of the body direct its metabolism, tho in what manner is not known. The blood serum is rich in common salt and other salts of sodium, while the red blood corpuscles are rich in potassium compounds. The nervous system and the nuclei of all cells are rich in phosphorus, and the skeleton is composed largely of calcium or lime, combined with phosphorus. The power of the blood to carry oxygen is due to hemoglobin, an iron-protein compound in the red corpuscles. Blood deprived of its calcium does not coagulate or clot. In the stomach the pepsin acts only in the presence of an acid, normally hydrochloric, derived from the salts of this acid present in the circulation. It is probable that the animal organism is, by reason of its perfection, able to use many of these mineral substances over and over again for the same functions, taking them back into the circulation after they have once been used. In spite of this frugal economy, however, losses of mineral matter from the body constantly occur, even during starvation. Ordinarily the rations of farm animals contain all the necessary mineral matters in small quantities, and since the body retains these with great tenacity when the supply is meager, these small amounts usually suffice. Common salt, lime, and phosphorus are often needed in such large amounts that they may fall short in certain rations, and hence must be added if normal results are to be obtained.

Appendix Table V sets forth the mineral constituents of feeding stuffs so far as it has been possible to secure them.

89. Lime and phosphorus.—Large amounts of lime are deposited in the bones of animals, chiefly as phosphate and in smaller amount as carbonate. It is not surprising, therefore, that a long-continued lack of lime and phosphorus in the food is harmful to the skeleton.

Hart, McCollum, and Humphrey of the Wisconsin Station[2] have shown that the animal skeleton acts as a reserve storehouse of mineral matter, doling out lime, phosphorus, etc., when the supply in the food is below requirements, in order that the metabolic processes of the body may be maintained. Under such conditions the lime and phosphorus content of the flesh and other soft parts remains as high as in animals liberally supplied with these mineral matters. In an experiment by these investigators it was found that a cow, fed a ration deficient in lime, during a period of 3.5 months gave off 5.5 lbs. more lime in milk and excrements than was

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[1] Text Book of Physiology, p. 832.

[2] Research Bul. 5; Am. Jour. Physiol., 1909.

in the food. This was fully 25 per ct. of all the lime in her body, including the skeleton, at the beginning of the trial. (**604**)

Such withdrawal of mineral matter from the skeleton produces porosity and brittleness of bone. In certain localities where the hay and other roughages are especially low in lime and phosphorus,[1] farm animals are so affected by the lack of these mineral substances that their bones are broken easily and in seemingly inexplicable ways, serious losses often occurring. Often this brittleness of bone is noticeable only in years when the normal absorption of lime and phosphorus by the roots of plants is hindered by drought. Of grown animals, those carrying their young are most apt to suffer from the lack of these substances, since considerable amounts are deposited in the fetus. Growing animals whose bones are rapidly increasing in size suffer from a lack of lime or phosphorus sooner than grown animals. Voit[2] found that young animals receiving a ration low in lime are soon attacked by rickets, the joints swelling, the limbs and the spinal column becoming crooked, the teeth remaining small and soft, the animal finally being unable to walk. Pigs, because of restricted diet, suffer from insufficient lime and phosphorus more often than do calves, colts, and lambs, which usually receive enough of these mineral matters in their hay and other food.

The superior value of such leguminous roughages as clover, alfalfa, and cowpea hay with farm animals has in the past been ascribed to their high content of protein. Ingle[3] holds that in such concentrates as linseed oil cake, Indian corn, oats, wheat, and barley, and in such roots and roughages as turnips, swedes, mangels, corn stover, wheat straw, etc., there is generally an excess of phosphorus over calcium or lime. He holds that this excess of phosphorus tends to waste or carry the lime out of the body to an excessive degree and is therefore unfavorable to normal nutrition. The leguminous roughages contain a large excess of lime over phosphorus, and accordingly supplying legumes with the other feeds named makes good such wastage of lime. To this high content of lime as well as to the high protein content we must hereafter ascribe the beneficent effects of clover, alfalfa, vetch, and other leguminous roughages on the growth, milk yield, and bone development of farm animals.

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[1] Kellner, Ernähr. landw. Nutztiere, 1907, p. 185.
[2] Ztschr. Biol., 16, 1880, p. 70.
[3] Jour. of Comparative Pathology and Therapeutics, Mar. 1907.

In forming rations the lime and phosphorus content of the feeds should be considered. Straw, chaff, the various root crops, molasses, and the cereals and their by-products, such as bran and middlings, are all low in lime. On the other hand, the legumes, as clover, alfalfa, etc., the meadow grasses, and many leguminous seeds, such as peas, beans, etc., are high in lime. Straw, chaff, beet pulp, potatoes, and molasses are low in phosphorus, while the cereals and brans, malt sprouts, oil cakes, brewers' grains, and slaughter-house and fish waste carry it in abundance. In many cases where soft water is drunk, there may be a lack of lime only, in others both lime and phosphorus may be deficient.

90. Inorganic phosphorus.—Köhler[1] found that lambs can assimilate and use calcium phosphate, bone ash, and steamed bone. J. Neumann[2] fed calcium carbonate and calcium phosphate to calves with good results. Experiments at Möckern[3] indicate beneficial results from the use of 30 to 50 grams of calcium phosphate in the daily ration of steers which had shown marked brittleness of bone. At the Wisconsin Station,[4] Hart, McCollum, and Fuller found that pigs were able to assimilate inorganic phosphorus supplied in the form of precipitated calcium phosphate, bone ash, or ground rock phosphate. (**122**)

Other experiments are somewhat contradictory in results, but on the whole it appears well established that mineral matter in inorganic form may be absorbed from the digestive tract of farm animals. Animals suffering from lack of lime and phosphorus absorb calcium phosphate with beneficial results, and even with normal rations the addition of calcium phosphate causes increased bone formation. Hence when a ration must be used which is deficient in either lime or phosphorus, or both, lime may be supplied in the form of calcium carbonate in wood ashes or ground limestone, or phosphorus and lime in the form of precipitated calcium phosphate, bone ash, or ground rock phosphate. This latter is by far the cheapest form of phosphorus easily available for such purposes.

91. Common salt.—The hunger of herbivorous animals for common salt is well known, but practical men have differed as to the necessity or advantage of adding it to the ration. In spite of the earlier belief that salt increased the digestibility of food, numerous experiments have shown that the digestibility of the ration

[1] Landw. Vers. Stat., 61, 1905; 65, 1907.
[2] Jour. Land., 41, 1893, p. 343.
[3] Landw. Vers. Stat., 57, 1902, p. 239.
[4] Research Bul. 1.

is neither increased nor diminished thereby. Rather than increasing the waste of protein from the body, as earlier investigators believed, salt appears to slightly lessen protein decomposition. Kellner[1] states that besides the physiological action of salt, it serves as a spice or condiment which stimulates the appetite and increases the palatability of many foods. It also stimulates the secretion of the digestive fluids, increases and hastens the circulation of the fluids of the body, and prevents digestive disturbances.

Excessive consumption of salt must be guarded against, since it greatly increases the amount of water excreted in the urine. On account of the consequent abnormal thirst, animals will then drink exceedingly large quantities of water, which will injure digestion and lead to other disturbances. If sufficient water is not supplied, the water content of the body will be lessened by the increased loss thru the kidneys, leading to increased breaking down of protein. (**87**) If animals are allowed free access to salt or supplied with it at frequent and regular intervals, they will consume only enough to meet the needs of the body.

Of the numerous salt-feeding experiments, only those of Babcock and Carlyle of the Wisconsin Station[2] are satisfactory and conclusive. In these trials dairy cows, well nourished otherwise, were given no common salt (sodium chlorid) for long periods—more than a year in some instances. The following conclusions were reached: "In every case the cows exhibited an abnormal appetite for salt after having been deprived of it for 2 or 3 weeks, but in no case did the health of the animal, as shown by the general appearance, the live weight, or the yield of milk, appear to be affected until a much longer time had elapsed. This period of immunity varied with individual cows from less than a month to more than a year. There was finally reached a condition of low vitality in which a sudden and complete breakdown occurred. This stage was marked by loss of appetite, a generally haggard appearance, lusterless eyes, a rough coat, and a very rapid decline in both live weight and yield of milk." If salt was supplied at this period recovery was rapid. In one case potassium chlorid was given instead of common salt (sodium chlorid). Considerable of the potassium salt was eaten, tho cows ordinarily refuse to touch it, and recovery followed as quickly as when common

[1] Ernähr. landw. Nutztiere, 1907, p. 173. [2] Rpt. 1905.

salt was supplied—evidence that not the lack of sodium but the lack of chlorin was responsible for the troubles. The breakdown due to the lack of salt usually occurred after calving when the milk flow was heavy, and generally the cows giving the largest amount of milk were the first to show distress.

Babcock points out that the amount of salt required in the ration will vary greatly in different localities. Soils which contain large quantities of salt doubtless produce feeding stuffs containing more salt than those poor in this ingredient; and again the water of streams and wells varies greatly in its salt content. These facts doubtless account for the disagreement among experimenters in different parts of the world as to the importance and value of salt. Cows in milk and sheep show the greatest need of salt; fattening cattle, horses, dry cows, and stock cattle require less salt; and pigs but little.

92. Light.—Graffenberger,[1] experimenting with young and full-grown rabbits confined in a dark room for long periods, found that the hemoglobin content of the blood was lowered and the amount of blood in the body was decreased by from 9 to 22 per ct. thru such confinement. An increased formation of fat was observed, which was especially marked in the case of mature animals. If confined too long in the dark the increase was relatively small. Graffenberger does not advocate entire darkness for fattening animals, but rather the partial absence of light, which tends to quiet and hence favors fattening. The development of the skeleton and the liver is retarded by darkness, so that the prolonged absence of light has a deleterious effect on animals. Darkened quarters are not advisable for fattening animals fed for long periods, and in no case for young ones designed ultimately for work, milk production, or breeding.

93. Quiet.—Farm animals are creatures of habit, and once accustomed to a routine of living show unrest with any change. The feed stable or feed lot should be free from disturbance, and the administration of feed and water should be uniform in time and manner. Animals soon learn when these are to occur, and as feeding time approaches the secretions begin pouring from the various glands in anticipation of the coming meal. The system of feeding and watering and the character of the rations should be changed gradually and only for good cause. In feeding operations a changing period is usually a losing period.

[1] Arch. Physiol. (Pflüger), 53, 1893, p. 238.

II. Growth, Maintenance, Fattening.

1. Growth.

94. Flesh formation.—The lean-meat tissues of the animal body are composed mostly of muscular fibers. Any increase of flesh tissues can be caused solely by an increase in number or by the thickening of these fibers. These fibers increase in number by dividing lengthwise, which process occurs with farm animals only while young and growing. The fibers of the muscles can thicken to a limited extent only, and hence the muscular tissues, or lean meat, of the mature animal cannot be increased beyond a narrow limit.

According to Rubner,[1] the storage of protein tissue by mature animals is accompanied by more rapid breathing, a rise in temperature, and more rapid oxidation of the circulating protein. Kellner[2] states that a full-grown 66-lb. dog may easily store 2 lbs. of fat in his body without the food requirements or bodily functions being materially changed. If the same amount of protein, having but one-half the energy value of the fat, is built up into protein body tissue, an extraordinary amount of food and energy must be expended, and marked changes will then be observed in the behavior of the animal. Nearly all the protein consumed by mature animals which are neither pregnant nor producing wool or milk is burned or broken down in the body, yielding heat and energy, or is partially decomposed and forms fat and glycogen, which may be stored in the body. Mature animals do not store over 10 to 15 per ct. of the digested protein as protein tissue, and often none at all.

The bones are partly and the muscles, ligaments, tendons, nervous system, and viscera of animals almost wholly protein. During youth all these parts of the body steadily increase in size. Thus growing animals store large amounts of protein in their bodies. Weiske[3] found that 5-months-old lambs stored over 22 per ct. of all the protein digested from their food, and Soxhlet[4] found that sucking calves used for the formation of flesh 72.6 per ct. of the digested protein of the milk consumed. The large and long-continued storage of protein in young animals does not cause changes in the body which lead to increased oxidation, such as occur in mature animals.

[1] Gesetze Energieverbrauch, 1902, p. 305.
[2] Ernähr. landw. Nutztiere, 1907, p. 119.
[3] Landw. Jahrb., 9, 1880, p. 205.
[4] Ber. land. chem. Vers. Stat. Wien, 1878, p. 133.

A healthy growing person with poor muscular development may by suitable food and exercise materially strengthen and increase the size of his muscles thru the thickening of the individual fibers. Caspari,[1] studying working dogs, and Bornstein,[2] experimenting with himself, found that when a considerable amount of muscular work was performed, if the body was supplied with an abundance of protein-rich food there was a small but continued gain of body protein. An animal whose muscles have wasted away thru lack of food or thru sickness will repair its tissues upon a return to favorable conditions, thereby storing protein. The storage of fat in the body is necessarily accompanied by a very slight increase of body protein, due to the growth of the tissues holding the fatty matter. The framework of bone, partly of protein but largely of mineral matter, is in general subject to the laws that govern the formation of protein tissues. Differing from protein, the water and especially the fatty matter of the body may vary greatly in total and relative amounts according to heredity, the abundance and character of the food, exercise, etc.

95. The growing animal.—The body of the young, growing animal undergoes a rapid increase in protein tissues and bone, but that of the mature animal is normally in equilibrium, i. e. the protein outgo equals the protein intake, there being neither increase nor loss of protein tissue. Equilibrium is not possible with young animals. Waters of the Missouri Station,[3] experimenting with yearling steers, has shown that young animals fed scanty rations increase in height, even tho losing in weight. With insufficient food some of the organs or parts may continue to grow at the expense of others, a process which, if long continued, results in injury or death. An abundant supply of protein is essential for the formation of the protein tissues of the body, and mineral matter is necessary for the framework of bone.

The suckling utilizes its food most economically. At the Wisconsin Station, lambs fed cow's milk gained 1 lb. in weight for each 0.75 lb. of dry matter consumed. In respiration studies with a calf 2 to 3 weeks old, Soxhlet[4] found a storage in the body of 72.6 per ct. of the protein, 96.6 per ct. of the lime, and 72.6 per ct. of the phosphorus fed in the milk, showing that the young animal stores a large portion of the digested food nutrients, including protein. As

[1] Archiv. Physiol., 83, 1901, p. 535.
[2] Ibid., p. 548.
[3] Proc. Soc. Prom. Agr. Sci. 1908.
[4] Ber. landw. chem. Vers. Stat. Wien, 1878, p. 101.

it grows and takes more exercise, the processes which lead to the breaking down of the nutrients and their waste from the body become more pronounced, and the proportion of food which forms body substances steadily diminishes.

Gain in body substances by well-nourished young animals is relatively much greater than by mature animals even when fattening. The unweaned calf may increase 2 to 3 lbs. daily for each 100 lbs. of body weight, while a gain of 0.3 to 0.4 lb. daily per 100 lbs. of body weight is large for the mature fattening ox. The more rapid increase in weight of young animals is due to several causes—their flesh contains more water; their food is more digestible and concentrated; and they consume more food in proportion to live weight. As growth continues, the total quantity of food eaten increases, but the amount per 1000 lbs. live weight diminishes. The daily gain and the consequent returns from food consumed also steadily decrease until maturity is reached, when there is no further gain whatever unless from the laying on of fat.

The following table by Armsby[1] shows the gain of protein, mostly muscular tissues, by the growing ox at various ages:

Storage of protein by the growing ox.

Average age of animal	Authority	Daily gain of protein to the body	
		Per 1000 lbs, of live weight	Computed on total protein in body
Days		Lbs.	Per cent
8	Soxhlet	3.99	2.35
15	Soxhlet	3.55	2.08
32	Soxhlet	2.76	1.69
50	Neumann	1.84	1.08
100	De Vries	1.19	0.71
840	Jordan	0.09	0.06

The table shows that when 8 days old a calf stored daily in its body tissues protein equal to 2.35 per ct. of the total protein then in its body, or about 4 lbs. daily per 1000 lbs. of live weight. The storage of protein, which practically measures the growth of muscular tissues in the body, steadily decreased with age and growth until the 100-day-old calf stored 1.19 lbs., or less than one-third as much as the 8-day-old calf. When 28 months old and nearly mature, the steer stored but 0.09 lb. of protein daily per 1000 lbs. of body weight. It is thus shown that, as the animal matures, the quantity of protein built up in the body steadily diminishes.

[1] U. S. Dept. Agr., Bur. Anim. Ind., Bul. 108.

2. Maintenance.

96. Maintenance rations for mature animals.—The maintenance ration must furnish sufficient nutrients to cover the requirements of the body for heat, to furnish the energy expended in the work of the heart, lungs, digestive and other internal organs, and in the slight movements of the body always occurring, as well as to furnish material for repairs. The heat requirements of the resting animal are ordinarily in excess of the energy requirements for internal work. Hence the maintenance ration of farm animals, except the pig, may consist largely of roughages, such as hay and straw, which furnish much heat but, being of rather low availability, do not yield much net energy. (**70**) The supply of protein must suffice to replace the small necessary daily loss of nitrogenous body tissues, and also to furnish material for the growth of the nitrogenous hair, hoofs, wool, etc. As this demand for protein is relatively small, the ration may have a wide nutritive ratio, nine-tenths or more of the nutrients consisting of carbohydrates used solely as fuel. The most economical maintenance ration provides no excess of protein, for such excess causes a greater waste of protein from the body. There is considerable variation in the maintenance requirements of different individuals of the same size and species kept under the same conditions, due to differences in temperament. Restlessness causes greater muscular activity, and thereby increases the demand for food fuel. A quiet animal requires less food for maintenance than a nervous, active one. During experiments with a horse in a respiration chamber, Zuntz and Hagemann[1] found that the presence of flies caused the animal to give off over 10 per ct. more carbonic acid gas than normally, which means that this much more food fuel was burned. Work is expended in merely maintaining the position of the body, especially when the animal is standing. Armsby[2] found that the ox in the respiration chamber produced over 30 per ct. more heat when standing than when lying down. The physical condition of the animal also affects the maintenance requirement. Kellner[3] shows that the ox in good condition, especially when fat, requires a larger ration for maintenance than a lean one of the same body surface.

Maintenance requirements vary with the size and weight of the animal. The loss of heat and energy from the body is not propor-

[1] Landw. Jahrb., 23, 1894, p. 161.
[2] Proc. Soc. Prom. Agr. Sci., 1902.
[3] Landw. Vers. Stat., 50, 1898, 245; 53, 1900, 14.

tional to the size or weight, but rather to the body surface. This is shown by Rubner,[1] who determined the quantity of heat given off daily by fasting dogs of different sizes but in the same bodily condition, as reported in the following table:

Heat given off by fasting dogs of different sizes.

Body weight	Body surface	Heat evolved daily	
		Per kgm. wt.	Per sq. m. surface
Kgms.	Sq. m.	Cal.	Cal.
3.2	0.24	88.1	1212
6.5	0.37	66.1	1153
9.6	0.53	65.2	1183
18.2	0.77	46.2	1097
24.0	0.88	40.9	1112
31.2	1.07	36.6	1036

It is shown that while the heat evolved daily per square meter of body surface remained nearly constant, the larger the animal the smaller was the daily loss per kilo of body weight. This is because large bodies have less surface in proportion to their weight than small ones, and the loss of heat from the body is largely determined by its relative surface. Hence maintenance rations should be proportional to the surface of the body rather than its weight. Since it is difficult to actually measure the surface of an animal's body, the maintenance ration for animals of different sizes may be computed by the well-known geometrical law that the surfaces of solids are proportional to the squares of the cube roots of their weights. The protein requirement for maintenance depends not upon the surface of the body of the animal, but directly upon its weight.[2]

The temperature of the animal's surroundings also influences the amount of food required for maintenance, tho not to the degree often supposed. Since with the mature animal at rest and on maintenance the fuel value of all digested food is finally liberated as heat, the heat furnished by the maintenance ration is usually amply sufficient to maintain the body temperature. At an unusually low temperature the animal on a mere maintenance diet may require additional food to keep the body warm.

97. Minimum protein requirement.—In view of the high cost and relative scarcity of crude protein in feeding stuffs, it is desirable to know the minimum requirement of crude protein by farm ani-

[1] Ztschr. Biol., 19, 1883, p. 535.
[2] Kellner, Ernähr. landw. Nutztiere, 1907, p. 410.

mals. C. Voit[1] found that from 1200 to 1500 grams of lean meat per day was required to keep a dog in nitrogen equilibrium while on an exclusive protein diet; when carbohydrates or fat was added, only from one-half to one-third as much lean meat was needed. By feeding rations exceedingly rich in carbohydrates to animals, some investigators have succeeded in reducing the requirement of nitrogenous matter to slightly more than the normal nitrogen waste of the body during starvation. At the Pennsylvania Station[2] Armsby found in experiments with steers, covering 70 days, that from 0.4 to 0.6 lb. of digestible protein daily per 1000 lbs. of live weight was sufficient to maintain the nitrogen equilibrium. Contrary to the observations of some of the earlier investigators, no ill effects followed this small supply of protein. Wintering cattle on feeds poor in crude protein—straw, inferior hay, corn stover, etc.—as practiced by many farmers, confirms this finding. During many years of patient study, Haecker of the Minnesota Station found that dairy cows under good care and otherwise liberal feeding would for long periods continue a good flow of milk on a surprisingly small allowance of crude protein. After some years of such feeding, however, their vitality was so depleted that they became physical wrecks years before their time. These studies led Haecker to raise his crude protein standard for the dairy cow above his earlier allowance. As elsewhere shown, such allowance is, however, still below the Wolff-Lehmann standard. (**140**) The proportion of digestible protein in a ration should always be large enough to insure the proper digestion of the ration. (**60**)

It is a physiological axiom that protein is a cell stimulant. Hence we may conclude that growing animals and those undergoing severe exertion, as cows in milk, horses at hard work, sheep producing wool, and pregnant animals, need considerably more digestible crude protein than the minimum on which they may barely subsist. Tho the protein requirement for such animals is certainly lower than the Wolff-Lehmann standards set forth, it is highly desirable and ultimately essential that they be given a liberal supply of digestible crude protein.

3. Fattening.

98. The object of fattening.—According to Armsby,[3] the accumulation of fatty tissue, as such, is only of secondary importance in

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[1] Ztschr. Biol., 5, 1869, p. 352.
[2] Principles of Animal Nutrition, 1903, p. 142.
[3] U. S. Dept. Agr., Bur. Anim. Ind., Bul. 108.

fattening, the main object being to otherwise improve the quality of the lean meat. To some extent during growth, and especially during fattening, there is a deposition of fat in the lean-meat tissue. A small portion of this may be deposited within the muscular fibers themselves, but the larger part is stored between the bundles of fibers, constituting the so-called "marbling" of meat. This deposition of fat adds to the tenderness, juiciness, flavor, and digestibility of the meat, besides increasing its nutritive value. It seems possible that there is also an increase in the soluble or circulating protein and in other extractives of the muscles, resulting in a further betterment of the quality of the meat as a secondary advantage from fattening.

99. Increase during fattening.—The changes in the composition of the bodies of farm animals during fattening were extensively studied by Lawes and Gilbert of the Rothamsted Station[1] from analyses of the entire bodies of oxen, sheep, and pigs slaughtered at different stages of fattening. They give data from which the following table is derived:

Percentage composition of the increase of fattening animals.

Animal	Protein	Fat	Mineral matter	Total dry substance	Water
	Per cent	Per cent	Per cent	Per cent	Per cent
Ox	7.7	66.2	1.5	75.4	24.6
Sheep	7.1	70.4	2.3	79.9	20.1
Pig	6.4	71.5	0.1	78.0	22.0

In most cases the animals studied had not entirely finished their growth when the tests began. The table shows that in 100 lbs. of live-weight gain made by the fattening ox, 7.7 lbs. was lean-meat tissue, 66.2 fat, and 1.5 mineral matter. In each 100 lbs. of gain 75.4 lbs. was dry substance and 24.6 water. The sheep resembles the ox in character of increase during fattening, but stores more mineral matter, due to the growth of wool. The fattening pig stores very little mineral matter.

Henneberg and Kern[2] selected 3 mature wethers for a study of the body changes which occur during fattening. One was slaughtered at the beginning of the trial while in lean condition; another after 70 days of fattening when half fat; and the third at the end of 203 days when extra fat, with results as follow:

[1] Phil. Trans., Part II, 1859; Jour. Roy. Agr. Soc., 1860.
[2] Jour. Land., 26, 1878, p. 549.

Effect of fattening on the carcasses of mature sheep.

	Lean meat	Fat
	Lbs.	Lbs.
Lean wether	26.2	11.9
Half-fat wether	25.9	33.2
Extra fat wether	26.7	41.9

It is shown that, during fattening, these mature sheep made practically no gain in muscle or lean meat, the increase being almost wholly fat. These results show that the fattening of animals is what the term implies—the laying on of fat.

100. Factors influencing fattening.—The deposition of fat in an animal depends primarily upon the quantity of food consumed in excess of maintenance and growth requirements. Fattening may take place at any age, tho the tendency of young animals to grow greatly reduces the proportion of food usually available for that purpose. Since the process of fattening depends upon the excess of digested nutrients over the wants of the body, it is evident that anything that decreases the waste due to external work or to excess of exercise, and which lessens the internal work of digestion and assimilation, may aid in fat formation. Exertion of any kind increases the oxidations going on in the body. Vigorous exercise must therefore be avoided in the case of fattening stock and milch cows. Supplying an abundance of feeds that are palatable, concentrated, and largely digestible tends to rapid fattening, because a large surplus of nutrients then remains after supplying the body needs, which surplus may go to the formation of fat.

The disposition of an animal to fatten depends upon breed and temperament. While a wild animal, nervous and active, can be fattened only with extreme difficulty, domesticated animals are more quiet and usually fatten readily. The restless animal is rarely a good feeder, while the quiet one which is inclined to "eat and lie down" will show superior gains. This is not due to difference in digestive or assimilative powers, but rather to the fact that the quiet animal has, from a given amount of food, a greater surplus of nutrients available for fat building.

The oxidations and decompositions taking place in the body depend on the amount of oxygen taken up by the blood. The amount of oxygen that can be absorbed by the blood is limited by the quantity of blood and by its content of hemoglobin, the characteristic coloring matter of the red blood corpuscles. A small amount of blood and a small hemoglobin content therefore favor fattening. Because of this, in some parts of Europe fattening animals are sometimes bled to hasten the process.

101. Comparative fattening qualities.—Lawes and Gilbert[1] state that for the whole fattening period farm animals require the following average quantities of feed to produce 100 lbs. of gain:

Ox, 250 lbs. oil cake, 600 lbs. clover hay, 3500 lbs. swedes (turnips).

Sheep, 250 lbs. oil cake, 300 lbs. clover hay, 4000 lbs. swedes.

Pig, 500 lbs. of barley meal.

The table which follows is based on feeding these allowances.

Comparative returns from the ox, sheep, and pig.

	Average live weight	Per head per week			
		Dry food eaten	Digested organic matter	Increase in live weight	Dry matter in manure and urine
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ox	1200	151	106	13.6	60
Sheep	130	21	16	2.3	7
Pig	175	48	40	11.3	11

	Per 1000 pounds live weight per week			Required to produce 100 pounds increase	
	Dry food eaten	Digested organic matter	Increase in live weight	Dry food eaten	Digested organic matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ox	125	88	11.3	1109	777
Sheep	160	121	17.6	912	686
Pig	270	227	64.3	420	353

The upper table shows that the average 1200-lb. fattening ox will consume during one week 151 lbs. of dry food and gain 13.6 lbs. Similar data follow for the sheep and pig. The second table shows that 1000 lbs. of fattening ox will consume about 125 lbs. of dry food each week, and from this will gain 11.3 lbs. in live weight. In one week 1000 lbs. of pigs will gain 64.3 lbs., or nearly 6 times as much, while consuming 220 lbs. of food, or only about 2.2 times as much as does the ox. The ox has 3.2 lbs. of stomach for each 100 lbs. live weight, the sheep 2.5 lbs., and the pig but 0.7 lb. On the other hand, the pig has a much greater proportion of intestines, in which digestion mostly occurs with this animal. (**28**) The pig requires far less food to produce 100 lbs. of increase than either the

[1] Warington, Chemistry of the Farm.

ox or sheep, but its food is much more concentrated and digestible. Therefore a smaller proportion is consumed in the work of digestion and assimilation, leaving a larger surplus for producing gain.

102. Returns from feed.—The following by Jordan[1] shows the amount of food suitable for man returned by the different classes of farm animals for each 100 lbs. of digestible matter consumed.

Human food produced by farm animals from 100 lbs. of digestible matter consumed.

Animal	Marketable product	Edible solids	Animal	Marketable product	Edible solids
	Lbs.	Lbs.		Lbs.	Lbs.
Cow (milk)	139.0	18.0	Poultry (eggs)	19.6	5.1
Pig (dressed)	25.0	15.6	Poultry (dressed)	15.6	4.2
Cow (cheese)	14.8	9.4	Lamb (dressed)	9.6	3.2
Calf (dressed)	36.5	8.1	Steer (dressed)	8.3	2.8
Cow (butter)	6.4	5.4	Sheep and lamb (dressed)	7.0	2.6

The table, which presents one side of a most complicated problem, shows that for 100 lbs. of digestible nutrients consumed:

The cow yields about 139 lbs. of milk, containing 18 lbs. of solids, practically all digestible.

The pig produces about 25 lbs. of dressed carcass. Allowing for water, bone, and gristle, there remains over 15 lbs. of edible dry meat.

The steer and sheep yield less than 10 lbs. of dressed carcass, nearly half of which is water. Deducting this and the bone and gristle, there remains only from 2.6 to 3.2 lbs. of water-free edible meat.

The cow easily leads all farm animals in her power to convert the crops of the field into human food, with the pig second, poultry following, and the steer and sheep coming lowest.

[1] The Feeding of Animals.

CHAPTER VI.

PRODUCTION OF HEAT AND WORK.

Science teaches that no energy is ever lost. The various forms of energy, whether latent energy or that of electricity, light, heat, or motion, may all be changed one into the other, but no loss of total energy ever occurs. Food consumed by the animal contains latent energy derived from the sun. When complex food nutrients or body tissues are decomposed or broken down in the body into simple compounds, this latent energy is released as active muscular energy or as heat. Thus all the energy used by the animal in maintaining its body temperature, and in the performance both of the internal work of the body and of all external work, is derived indirectly from the energy of the sun.

I. Heat.

103. Body temperature.—Cold-blooded animals maintain their bodies at but little above the temperature of the surrounding air or water. With warm-blooded animals the body temperature is usually above that of the surrounding air and quite independent of it. The normal body temperature of the principal farm animals is as follows:[1]

	Deg. Cent.	Deg. Fahr.
Horse	36.9–38.2	98.4–100.8
Ox	38.0–39.3	100.4–102.8
Sheep	38.4–41.0	101.3–105.8
Pig	38.2–40.7	100.9–105.4

The wide difference between the normal temperatures of different animals of the same species is remarkable, and is especially noticeable in the case of the sheep. The temperature of the individual animal may vary within narrow limits even when the animal is perfectly healthy, but a variation of even 1 degree from normal with any farm animal generally indicates some bodily derangement.

A high stable temperature for animals increases the amount of water drank, induces sweating, and leads to loss of appetite. Too low a temperature is likewise objectionable, since more food is needed to maintain the heat of the body. Animals that are being wintered over and are merely holding their own, dairy cows, young

[1] Smith, Man. Vet. Physiol., p. 339.

and tender animals, and those with thin coats need more shelter and a higher stable temperature than mature heavily-coated animals or those laying on fat. Over large portions of America, particularly in the West, where there is much sunshine and but scant precipitation during winter, mature and fattening animals thrive in the open if protected from the wind. Animals exposed to cold rains or snow not only suffer therefrom but require more food, because the cold water which falls on them must be warmed and evaporated from their bodies by heat generated thru the burning of food.

104. Heat production.—Heat is produced by all the decompositions or oxidations occurring in the body, whether in the muscular tissues, the alimentary tract, or the glands. Air breathed into the lungs brings oxygen to the blood. Floating in the blood are myriads of microscopic bodies called red corpuscles. These contain hemoglobin in which there is iron, the latter giving to blood its red color. The hemoglobin absorbs the inspired oxygen and holds it loosely. The oxygen-laden blood, as it permeates the capillary system, gives up its oxygen to the cells of the tissues, where it is used for the combustion of a portion of the body nutrients with the result that heat is formed. Unlike the burning of fuel in a stove, the oxidations in the body take place at a low temperature. In the case of combustion in the body where before there were glucoses, fats, and proteins in the tissues, there now remain carbonic acid gas, water, and urea, the latter substance representing the principal nitrogenous waste of the protein nutrients.

So long as there is a normal supply of oxygen the rate of burning of the food nutrients is independent of the supply of air, but is under the control of the nervous system. The muscular work which necessarily accompanies enforced breathing leads to some increase in oxidation and consequently to increased heat production. An increased supply of oxygen does not of itself, however, lead to increased oxidation. In this respect body oxidations differ radically from ordinary fuel combustion, where the rate of burning is almost proportional to the oxygen supply. All the energy expended in the various form of internal work of the body appear as heat, a considerable amount being thus evolved. Most of the heat generated within the body is produced in the muscular tissues, four-fifths of the heat produced daily in the human body being there generated. The muscles are not always actively contracting, yet heat is always being produced in them. This production of heat in the muscles is under the control of the nervous system. The heat produced in the

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different parts of the body is more or less equalized, chiefly by the circulation of the blood. Generally, however, the temperature of the body in its different parts varies somewhat according to the activities of the parts.

An increase in the amount of work performed will result in an increased production of heat within the body. All the heat generated within the animal body is, as it were, a by-product of internal or external work, but is available for the maintenance of the body temperature. Some eminent physiologists hold that the amount of heat evolved in the production of internal and external work is sufficient to warm the body under all conditions, and that there is no production of heat in the body to simply keep it warm. Convincing proof of this theory is lacking, and it seems reasonable to believe, as do many eminent scientists, that, at least when there is an unusual demand for heat, caused by a low external temperature, the heat generated as a result of internal and external work is not sufficient, and food or body tissue is burned up for the direct and sole purpose of warming the body.

105. Heat regulation.—As heat is constantly being produced in the body, if means were not provided for its escape and for the regulation of body temperature, the temperature would steadily rise until the animal was destroyed. It has been shown that the horse at rest produces sufficient heat in two days to raise the temperature of the body to the boiling point.[1] However, the body possesses means for controlling both the production and the loss of heat, this twofold heat regulation being under the control of the nervous system.

The production of heat in the body is regulated by increasing or decreasing the oxidations taking place therein, this regulation being known as *chemical regulation.* Heat production is controlled more or less voluntarily by regulating the exercise taken and the amount of food consumed. The degree of external heat or cold also causes an involuntary rise or fall in the amount of heat produced in the body. For instance, as a result of nervous stimuli more fuel is burned in the body during extreme cold than normally.

The second means of heat regulation, called *physical regulation,* is by controlling the amount of heat lost from the body. This is accomplished in part by varying the distribution of the blood on the surface of the body, and thus controlling the amount of heat lost from the skin by radiation and conduction. The loss of heat is

[1] Smith, Man. of Vet. Physiol., p. 343.

further regulated by the production of sweat and the vaporization of water from the lungs. The clothing of man and the thick skin, hair, wool, and feathers of animals also check and control the loss of heat.

According to Howell,[1] the heat lost from the human body escapes as follows:

Avenue of escape	Heat lost Per ct.
By urine and feces	1.8
By warming expired air	3.5
By vaporizing water from lungs	7.2
By evaporation of water from skin	14.5
By radiation and conduction from skin	73.0
Total	100.0

The relative importance of these channels of heat loss depends upon various conditions and upon the species of animal. Animals that do not sweat give off more heat by the lungs and less by the skin. In proportion to their weight small animals lose relatively more heat by radiation than do larger ones of the same species. (**96**) High external temperature tends to diminish the loss by radiation and increase that due to evaporation from the skin or vaporization from the lungs. Violent exercise calls for the rapid burning of food and tissue fuel, with a consequent increase of body heat. This heat passes off by the more rapid breathing and by the increased losses from the skin.

In humans the loss of heat is largely controlled by the clothing worn. As a consequence, man has, in some measure, lost his power of heat regulation. With many of the warm-blooded animals, however, the reverse is true, as is admirably shown by the following table of Rubner[2] giving the heat lost by a small dog before and after the removal of his coat of long hair.

Loss of heat by a dog before and after being shaved.

Temperature of the air	Heat lost per lb. live weight	
	Normal coat	Coat shaved off
Degrees F.	Cal.	Cal.
68	25.4	37.4
77	24.6	27.8
86	25.5	23.6

The table shows that the coat of the dog prevented the loss of heat from his body, so that no more heat was lost at a temperature of

[1] Text Book of Physiol., 1907, p. 861.
[2] Gesetze des Energieverbrauchs, 1902, p. 14.

68° F. than at 86° F. When he was clipped, the loss of heat from his body rose from 23.6 to 37.4 Calories, an increase of 58 per ct. To cover the increased heat loss at the lower temperature, an increase in the rate of combustion or burning of fuel in the body was produced thru the nervous system by the sensation of chill.

II. Work.

It has long been known that muscular exertion or external body work greatly increases the amount of food material burned or broken down in the body, but scientists have disagreed widely as to whether one or all of the three classes of nutrients—protein, carbohydrates, or fat—furnishes the energy. Liebig held that the protein of the muscular tissues was the only material broken down in producing the voluntary and involuntary motions of the body, whether of the limbs, heart, or other viscera.

106. Waste of protein tissues during work.—That protein is not an important source of body energy was shown by Professors Fick and Wislicenus,[1] who in 1865 ascended the Faulhorn, an Alpine mountain. While ascending the mountain these investigators consumed only non-protein food, i. e. starch, sugar, and fat, and during this time they collected all the urine passed. The amount of nitrogen excreted in the urine during the trial follows:

Nitrogen excretions during mountain climbing.

	Total nitrogen excreted		Nitrogen excreted per hour (average)	
	Fick	Wislicenus	Fick	Wislicenus
	Grams	Grams	Grams	Grams
Night before ascent	6.92	6.68	0.63	0.61
During ascent	3.31	3.13	0.41	0.39
After ascent	2.43	2.42	0.40	0.40
Night after ascent	4.82	5.35	0.45	0.51

The table shows that only about two-thirds as much nitrogen was excreted per hour during and immediately after the climb as prior to it, when there was more or less residue in the system from the previous meal containing protein. Had the nitrogenous tissues or the muscles of the body been broken down directly in proportion to the labor performed, there would have been a large increase in the nitrogen excretion during and following this fatiguing work; but

[1] Jour. Roy. Agr. Soc., 1895; U. S. Dept. Agr., Office of Expt. Sta., Bul. 22.

such was not the case. Measured by the nitrogen in the urine, the protein broken down during the trial could not possibly have furnished energy for more than one-third of the work done by these men in lifting their bodies to the top of the mountain.

From this trial and experiments by Voit, Pettenkofer, and Parks, it was decided that only carbohydrates and fats were oxidized and burned in the production of muscular energy. Still later experiments by Argutinsky, Zuntz, and others have shown that when carbohydrates and fat are sufficient in amount they furnish all the muscular energy, and in such cases the breaking down of protein is not increased during work. However, if the supply of carbohydrates and fat in the food is insufficient, some of the energy for the production of work may be furnished thru the breaking down of protein, with a resultant increase in the nitrogen excretion in the urine.

107. Excretion of carbon dioxid.—Whether the material burned to furnish muscular energy be carbohydrates, fat, or the non-nitrogenous part of the protein molecule, carbonic acid gas will be produced, the quantity directly depending upon the amount of work done. This was shown by Smith,[1] who determined the quantity of carbonic acid gas exhaled by the horse when at rest and performing labor as follows:

Form of work	Cubic feet per hour
At rest	1.03
Walking	1.10
Trotting	2.95
Cantering	4.92
Galloping	14.97

Thus, unlike the nitrogen excretion, the amount of carbon dioxid exhaled per hour is increased by the performance of work, and depends upon the work done in that time.

108. Production of muscular energy.—We know that in doing work the muscles of the body contract, that is, become shorter and thicker. Yet in spite of all the study of scientists we do not yet know definitely the direct cause of muscular contraction. In just what manner the energy stored in the food is converted into the energy of muscular action is still an unsolved question. We do know, however, some of the processes which take place in the working muscles.

The most significant change which takes place during muscular contraction is the increased production of carbon dioxid already

[1] Jour. Physiol., 1890, No. 1; U. S. Dept. Agr., Office of Expt. Sta., Bul. 22.

noted, which seems to bear a definite relation to the amount of internal and external work performed. There is also a large increase in the amount of oxygen taken up by the muscles from the blood during work. The increase in oxygen consumed and carbon dioxid given off might lead to the conclusion that the activity of the muscle during contraction is due to simple oxidation, such as occurs when fuel is burned. Certain facts which cannot be dwelt upon here lead scientists, however, to believe that the chemical changes by which energy is liberated are not simple oxidations, but are more in the nature of sudden decompositions or cleavages of some complex substance or substances built up in the muscle during rest, carbon dioxid being evolved in such cleavage.[1] Part of the energy liberated in this decomposition appears as heat, and another part as mechanical work.

Glycogen, or animal starch, is stored in the muscle during rest, forming between 0.5 and 0.9 per ct. of the weight of well-nourished muscle in the resting condition. (**52**) A smaller quantity of glucose is also found in the muscular tissues. During muscular activity, this stored glycogen and glucose disappear more or less in proportion to the extent and duration of the contractions, so that after prolonged muscular activity or hard work the supply may be entirely exhausted. Tho the amount of these carbohydrates in the body tissues at any one time is small, the supply, especially of glucose, is being continuously produced from the food nutrients or body tissues to replace that oxidized in the production of work. As the larger part of the food of farm animals consists of carbohydrates, the oxidation of the glucose formed from them probably furnishes most of the energy for the production of heat and work by these animals.

To supply the muscles with the necessary oxygen and also carry away the waste products formed during muscular exertion, the circulation of the blood must be hastened and larger quantities of air be taken in by the lungs.

109. Source of muscular energy.—All the organic nutrients absorbed from the food, not only the carbohydrates and fats, but also the proteins and apparently the pentosans, serve as the source of energy to the body. Under normal conditions the non-nitrogenous nutrients and the glycogen are first drawn upon for the production of work, no more protein being broken down than during muscular rest. If the non-nitrogenous nutrients do not suffice for the

[1] Armsby, Principles of Animal Nutrition, 1903, p. 187.

production of muscular energy, then the body fat is next drawn upon for this purpose. If this is insufficient in amount or is much diminished by continued work, then as the last resort the protein tissues or muscles will be called upon to furnish the needed energy.

110. Relative value of nutrients.—Investigations by Zuntz and his associates have clearly shown that the value of each of the different classes of food nutrients for the production of work depends upon the total energy it contains. In one experiment[1] the diet of a man turning a wheel consisted, during separate periods, chiefly of either fat, carbohydrates, or protein. For 1 kgm. of work the following amounts of energy were expended:

Period	Nutrient eaten	Energy expended per kgm. of work
		Cal.
I	Protein	11.92
II	Carbohydrate	11.54
III	Fat	9.53
IV	Protein	10.78
V	Fat	9.25

It is shown that approximately the same fuel rations were required to produce a given amount of work whether the fuel was protein, carbohydrates, or fat. It will be noticed that the energy expended was less in the last trials on account of the proficiency which had been attained in the work.

111. Energy requirements for work.—The total energy required to produce a certain amount of external work depends upon many factors. Experiments by Zuntz[2] with the horse show that an increase in the speed at which work is performed results in an increased expenditure of energy per unit of work. Practice in performing a certain work lessens the energy expenditure for that particular form of labor. In experiments upon himself Gruber[3] found that in climbing a tower the amount of carbon dioxid exhaled and hence the energy expended was decreased by 20 per ct. after training for 2 weeks. In experiments by Löwy[4] on himself, and by Zuntz[5] upon horses, fatigue caused an increase of from 14 to 41 per ct. in the amount of energy expended in performing a given amount of work. This increased expenditure of energy is largely due to the fact that with increasing fatigue the muscles normally called into use, which are the most efficient in performing the given work.

[1] Arch. Physiol. (Pflüger), 83, 1901, p. 564.
[2] Landw. Jahrb., 27, 1898, Sup. III.
[3] Ztschr. Biol., 38, 1891, p. 466.
[4] Arch. Physiol. (Pflüger), 49, 1891, p. 413.
[5] Loc. cit.

are put out of use and other less used muscles are called upon to a constantly increasing degree. These muscles cannot perform the work so efficiently or economically.

The part of the expended energy appearing in useful work varies in accordance with the build of the animal, the development of its muscular apparatus, and the structure of its extremities which bring about the work. Zuntz found great variations in the energy expended by different horses of the same weight in traveling upon a level track, a lame horse expending 99 per ct. more energy than a sound one. In the work of climbing a grade he found a variation with different horses of as much as 52 per ct. in the proportion of the total energy expended which appeared as useful work. An animal which is able to accomplish one form of work most economically may have to expend an unusual amount of energy at other kinds of work. Horses bred for generations to the saddle can carry the rider with smaller expenditure of energy than those whose breeding, form, and qualities specially fit them for draft purposes.

Certain forms of labor are performed with greater economy of energy than others. Katzenstein[1] found in experiments with men that about 65 per ct. more energy was used in turning a wheel a given number of times with the arms than was required when the same work was done with the legs.

112. The animal as a machine.—The extensive investigations by Zuntz and associates with men, dogs, and horses show that aside from small variations, due to the nature of the work and other factors, the part of the energy expended which is actually transformed into external work is quite constant for each class. With animals at moderate work the part of the energy which appeared in external work varied from 28.8 to 36.6 per ct. of the total energy expended. On the average it is reasonable to hold that with men and animals about one-third of the energy consumed in muscular exertion is recovered as external work. The rest takes the form of heat within the body, and is lost so far as the production of work is concerned. This does not take into account the energy lost in the excreta, nor that expended for digestion, assimilation, and the maintenance of the body during rest. Atwater[2] found that a man returned 19.6 per ct. of the fuel value of his food as external work. The best steam engines have about the same efficiency, while the average engine falls below 10 per ct. Gasoline engines range in efficiency from 18 to 25 per ct. Thus as a mere machine the animal

[1] Wolff, Farm Foods, p. 84.

[2] U. S. Dept. Agr., Office Expt. Sta., Bul. 136.

body compares favorably with the best modern engines. In addition to performing external work the body must prepare its own fuel, store and transport it until needed, make all repairs, and maintain a definite temperature, as well as direct, move, and control itself. When all these functions are considered, the marvelous perfection of the animal body as a machine becomes apparent.

113. The body not a heat machine.—The animal body is not an engine which converts heat into mechanical work. As Armsby[1] points out, the mechanical work of a steam engine is derived directly from the heat produced by the burning coal, but in the animal body the energy of the food is transformed into work in quite another way. While the fuel value of a food represents the total amount of energy it can liberate in the body, a varying part of this total energy is always set free in the body as heat, and this heat can do no external work, tho it warms the body. Only that part of the food energy which is liberated in other forms than heat can be utilized for the production of either internal or external work. By processes still unknown the animal machine produces muscular energy, heat, light, and electricity with an efficiency greater than any machine made by man. With animals the fuel is burned at low temperature. The glow worm and firefly produce light without sensible loss of heat or other energy, and the torpedo fish and electric eel generate electricity by means unknown. Scientists and inventors alike are baffled by the mysterious and wonderful processes continuously occurring in the animal body.

As the horse is the principal animal machine for performing work, this subject is appropriately continued in Chapter XVII.

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[1] Penn. Expt. Sta., Bul. 84.

CHAPTER VII.

MISCELLANEOUS STUDIES BEARING ON NUTRITION PROBLEMS.

114. Wide and narrow rations.—At the Maine Station[1] Jordan studied the influence of a ration rich in crude protein and of one poor in crude protein on the rate of growth and character of the flesh formed by growing steers. Four high-grade Shorthorn steer calves, from 5 to 7 months old when the trial began, were used. Two were fed a liberal ration rich in crude protein, while the others received one equally ample in total nutrients, but poorer in crude protein. One steer in each lot was slaughtered at the end of 17 months and the remaining two at the end of 27 months, all carcasses being analyzed to determine whether any difference existed therein. The concentrates fed were as follows:

Lot I.
Narrow ration
Linseed meal, 2 parts.
Corn meal, 1 part.
Wheat bran, 1 part.

Nutritive ratio, 1:5.2.

Lot II.
Wide ration
Corn meal, 2 parts.
Wheat bran, 1 part.

Nutritive ratio, 1:9.7.

The roughage, the same for all, consisted mostly of timothy hay, some corn fodder and corn silage being fed during the first winter only. It is seen that Lot I received a narrow ration, rich in crude protein and mineral matter, while Lot II was fed a wide ration with much less, tho sufficient, protein and mineral matter. Both lots were liberally fed, tho there was no attempt to force growth.

Results of feeding wide and narrow rations to growing steers.

	Total gain	Digestible matter for 100 pounds gain	Composition of entire body except skin			
			Water	Protein	Fat	Ash
	Lbs.	Lbs.	Per cent	Per cent	Per cent	Per cent
Steer fed 17 months						
On narrow ration	737	495	59.02	17.89	18.53	4.56
On wide ration	552	686	56.30	17.82	20.27	5.61
Steer fed 27 months						
On narrow ration	962	773	51.91	16.93	25.86	5.30
On wide ration	1005	708	52.16	17.10	25.32	5.42

[1] Rpt. 1895.

The table shows that during the first 17 months the steer on the narrow ration gained 185 lbs. more than the other on the wider one and that a given gain was made on less feed. The carcasses of both steers showed practically the same percentage of protein or lean-meat tissue, while that of the one getting the narrow ration had more water and less fat and ash. Of the steers fed 27 months, the one on the wide ration made the larger total gain and required less feed for 100 lbs. of gain. The water, protein, and ash in the bodies of these 2 steers were practically the same. Thus it appears that when there is fed a ration as wide as 1: 9.7, provided it contains sufficient crude protein for the demands of the body, the animal fed thereon will conserve and utilize the nutrients in such manner as to make economically a normal growth in all particulars. Giving an excess of protein does not lead to any material increase in the size or weight of the muscular tissues, but rather to a storage of somewhat less fat and more water, especially with young animals.

From these and other data we may conclude that rations having a narrow nutritive ratio are conducive to the rapid growth and fine general appearance of the young, growing animal. On the other hand, when the body is partly or largely grown, the largest gains, which are then mostly fat, come from liberal feeding with rations which are rich in digestible carbohydrates and rather limited in crude protein—in other words, having a comparatively wide nutritive ratio.

115. Exclusive corn feeding.—In 1884 Sanborn of the Missouri Agricultural College[1] conducted studies in which growing pigs fed exclusively on corn meal were compared with others fed on corn meal and either wheat middlings or dried blood. The corn-meal ration furnished an abundance of easily digested carbohydrates and fat, but was deficient in crude protein and mineral matter. The addition of dried blood or wheat middlings to corn meal formed a ration rich in crude protein and mineral matter as well as carbohydrates and fat. Sanborn showed that, compared with the corn-fed pigs, those getting rations rich in crude protein had a larger muscular development and more blood, and that some of their internal organs were larger.

Realizing the fundamental importance of Sanborn's studies, the author conducted numerous trials at the Wisconsin Station[2] in which dried blood, wheat middlings, field peas, and skim milk, with

[1] Buls. 10, 14, 19. [2] Rpts. 1886, '87, '88, '89.

or without corn meal, were fed in opposition to corn meal alone. Shelton of the Kansas Station[1] fed pigs a mixture of wheat shorts and wheat bran in opposition to corn meal, potatoes, and tallow. At the Alabama Station[2] Duggar fed cowpeas, which are rich in crude protein, against corn meal. In France Fortier[3] duplicated a trial by the author, feeding skim milk, dried blood, and wheat middlings in opposition to corn meal. Thus at 5 widely separated points pigs were fed rations rich in crude protein and mineral matter, usually containing some corn meal, in opposition to corn meal alone, which is rich in carbohydrates and fat but low in crude protein and mineral matter. The table on the next page summarizes the findings of two trials at the Wisconsin and one at the Kansas Station, these being typical of all.

The upper division of the table shows that the pigs fed rations rich in crude protein made heavier gains, and also that the weight of their blood, livers, kidneys, etc., was greater than that of others fed rations poor in crude protein. The tenderloin muscles were dissected from the carcasses and weighed, and the thigh bones were dissected from the hams and their relative breaking strength determined. As the pigs were of different weights at the time of slaughter, the second division of the table is given to show the weights of the different organs and parts in percentages of dressed carcass. It is shown that the carcasses of the pigs getting the rations rich in crude protein shrank more than those getting the corn-meal rations, in part due to the larger amount of blood and heavier livers and other organs of the pigs fed the heavy crude protein ration, and also to the fact that the nitrogenous rations produced more watery tissues.

In the first Wisconsin trial the pigs getting milk, wheat middlings, and dried blood had over 54 oz., or nearly 3.5 lbs., of blood for each 100 lbs. of dressed carcass, while those getting only corn meal had less than 42 oz., or but little over 2.5 lbs. The livers and kidneys of the pigs fed the rations rich in crude protein were in all cases relatively heavier. The tenderloin muscles, lying along the back, were also relatively heavier, showing that a superior muscular development was associated with the larger internal organs, more blood, etc. The corn-fed pigs, on the other hand, had stored more fat, as the proportion of leaf lard shows.

[1] Bul. 9. [2] Bul. 82. [3] Ext. Trav. Soc. Cent. d' Agr., Dept. Seine-Inf., 1889, 1890.

I. Weights of carcass and internal organs of pigs fed rations rich in crude protein in opposition to corn meal.

Station and feed	Live weight	Dressed weight	Blood	Liver	Kidneys	Tender-loin	Leaf lard	Strength of thigh bone
	Lbs.	Lbs.	Oz.	Oz.	Oz.	Oz.	Lbs.	Lbs.
Wisconsin								
Lot I, Milk, middlings, blood	223	181	98.6	48.8	9.0	30.9	144	910
Lot II, Corn meal	187	150	62.0	36.5	6.3	20.8	134	571
Wisconsin								
Lot I, ⅓ blood, ⅔ corn meal	298	248	117.0	55.0	9.6	------	------	955
Lot II, ½ peas, ½ corn meal	277	228	102.0	48.5	7.7	------	------	1,075
Lot III, Corn meal	254	212	93.0	37.7	5.9	------	------	750
Kansas								
Lot I, Shorts, bran	211	162	81.6	72.3	11.8	21.0	105	578
Lot II, Potatoes, tallow, corn meal	183	146	54.4	49.3	8.5	14.7	110	485

II. Shrinkage and proportional weight of internal organs and parts per 100 lbs. of dressed carcass.

Station and feed	Shrinkage	Blood	Liver	Kidneys	Tenderloin	Leaf lard	Strength of thigh bone
	Lbs.	Oz.	Oz.	Oz.	Oz.	Oz.	Lbs.
Wisconsin							
Lot I, Milk, middlings, blood	19	54.4	26.9	5.0	17.1	79.9	503
Lot II, Corn meal	20	41.3	24.3	4.2	13.8	89.3	380
Wisconsin							
Lot I, ⅓ blood, ⅔ corn meal	17	47.1	22.2	3.9	------	------	385
Lot II, ½ peas, ½ corn meal	18	44.7	21.3	3.4	------	------	471
Lot III, Corn meal	17	43.8	17.7	2.8	------	------	354
Kansas							
Lot I, Shorts, bran	23	50.4	44.7	7.4	13.0	65.1	357
Lot II, Potatoes, tallow, corn meal	21	36.8	33.8	5.8	10.0	75.3	332

The strength of the thigh bones was determined in the following manner: The two rounded, iron supporting edges of a machine used for testing the breaking strength of materials were set four inches apart. On these a thigh bone was placed, the rounded edge of the breaking-bar pressing down on the bone from above, midway of its length. The downward pressure was gradually increased, being measured by the tilting beam of the machine. Under the steadily increasing pressure the bone finally broke, its resistance at the time of breaking being recorded. The trials showed that the pigs fed the ration rich in crude protein had the strongest bones. In the first Wisconsin trial, as the table shows, the bones of the corn-fed pigs broke at an average pressure of 380 lbs. for each 100 lbs. of carcass, while those of the pigs fed milk, dried blood, and middlings broke at about 500 lbs.—a difference of 32 per ct. in favor of the pigs getting the ration rich in crude protein. Analyses of the organs and parts of the pigs used in the second Wisconsin trial showed further that the corn-fed pigs had proportionately less dry matter in their blood and kidneys and a smaller amount of dry lean-meat tissue than those on the narrow ration.

Later investigations show that the differences produced by the exclusive corn rations and those rich in crude protein were not entirely due to the difference in the supply of crude protein. In each case the ration rich in crude protein was also the richer in mineral matter, for corn is not only rather low in crude protein but it also lacks mineral matter.

116. Effect on tenderloins of exclusive corn feeding.—At the Missouri Station[1] Forbes fed 6 lots, each of five 120-lb. pigs, on unlimited rations for 60 days. One lot was fed corn only, while the others received corn supplemented with the various by-feeds shown below. All rations but the one exclusively of corn had the same nutritive ratio. On slaughtering the pigs, portions of the tenderloin muscles were analyzed, with the results shown below:

Composition of the tenderloin muscles of pigs variously fed.

Supplement fed per 100 lbs. of corn	Water	Protein	Fat	Ash
	Per cent	Per cent	Per cent	Per cent
Lot I, Corn only	71.5	19.2	7.28	1.11
Lot II, Wheat middlings, 81.8 lbs.	72.9	20.7	5.04	1.15
Lot III, Linseed meal, n. p., 17.8 lbs.	74.1	20.5	4.01	1.18
Lot IV, Soybeans, 19.6 lbs.	72.9	20.9	4.79	1.13
Lot V, Tankage, 8.1 lbs.	73.7	19.8	5.17	1.13
Lot VI, Germ oil meal, 39.4 lbs.	73.5	20.5	4.67	1.08

[1] Bul. 81.

It is shown that the muscles resulting from exclusive corn feeding had more fat and less water and protein than the others. The corn ration and the corn and germ oil meal ration, both low in mineral matter, produced muscle lower in ash than the other rations. While the muscles from the pigs fed exclusively on corn contained less protein than the others and were therefore really smaller in size, because of the high percentage of fat they carried they would, on cooking, furnish meat which would be more juicy and toothsome than that of the other lots.

117. Discussion of the pig-feeding experiments.—In analyzing the two preceding experiments we should hold that the pigs given feeds rich in crude protein and mineral matter developed bodies that were normal in skeleton, muscles, and all internal organs. Those fed corn exclusively were prevented from building a normal body structure because of the insufficient supply of crude protein and mineral matter in their food. We should not forget that all parts of the normally nurtured body attain a certain normal development which cannot be materially increased beyond a constitutional limit. Only in a small degree can the stockman in a single generation increase by what he may feed the size of the bones and the muscles of the animals under his care. On the other hand, Nature sets no such close limitations on the amount of fat that may be stored. This varies according to inheritance, the nature and abundance of the food, the amount of exercise, etc. The skeleton, the muscles, and all the organs of the body increase during the plastic stage of youth and cannot be augmented in the mature animal. (**95**) The quantity of fat which the animal may lay on is limited during youth and is more easily and largely stored after maturity has been reached. (**100**)

These experiments should impress upon the stockman the plastic nature of the bodies of young, growing animals. They show it possible for immature animals living on unsuitable food to survive a long time and develop bodies that are dwarfed in size and made unnaturally fat. They help to show that Nature's plan is to first grow the body framework and afterwards to lay on the fat. They point to the reasonable, important, and far-reaching conclusion that if a pig or other young animal is improperly fed so as to modify its bones, muscles, and vital organs even a very little, and the process is repeated during several generations, the cumulative effects will be marked and permanently injurious. The practical lesson is taught that young animals should be nurtured on a combination of feeding stuffs that will develop the normal framework of bone, muscle, and all body organs. This is accomplished thru an ample supply of feeding stuffs reasonably rich in crude protein and mineral matter. Having developed the proper framework of bone, together with the enveloping muscular system and all the organs of the body, the food supply may then consist largely of carbohydrates and fat, which are the cheap and abundant sources of animal fat.

In America corn is the common feeding stuff for swine, and pigs show such fondness for it that harm often results because the practice of the feeder and breeder is guided by the appetite of the animal rather than by a knowledge of the composition and limitations of feeds. Let us not despise corn because, when wrongly and excessively used as it purposely was in these experiments with young, growing pigs, it fails to develop the normal framework of bone and muscle. Each feed has its function in the nutrition of animals, and only by its abuse can unfavorable results follow.

118. Feeding concentrates only.—In 1874 a Mr. Miller[1] of New York reported that for several years he had successfully maintained dry dairy cows in winter for a period of about 8 weeks by giving to each animal as its sole feed not above 3 quarts of finely-ground corn meal daily. It was his practice to cut off the hay supply when meal feeding began. At first the cows were restless, but soon quieted down, all rumination or chewing of the cud ceasing and only a small quantity of water being drunk. He further claimed that the animals remained in fair flesh and that the calves from cows so maintained were strong and healthy. In the spring on changing back to normal feeding a limited amount of hay was at first given, and the supply gradually increased.

A committee of the American Dairyman's Association, on visiting Mr. Miller's stables, reported that cows weighing about 900 lbs. each had been fed exclusively on corn meal for 7 weeks previous to the time of inspection, each animal receiving on the average 3 quarts of meal daily. They stated that the cows did not ruminate, were quiet, and evinced no inordinate desire for food when hay was shown them. They were much more quiet than cows fed meal and 4 or 5 lbs. of hay daily. The committee saw no signs of suffering or unrest. On a second visit 13 days after hay feeding had been resumed in the spring the cows were filled up

[1] Rpt. Am. Dym'ns Assn. 1874; Meal Feeding and Animal Digestion, 2d ed., Linus W. Miller (out of print); Armsby, Manual of Cattle Feeding.

and did not appear different from others wintered in the usual way. The calves from these cows were fleshy, strong, active, healthy, and of more than ordinary size. This report excited much discussion in the agricultural press at the time, but the practice has never become general.

119. Sanborn's studies.—At the Utah Station[1] Sanborn maintained a calf for 6 weeks in winter on grain and milk, when, thru its craving for roughage, the sawdust used for bedding was eaten, causing death. Sheep were successfully maintained for several months on grain and roots only. They shrank in weight at first, but after the paunch was cleared of coarse food made fair gains. A 2-year-old steer weighing 635 lbs. was fed grain and water only for nearly 8 months, at the end of which time it weighed 825 lbs. Rumination ceased upon the withdrawal of coarse food, and gains were made on about the same amount of feed as pigs required. Little water was drunk, and a larger proportion was voided as urine. The first and second stomachs of the sheep and cattle so fed weighed less than the average for such animals, the first stomach notably so. When the steer was slaughtered the first stomach was found hardly half full, and the blood weighed more and the lungs less than the average.

120. Davenport's findings.—At the Illinois Station[2] Davenport maintained calves on skim milk, with or without grain, for long periods. A calf was fed skim milk exclusively for 7 months, by which time it refused its feed, could not hold up its head, and appeared nearly dead. When straw and hay were placed before it they were greedily consumed, and 3 hours later the calf was ruminating in contentment, thereafter making satisfactory gains on mixed feed. In a second experiment a May calf subsisted on skim milk alone until September, when, altho consuming 70 lbs. daily, it showed great unrest. Some grain was then fed in addition to the milk, with still unfavorable indications. In October when hay was offered it was greedily eaten, and rumination began some five hours later. Another calf was maintained from June until September upon milk and mixed grains. By the latter date it evinced no desire for feed and would not rise; later it suddenly died. Altho enormous quantities of milk or milk and grain were consumed, there was no fat on the carcass or about its kidneys, and the muscles, tho plump, were exceedingly dense and rigid. From these

[1] Bul. 21. [2] Bul. 46.

several trials we may conclude that mature ruminants can be maintained for considerable periods, if not indefinitely, on a limited amount of ground grain with no roughage, and if liberally supplied with grain only, they may make fair gains in weight. With young ruminants Nature seems less yielding. Apparently calves cannot be brought to maturity upon grain and skim milk, either separately or combined, as their sole feed, but they must have some coarse forage, without which rumination is impossible.

121. McCollum's experiment.—At the Wisconsin Station[1] McCollum placed a 23-lb. sow pig in a dry lot with shelter, and fed it from May to July of the following year, at first on whole milk and skim milk, and later on skim milk alone. The sow remained in excellent condition, and at about 1 year of age, when weighing 406 lbs., gave birth to 8 living pigs averaging 2.3 lbs. each, and 2 dead ones, all normal. Before winter, the pigs made an average daily gain of 0.39 lb. each, reaching an average weight of 18.6 lbs. in 6 weeks.

This shows that milk alone will support the pig, and indicates that the failure of Davenport to maintain calves on skim milk and grain was probably due to the physiological requirement of herbivora for coarse food to fill the first three stomachs in order that they may develop normally. (**32**) The pig has no such peculiarity in the structure of its digestive tract, and hence no physiological disturbances result from taking liquid food alone in the form of milk.

122. Inorganic phosphorus for pigs.—Hart, McCollum, and Fuller of the Wisconsin Station[2] conducted experiments to determine whether animals can assimilate inorganic phosphorus compounds—a point in dispute among scientists.

Wheat bran contains about 6 per ct. of phytin, an organic compound of lime, phosphorus, magnesia, and potash. By washing a quantity of bran with warm water the phytin was dissolved and removed. After drying, the material was mixed with wheat gluten and rice, which are both extremely poor in mineral matter. To this mixture was added sugar to give palatability, also a quantity of sodium chlorid, magnesium chlorid, and potassium sulfate sufficient to replace the amount of these salts washed from the bran. The combination formed a basal ration poor in phosphorus.

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[1] Unpublished data.

[2] Research Bul. 1.

The pigs in the experiment were fed as follows:

Lot I, Basal ration, poor in phosphorus.
Lot II, Basal ration + precipitated calcium phosphate.
Lot III, Basal ration + bone ash.
Lot IV, Basal ration + ground rock phosphate.
Lot V, Ration of unwashed wheat bran, rice, and wheat gluten, used as a check.

For a considerable period all the pigs throve fairly well, tho no ration was entirely satisfactory. As time went on, those in Lot I fell behind the others; they had no appetite and remained lying down; later they lost control of their hind quarters and had to be carried to the trough at feeding time: they had reached a broken-down condition. At the end of 4 months when a pig of each lot was slaughtered, the findings given below were obtained:

Feeding scant and full allowance of organic and inorganic phosphorus to pigs.

	Lot I No phosphorus added	*Lot II* Precip. calc. phosphate	*Lot III* Bone ash	*Lot IV* Ground rock phosphate	*Lot V* Unwashed wheat bran
Av. amt. phosphorus fed daily, grams	1.12	5.29	5.45	5.20	5.28
Weight of pig at slaughter, lbs.	77	87	85	82	87
Average gain per pig, lbs.	32	42	35	43	58
Weight of skeleton, grams	870	950	950	1495	850
Breaking strength of thigh bone, per sq. millimeter, lbs.	0.87	1.70	1.77	1.65	1.86
Diam. of thigh bones, millim'rs	16	16	15.5	20	17
Specific gravity of thigh bone	0.98	1.15	1.12	1.19	1.14
Ash in thigh bone, per cent	33	46	53	57	54

The pigs of the first lot, getting little phosphorus, had light, weak thigh bones, of low specific gravity and low in ash. The ones getting a liberal supply of inorganic phosphorus, especially those fed ground rock phosphate, had heavier skeletons than either the low-phosphate lot or even those getting organic phosphate in the unwashed bran. The thigh bones of the rock-phosphate lot were the largest in size and the highest in ash and specific gravity.

In general the pigs getting inorganic phosphorus—precipitated calcium phosphate, bone ash, or ground rock phosphate—grew as fast as or faster than those fed organic phosphorus supplied in the unwashed wheat bran. From this it seems settled that pigs, at least, can digest and build into their skeletons inorganic phosphorus and lime when supplied in such forms as precipitated cal cium phosphate, burned bone, or ground rock phosphate. And what is true of pigs is doubtless true with other farm animals. This is most helpful information to stockmen, especially in the corn-growing districts of America where feeding stuffs available for swine and other farm animals are often low in lime and phosphorus. Ground rock phosphate, or floats, will apparently supply the needed phosphorus and also lime at nominal cost.

123. Rich and poor milk for young animals.—Beach of the Connecticut (Storrs) Station[1] fed calves, pigs, and lambs on three grades of milk—skimmed milk, ordinary milk containing from 3 to 3.5 per ct. fat, and rich milk containing from 5.1 to 5.7 per ct. of fat. The lambs also received a small quantity of hay. The table shows the milk solids, including fat, required to produce 1 lb. of gain:

Milk solids consumed per lb. of gain by calves, pigs, and lambs.

Length of feeding period	Skim milk	Milk poor in fat	Milk rich in fat
	Lbs.	Lbs.	Lbs.
Calves fed 45 days	----------	1.03	1.18
Pigs fed 40 days (1st trial)	----------	1.36	1.78
Pigs fed 30 days (2d trial)	1.48	1.40	1.56
Lambs fed 60 days	----------	1.08*	1.37*

*0.42 lb. digestible matter in hay, additional.

It is seen that in every case milk rich in fat was less valuable per lb. of dry matter, fat included, than was milk poor in fat, or even skim milk. Beach reports that the pigs fed rich milk suffered loss of appetite and were attacked by diarrhea, finally not eating enough to sustain life. Those fed skim milk or milk low in fat, but under otherwise identical conditions, throve. The lambs on rich milk also showed lack of appetite.

In Europe studies on infant feeding lead to the same conclusion. They show that cow's milk rich in fat tends to produce intestinal disturbances and is not so well adapted to the needs of the human infant as poorer milk. The following explanation of this harmful effect of excess of fat in the food of infants has been offered: The general capacity of an organism for the absorption of fat is strictly confined within narrow limits, and consequently any excess is not absorbed but remains in the intestine. There it is converted into soaps, composed of part of the fats and an alkali, and as such eliminated from the body in the excreta. This ex-

[1] Bul. 31.

cretion of soap brings about a heavy loss from the body of alkaline bases, such as soda, potash, lime, etc., which, if continued, results in disturbed nutrition. On an exclusive diet of milk containing about 3.5 per ct. fat, the supply of alkaline bases is only sufficient for normal development. Milk that is rich in fat does not likewise contain proportionally more of the alkaline bases, for man has bred and selected cows only to meet the demands for more milk and for that which is richer in fat.

123a. Growth under adverse conditions.—At the Missouri Station[1] Waters kept 15 steers, varying from fat show animals to those in ordinary farm condition, for long periods of time on rations sufficient for maintenance. Below are given the results obtained with 4 yearling steers kept at constant body weight:

Growth of steers maintained at constant body weight.

Age at beginning	Length of period	Increase in			Decrease in width of chest	Decline in condition from—
		Height at withers	Length of head	Depth of chest		
Months	Months	Per cent	Per cent	Per cent	Per cent	
11	7	10.2	11.1	5.6	10.1	Good to com.
9.5	12	9.9	19.7	8.5	12.1	Med. to thin
16.5	12	6.8	12.0	6.0	10.6	Prime to com.
17	12	5.8	9.6	1.1	9.4	Prime to com.

The table shows that in each case there was a marked increase in the height of the animal at the withers, the length of head, and the depth of chest, denoting a growth of the skeleton. The decrease in width of chest shows a thinning of the flesh covering the skeleton, indicating that the stored fat was reabsorbed or withdrawn from the tissues in the effort to continue growth on insufficient food. Examination of the fat cells of these animals showed a uniform reduction in their size as compared with those of animals receiving liberal rations.

After a feeding trial lasting 6 months in which one steer was liberally fed, one given a maintenance ration, and another fed less than enough to maintain its weight, chemical analysis of the fatty tissues showed the composition given in the table.

The table shows that while the withdrawal of stored fat had not progressed far enough to use up all the fat of the body, a decided emptying of the fat cells had occurred, the fatty tissues of

[1] Proc. Soc. Prom. Agr. Sci., 1908.

the animal which had received less than a maintenance ration containing only about one-half as much fat as that of the liberally fed steer.

Composition of fatty tissues of growing steers.

Amount fed	Water	Fat	Protein	Ash
	Per cent	Per cent	Per cent	Per cent
Liberal ration	20.05	72.90	7.76	0.99
Maintenance ration	25.49	62.82	9.21	0.93
Less than maintenance ration	42.37	37.69	13.84	0.93

In the process of fattening, the fat is laid on the body in a certain order, being deposited first and most rapidly in certain regions, while in others little is stored until fattening is well advanced. Waters states that the reabsorption or withdrawal of fat from the tissues occurs in the reverse order from which it was laid on—that first deposited being the last to be absorbed.

The skeleton is not affected by poor nutrition until practically all the fat has been removed from the muscles and other organs. After the removal of fat from the muscles and other organs the principal effect caused by poor nutrition is the removal of the fat or marrow from the skeleton and the replacement of this with water. In the case of a steer kept on submaintenance for 11 months, the marrow had nearly all disappeared, and in its place was a watery, ill-smelling liquid. The reabsorption of fat takes place from all parts of the skeleton.

An experiment with two 8-months-old steers, one on full feed and the other on a maintenance ration, showed that on the whole the animal on full feed increased in height more rapidly than the one on maintenance. However for a considerable period the poorly fed steer grew as rapidly as the other. Waters states that the length of the period during which poorly fed animals gain as rapidly in height as well nourished ones ranges from 70 to 120 days, depending on the constitutional vigor of the individual and the excess fat with which it starts. After this period the increase in height becomes less rapid, ceasing altogether in from 6 months to a year and a half, by which time the animal has become quite thin and has reabsorbed all fat not necessary to its life. For 5 months a steer fed less than a maintenance ration and losing in weight grew in height as fast as one on full feed.

Growth on scanty rations is not due directly to the fat reabsorbed from the body. The animal burns its stored fat to support the body, and the protein in its food is used for building body tissue. The supply of mineral matter in the maintenance ration used in these studies was probably sufficient to provide an excess for growth. The steers also developed depraved appetites in a short time after being placed on scanty rations and ate considerable earth, possibly making use of some of its mineral matter.

Waters concludes that the young animal may advance to normal size by any or all of the following ways:

1. By growing steadily from birth to maturity.

2. By storing fat in a period of abundant food supply to assist in tiding over a limited period of sparse food supply without serious interruption of growth.

3. By prolonging the growth period.

4. By an increase in the rate of growth during a period of liberal feeding following a period of low nourishment and low gain.

5. By conserving the cost. Apparently the animal when kept for a long period on scanty food gets on a more economical basis than when more liberally fed. A ration which is at first insufficient to maintain the animal may be capable later of keeping the animal at a constant body weight, and still later of causing gain.

CHAPTER VIII.

FEEDING STANDARDS—CALCULATING RATIONS.

I. History of Feeding Standards.

At the beginning of the last century almost nothing was known concerning the chemistry of plants and animals. At that time the farmer gave his ox hay and corn without the least conception of what there was in this provender that nourished the animals. But science soon permeated every line of human activity, and agriculture was benefited with all the other arts. Davy, Liebig, Boussingault, Henneberg, Wolff, Lawes and Gilbert, and other great scientists were early laying the foundations for a rational agricultural practice based on chemistry, and animal feeding gained with the rest.

124. Hay equivalents.—The first attempt to systematically compare the feeding values of different feeding stuffs was by Thaer[1] of Germany, who in 1810 published a table of hay equivalents in which meadow hay served as the standard. According to this writer the amounts of various other feeding stuffs required to equal 100 lbs. of meadow hay were:

91 lbs. clover hay	417 lbs. rutabagas
91 lbs. alfalfa hay	602 lbs. cabbages
200 lbs. potatoes	625 lbs. mangels

Naturally opinions on feed values varied, and so there were about as many tables of hay equivalents as there were writers on the subject.

125. The first feeding standard.—Chemistry having paved the way, Grouven[2] in 1859 proposed the first feeding standard for farm animals, based on the crude protein, carbohydrates, and fat in feeding stuffs. This, however, was imperfect since it was based on the total instead of the digestible nutrients.

126. The Wolff feeding standards.—In 1864 Dr. Emil von Wolff, the great German scientist, presented for the first time in the Mentzel & von Lengerke's Agricultural Calendar[3] for that year a table

[1] Landwirtschaft, New ed., 1880, p. 211.
[2] Feeding Standard for Dom. Anim., Expt. Sta. Rec., IV; also Agriculturchemie, Köln, 1889, p. 834.
[3] Published annually by Paul Parey, Berlin, Germany.

of feeding standards based on the digestible nutrients contained in feeding stuffs. These standards set forth the amount of digestible crude protein, carbohydrates, and fat required daily by the different classes of farm animals.

The value and importance of the Wolff standards were at once recognized; and with their promulgation and adoption came the first widespread effort toward the rational feeding of farm animals. The Wolff standards were first brought to the attention of the American people in 1874 by Atwater,[1] America's worthy pioneer in the science of animal nutrition. Armsby's Manual of Cattle Feeding, based on Wolff's book[2] on the same subject, appeared in 1880.

The Wolff standards are still popular among progressive American farmers and stockmen and have been used wherever agricultural science is recognized. Their abiding popularity is due to their simplicity, ease of application, and the positive nature of the statements made. In these standards, accompanied by tables of the composition and digestibility of feeding stuffs, the stockman has all the data necessary to formulate rations for the different farm animals, little or nothing being left to uncertainty.

The Wolff feeding standards appeared annually in the Mentzel-Lengerke Calendar down to 1896. From 1897 to 1906 they were presented by Dr. C. Lehmann of the Berlin Agricultural High School with but slight modification. In 1907, however, Dr. O. Kellner, the talented director of the Möckern (Germany) Experiment Station, took charge of this portion of the Calendar and substituted tables and feeding standards based on starch values, as elsewhere briefly presented in this work.

In this chapter are set forth the other feeding standards which have followed those of Wolff, all seeking the same end in somewhat different ways. In their efforts to avoid the weaknesses of the Wolff system, each gains in some particulars and loses in others. In this work the Wolff standards are given first place because of their historical and foundational importance. The student of feeding problems should begin by familiarizing himself with them, no matter where he closes his studies.

II. Tables of Feeding Stuffs and the Wolff-Lehmann Standard Rations.

127. Nutrients.—The term *nutrient* is applied to any food constituent, or group of food constituents of the same general chemical

[1] Rpt. Me. State Bd. Agr., 1874; Rpt. Conn. Bd. Agr., 1874–5.

[2] Futterungslehre, 1st ed., 1874.

composition, that may aid in the support of animal life. Crude protein, the carbohydrates, and fat constitute the generally recognized classes of nutrients, altho air, water, and mineral matter might likewise be so termed. Gluten, starch, sugar, etc., are also nutrients. The relative availability and therefore usefulness and value of any given nutrient is necessarily not fixed, but varies with circumstances. Fiber is a nutrient, yet the fiber in hay is almost valueless to the calf when very young, because its digestive organs cannot utilize it. With the horse the same material is partially, and with the ox still more largely, digestible. The term *digestible nutrient* covers that portion of each nutrient which is digested and taken into the body, as determined by digestion trials with various mature animals.

128. Nutrients in feeding stuffs.—From the extensive data given in Table I of the Appendix, showing the total nutrients in feeding stuffs, Example Table I follows for illustration:

Example Table I, showing the total nutrients in 100 lbs. of various common feeding stuffs.

Feeding stuffs	Water	Crude protein	Fiber	N-free extract	Fat
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Roughages					
Corn stover, field cured	40.5	3.8	19.7	31.5	1.1
Red clover hay	15.3	12.3	24.8	38.1	3.3
Timothy hay	13.2	5.9	29.0	45.0	2.5
Oat straw	9.2	4.0	37.0	42.4	2.3
Concentrates					
Corn	10.6	10.3	2.2	70.4	5.0
Oats	10.4	11.4	10.8	59.4	4.8
Wheat bran	11.9	15.4	9.0	53.9	4.0
Linseed meal, o. p.	9.8	33.9	7.3	35.7	7.8

The table shows that, on the average, 100 lbs. of field-cured corn stover contains 40.5 lbs. of water, while the same weight of oat straw has but 9.2 lbs. The next column shows that 100 lbs. of stover contains 3.8 lbs. of crude protein, while the same weight of oat straw has 4 lbs. Were it not for the large amount of water in stover its crude protein would exceed that of straw. Stover contains 19.7 lbs. of fiber, while oat straw has nearly twice that amount, and corn grain but 2.2 lbs. per 100 lbs. Among the grains, oats are relatively high in fiber because of the woody hull which surrounds the kernels. One hundred lbs. of corn contains 70.4 lbs. of nitrogen-free extract, principally starch. The roughages are usually low in fat, while corn and oats are relatively high.

129. Coefficients of digestibility.—The digestible portion of each nutrient in a feeding stuff, expressed in per cent, is termed its *coefficient of digestibility.* The nutrients of feeds are not wholly digestible, a part always passing thru the animal without having been dissolved by the digestive fluids and thereby being made usable. Digestion trials showing what per cent of each nutrient in feeds is digestible have been collected in Table II of the Appendix, from which the following data are taken:

Example Table II, showing the digestion coefficients of the feeding stuffs given in Table I.

Feeding stuffs	No. of trials	Dry matter	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
		Per cent	Per cent	Per cent	Per cent	Per cent
Roughages						
Corn stover	31	57	36	64	59	67
Red clover hay	18	57	58	54	64	55
Timothy hay	64	55	48	50	62	50
Oat straw	11	48	33	54	46	36
Concentrates						
Corn	12	91	76	58	93	86
Oats	6	70	77	31	77	89
Wheat bran	11	66	77	41	71	63
Linseed meal, o. p.	3	79	89	57	78	89

The first line of the table shows that, taking the average of 31 digestion trials with corn stover, 36 per ct. of the crude protein, 64 per ct. of the fiber, 59 per ct. of the nitrogen-free extract, and 67 per ct. of the fat are digestible. The concentrates—corn, oats, etc.—are usually much more digestible than the roughages—corn stover, oat straw, etc.

130. Digestible nutrients.—The *digestible nutrients* in a feeding stuff are found by multiplying the pounds of each nutrient it contains by the numerical coefficient of digestibility for that nutrient in the given feed. Example Table III on the next page is a fragment of the extensive Table III of the Appendix. Its data are derived by multiplying the nutrients in each feed as given in Table I by their corresponding coefficients of digestibility given in Table II. After determining the several digestible nutrients it is customary to combine the fiber and nitrogen-free extract under the group-term *carbohydrates.*

Table I shows that average corn stover contains 3.8 lbs. of crude protein, 36 per ct. of which is digestible according to Table II.

Thirty-six per ct. of 3.8 lbs. is 1.4 lbs., which sum is placed in Table III as the digestible crude protein in 100 lbs. of corn stover.

In Tables I and II the fiber and nitrogen-free extract are given in separate columns, since, tho of the same chemical composition, they often differ materially in digestibility. The digestible portion of each is determined separately and then combined under the term "carbohydrates" in the following table:

Example Table III, showing the digestible nutrients in 100 lbs. of the feeding stuffs in Table I.

Feeding stuffs	Total dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates*	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Roughages					
Corn stover	59.5	1.4	31.2	0.7	1:23.4
Red clover hay	84.7	7.1	37.8	1.8	1: 5.9
Timothy hay	86.8	2.8	42.4	1.3	1:16.2
Oat straw	90.8	1.3	39.5	0.8	1:31.8
Concentrates					
Corn	89.4	7.8	66.8	4.3	1: 9.8
Oats	89.6	8.8	49.2	4.3	1: 6.7
Wheat bran	88.1	11.9	42.0	2.5	1: 4.0
Linseed meal, o. p.	90.2	30.2	32.0	6.9	1: 1.6

*Nitrogen-free extract and fiber combined.

According to Table I, there are 19.7 lbs. of fiber in 100 lbs. of corn stover, 64 per ct. of which is digestible, according to Table II. Likewise there are 31.5 lbs. of nitrogen-free extract, 59 per ct. of which is digestible. Multiplying in each case and adding the two products, we have 31.2 lbs., which is placed in the column marked "digestible carbohydrates" in Table III. The digestible fat is obtained in the same manner as the digestible crude protein. For example, 1.1 lbs. of fat in corn stover multiplied by 67, the factor of digestibility, gives 0.7 lb., which is entered in Table III as the digestibile fat in 100 lbs. of corn stover.

131. Nutritive ratio.—By *nutritive ratio* is meant the ratio which exists in any given feeding stuff between the digestible crude protein and the combined digestible carbohydrates and fat. It is determined in the following manner: The digestible fat in 100 lbs. of the given feed is multiplied by 2.25, because fat has that heat value compared with the carbohydrates, and the product is then added to the digestible carbohydrates. The sum of the two divided by the amount of digestible crude protein gives the second factor of the ratio. The nutritive ratio of corn stover given in Table III is thus found:

$$\frac{\underset{\text{Diges. fat}}{0.7} \times \underset{\text{Heat equiv.}}{2.25} + \underset{\text{Diges. carbohy.}}{31.2}}{\underset{\text{Diges. crude protein}}{1.4}} = \underset{\text{Second factor of nutritive ratio}}{23.4}$$

Nutritive ratios are expressed with the colon, thus, 1:23.4. The nutritive ratio of corn stover is therefore 1:23.4; *i. e.* for each lb. of digestible crude protein in corn stover there are 23.4 lbs. of digestible carbohydrates or fat equivalent. A feed or ration having much crude protein in proportion to carbohydrates and fat combined is said to have a *narrow nutritive ratio;* if the reverse, it has a *wide nutritive ratio.* Oat straw has the wide nutritive ratio of 1:31.8, corn the medium one of 1:9.8 and protein-rich linseed meal the very narrow ratio of 1:1.6, the carbohydrates being less than twice the crude protein.

132. Concerning rations.—On the farm a *ration* is the feed allowed or set apart to maintain a given animal during a day of 24 hours, whether all thereof is administered or fed at one time or in portions at different times.

A *balanced ration* is the feed or combination of feeds furnishing the several nutrients—crude protein, carbohydrates, and fat—in such proportion and amount as will properly and without excess of any nutrient nourish a given animal for 24 hours.

A *maintenance ration* is one that furnishes a sufficiency of each and all of the several nutrients but no more than is required to maintain a given resting animal, so that it will neither gain nor lose in weight.

133. The Wolff-Lehmann feeding standards.—Example Table IV, given below, taken from Table IV of the Appendix, presents the nutrients required by certain farm animals according to the Wolff-Lehmann feeding standards:

Example Table IV, showing digestible nutrients required daily by farm animals per 1000 lbs. live weight.

Animal	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Ox, at rest	18	0.7	8.0	0.1	1:11.8
Fattening cattle, 1st period	30	2.5	15.0	0.5	1: 6.5
Cow, yielding 22 lbs. milk	29	2.5	13.0	0.5	1: 5.7
Horse, at medium work	24	2.0	11.0	0.6	1: 6.2

The table shows that according to Wolff's teachings a 1000-lb. ox at rest, neither gaining nor losing in weight, requires for 1 day's maintenance 18 lbs. of dry matter containing the following digestible nutrients: 0.7 lb. crude protein, 8.0 lbs. carbohydrates, and 0.1 lb. fat, with a nutritive ratio of 1:11.8. Tho the ox is resting, work is still being performed; the beating of the heart, mastication, digestion, standing, breathing—all the manifestations of life in fact—imply internal work and call for energy and for repair material.

When the animal is growing, fattening, giving milk, or doing external work, a larger quantity of nutrients must be supplied than for maintenance, as the table shows. For the cow yielding 22 lbs. of milk daily, the standard calls for the following quantities of the several digestible nutrients: Crude protein 2.5 lbs., carbohydrates 13.0 lbs., and fat 0.5 lb. These have a nutritive ratio of 1:5.7, which is much narrower than for the ox at rest. In his effort to attain the proper standard Wolff[1] reasoned that, since pasture grass is the natural food of the dairy cow, the nutritive ratio of such grass might most properly serve as the chosen standard.

III. Calculating Rations for Farm Animals.

We have now advanced to a point where the tables of nutrients and the feeding standards can be put to use in calculating rations for farm animals according to the Wolff-Lehmann standards.

134. Ration for a steer at rest.—In Example Tables III and IV we have the data for calculating the feed required to maintain a 1000-lb. ox at rest in his stall when neither gaining nor losing in weight. If for the trial ration it is decided to feed 10 lbs. of corn stover and 10 lbs. of oat straw for roughage, then the calculations for dry matter and digestible nutrients would be as given below:

	In 100 pounds					In 10 pounds
Corn stover						
Dry matter	59.5	÷	100	×	10 =	5.95
Crude protein	1.4	÷	100	×	10 =	0.14
Carbohydrates	31.2	÷	100	×	10 =	3.12
Fat	0.7	÷	100	×	10 =	0.07
Oat straw						
Dry matter	90.8	÷	100	×	10 =	9.08
Crude protein	1.3	÷	100	×	10 =	0.13
Carbohydrates	39.5	÷	100	×	10 =	3.95
Fat	0.8	÷	100	×	10 =	0.08

[1] Farm Foods, Eng. ed., p. 224.

Arranging in tabular form the digestible nutrients so found, we have:

First trial maintenance ration for a 1000-lb. ox at rest.

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Corn stover, 10 lbs.	5.95	0.14	3.12	0.07	
Oat straw, 10 lbs.	9.08	0.13	3.95	0.08	
First trial ration	15.03	0.27	7.07	0.15	
Wolff-Lehmann standard	18.00	0.70	8.00	0.10	1:11.8
Excess or deficit	−2.97	−0.43	−0.93	+0.05	

The trial ration falls below the standard in each nutrient except fat, the deficiency in crude protein being large. To bring it nearer to the standard, we add 1 lb. each of oil meal and oats.

Second trial maintenance ration for a 1000-lb. ox.

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Partial ration as above	15.030	0.270	7.070	0.150	
Oil meal, 1 lb.	0.902	0.302	0.320	0.069	
Oats, 1 lb.	0.896	0.088	0.492	0.043	
Second trial ration	16.828	0.660	7.882	0.262	1:12.8
Wolff-Lehmann standard	18.000	0.700	8.000	0.100	1:11.8
Excess or deficit	−1.172	−0.040	−0.118	+0.162	

This trial ration falls below the standard by more than 1 lb. of dry matter, but this deficiency is unimportant. Dry matter is only an indication of the bulk or volume of the ration, and may vary greatly with different feeds and animals without affecting results. In crude protein and carbohydrates the ration is slightly below the standard, while the fat is in excess. Its nutritive ratio is 1 : 12.8 This ration approximates the standard about as closely as is possible without using fractions of pounds, and is near enough for our purpose. We learn from this that 10 lbs. each of corn stover and oat straw, with 1 lb. each of oil meal and oats, should furnish sufficient food to maintain a resting 1000-lb. ox for 24 hours when neither gaining nor losing in weight.

135. A ration for the dairy cow.—In formulating a ration for a dairy cow yielding 22 lbs. of milk daily, as called for by the feeding standard in Example Table IV, we choose from Example Table III 8 lbs. of red clover hay, 10 lbs. of corn stover, and 3 lbs. of oat straw for roughage, with 5 lbs. each of corn and wheat bran for concentrates.

Calculations for dry matter and digestible nutrients in trial ration for a dairy cow.

Red clover hay

	In 100 pounds	In 8 pounds
Dry matter	84.7÷100×8=	6.776
Crude protein	7.1÷100×8=	0.568
Carbohydrates	37.8÷100×8=	3.024
Fat	1.8÷100×8=	0.144

Corn stover

	In 100 pounds	In 10 pounds
Dry matter	59.5÷100×10=	5.95
Crude protein	1.4÷100×10=	0.14
Carbohydrates	31.2÷100×10=	3.12
Fat	0.7÷100×10=	0.07

Oat straw

	In 100 pounds	In 3 pounds
Dry matter	90.8÷100×3=	2.724
Crude protein	1.3÷100×3=	0.039
Carbohydrates	39.5÷100×3=	1.185
Fat	0.8÷100×3=	0.024

Corn

	In 100 pounds	In 5 pounds
Dry matter	89.4÷100×5=	4.470
Crude protein	7.8÷100×5=	0.390
Carbohydrates	66.8÷100×5=	3.340
Fat	4.3÷100×5=	0.215

Bran

	In 100 pounds	In 5 pounds
Dry matter	88.1÷100×5=	4.405
Crude protein	11.9÷100×5=	0.595
Carbohydrates	42.0÷100×5=	2.100
Fat	2.5÷100×5=	0.125

Arranging these findings we have:

First trial ration for a 1000-lb. cow yielding 22 lbs. of milk daily.

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
Roughages					
Red clover hay, 8 lbs.	6.776	0.568	3.024	0.144	
Corn stover, 10 lbs.	5.950	0.140	3.120	0.070	
Oat straw, 3 lbs.	2.724	0.039	1.185	0.024	
Concentrates					
Corn meal, 5 lbs.	4.470	0.390	3.340	0.215	
Bran, 5 lbs.	4.405	0.595	2.100	0.125	
First trial ration	24.325	1.732	12.769	0.578	
Wolff-Lehmann standard	29.000	2.500	13.000	0.500	1:5.7
Excess or deficit	−4.675	−0.768	−0.231	+0.078	

This trial ration falls considerably below the standard, especially in crude protein, and to correct this 3 lbs. of nitrogenous oil meal is added.

Second trial ration for a 1000-lb. cow yielding 22 lbs. of milk daily.

Feeding stuffs	Dry matter	Digestible nutrients			Nutritive ratio
		Crude protein	Carbo-hydrates	Fat	
	Lbs.	Lbs.	Lbs.	Lbs.	
First trial ration	24.325	1.732	12.769	0.578	
Oil meal, 3 lbs.	2.706	0.906	0.960	0.207	
Second trial ration	27.031	2.638	13.729	0.785	1:5.9
Wolff-Lehmann standard	29.000	2.500	13.000	0.500	1:5.7
Excess or deficit	−1.969	+0.138	+0.729	+0.285	

The second trial ration falls below the standard in dry matter, which is unimportant. All the nutrients are in slight excess, and the nutritive ratio, 1:5.9, is close to the standard, 1:5.7. We thus learn that a satisfactory ration for a dairy cow weighing 1000 lbs. yielding 22 lbs. of milk daily may be composed of 8 lbs. red clover hay, 10 lbs. corn stover, 5 lbs. each of corn and bran, and 3 lbs. each of oats and oil meal.

136. Hints and helps.—In formulating rations for ruminants it is well to start with such an amount of 2 kinds of roughage as will furnish from 16 to 20 lbs. of dry matter and about 10 lbs. of digestible carbohydrates, together with such an amount of some concentrate as will, on rough calculation, bring the total crude protein somewhat under the standard. When the nutrients of these 3 feeds have been placed in tabular form, a little study will show the quantity and kind of concentrates still needed to bring the ration to the standard.

It is practically impossible, as well as useless, to attempt to formulate rations that will exactly agree with the standard in all nutrients. It is usually better to allow the ration to fall somewhat below the standard in dry matter than to use an excess of low-grade roughage with its large content of inert matter. There is usually an excess of fat over the standard, which cannot well be avoided. When the fat is much in excess, the carbohydrates may fall somewhat below the standard as an offset.

Several devices and expedients have been offered to shorten the work of calculating rations. Willard of the Kansas Station[1] presents a system based on alligation, while Spillman of the Washington Station[2] and Jeffers[3] have invented ingenious mechanical computers. It seems best in this work to show how to perform the calculations in the simplest and most direct manner. Thru such drill the student will become familiar with the quantity and proportion of the several nutrients in common feeding stuffs and the amount of these required by farm animals according to the standards. The whole matter is less difficult and no more fatiguing than the simpler arithmetical operations of the secondary schools, while the benefits should richly compensate the agricultural student for the time and effort.

It should be borne in mind that both the table of digestible nutrients and the feeding standards are but averages and approximations—something far different from the multiplication table or a table of logarithms. Those who will regard them as reasonable approximations to great vital facts and principles in the nurture of farm animals will be guided and helped by what they teach.

137. Practical considerations.—It is evident that the balanced ration is only a theoretical possibility and can only be approximated in practice. Indeed, in practice it is often best to feed rations which are not balanced according to the standards, tho it is rarely wise to depart far from them. It has been shown that crude protein in excess of the actual amount of that nutrient required may take the place of the carbohydrates in part (**75**) and that the carbohydrates and fats may in some measure replace each other. (**79**) Unbalanced rations are often the most economical financially; for example, alfalfa is relatively rich in crude protein, while corn and corn forage are rich in carbohydrates but low in crude protein. Where alfalfa is abundantly grown it usually sells for a low price, and there is advantage in giving rations rich beyond the standard in crude protein. The allowance of crude protein given in the Wolff-Lehmann feeding standards materially exceeds the possible minimum. In the great corn districts of the Mississippi Valley, where protein-rich feeds are in relatively low supply, the feeder will naturally formulate a ration made up largely of the corn plant, and such rations will usually run low in crude protein, with an ex-

[1] Bul. 115; Cyclopedia of Am. Agr., Bailey, Vol. III, p. 103.
[2] Bul. 48.
[3] H. W. Jeffers, Plainsboro, N. J.

cess of highly digestible carbohydrates. In the latter case, provided there is sufficient crude protein to meet the minimum requirement of the animal, such rations will generally be found the most economical. (**97**)

138. Notes on the Wolff standards.—Recent investigations by the scientists show that the Wolff standards are only approximately correct. Kühn of the Möckern Station[1] found that the 1000-lb. ox can be maintained on 0.7 lb. of digestible crude protein and 6.6 lbs. of digestible carbohydrates. Kellner, who is Kühn's successor, has practically adopted the Kühn standard in providing 0.6 lb. of digestible protein and a starch value of 6 lbs. for its maintenance.

Haecker of the Minnesota Station[2] found that the 1000-lb. dry, barren cow can be maintained on 0.6 lb. of crude protein, 6 lbs. of carbohydrates, and 0.1 lb. of fat, all digestible. For the maintenance of the 1000-lb. cow producing milk he would allow 0.7 lb. of crude protein, 7 lbs. of carbohydrates, and 0.1 lb. of fat, all digestible. He found that the Wolff allowance of crude protein for the dairy cow may be advantageously cut as much as 20 per ct., unless feeds rich in that nutrient are available at relatively low cost. Woll of the Wisconsin Station[3] also found that the Wolff standard for dairy cows was higher in crude protein than necessary.

The Wolff allowance of crude protein for fattening animals may generally be reduced by as much as 40 per ct. Kellner and Armsby recognize this in their standards.

139. In conclusion.—When the students of feeding problems and stockmen conducting practical feeding operations learn that neither the tables of digestible nutrients in feeding stuffs nor the Wolff feedings standards are exact and wholly reliable, they will be tempted to cast them aside as of no value. Due reflection will check such a course, for enormous gain has already come to our stock interests thru this source. The Wolff standards, coupled with tables of the digestible nutrients in feeding stuffs, have been profoundly useful in advancing the great art of feeding farm animals. Both students and stockmen should familiarize themselves with the Wolff standards because of their historical interest and their great general usefulness. From what is thus learned, all are better prepared for the study of other more advanced systems and standards now in the process of formation.

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[1] Landw. Vers. Stat., 44, p. 550. [2] Bul. 79. [3] Rpt. 1894.

IV. The Haecker Standard for Dairy Cows.

As the result of long years of intimate study with a high-grade working dairy herd at the Minnesota Station,[1] Haecker holds that the feed requirements of the dairy cow vary not only according to her weight and the quantity of milk yielded, but also according to its quality.

140. The Haecker standard.—In his standard Haecker first sets down the total digestible nutrients daily required to maintain the 1000-lb. cow, independent of the milk she produces, as follows: Crude protein 0.7 lb., carbohydrates 7.0 lbs., and fat 0.1 lb.

For each 100 lbs. in live weight the cow may exceed or fall below the 1000-lb. standard there is added or subtracted one-tenth of the standard ration.

To this maintenance provision the further allowance set forth in the table is made.

Haecker's feeding standard for the dairy cow.

	Daily allowance of digestible nutrients		
	Crude protein	Carbo-hydrates	Fat
	Lbs.	Lbs.	Lbs.
For support of the 1000-lb. cow	0.700	7.00	0.100
To the allowance for support add:			
For each lb. of 3.0 per cent milk	0.040	0.19	0.015
For each lb. of 3.5 per cent milk	0.042	0.21	0.016
For each lb. of 4.0 per cent milk	0.047	0.23	0.018
For each lb. of 4.5 per cent milk	0.049	0.26	0.020
For each lb. of 5.0 per cent milk	0.051	0.27	0.021
For each lb. of 5.5 per cent milk	0.054	0.29	0.022
For each lb. of 6.0 per cent milk	0.057	0.31	0.024
For each lb. of 6.5 per cent milk	0.061	0.33	0.025
For each lb. of 7.0 per cent milk	0.063	0.35	0.027

The table shows that if a cow is yielding milk containing 3 per ct. of butter fat, she should be fed in addition to the maintenance ration 0.040 lb. crude protein, 0.19 lb. carbohydrates, and 0.015 lb. fat, all digestible, for each lb. of milk she gives. If the milk is richer than 3 per ct. the provision must be greater.

To illustrate the use of the table there is below formulated the nutrient allowance for a 1100-lb. cow producing 25 lbs. of 4 per ct. milk daily:

[1] Buls. 35, 67, 71, 79, and information to the author.

Digestible nutrients required daily by a 1100-lb. cow yielding 25 lbs. of 4 per ct. milk.

	Crude protein	Carbo-hydrates	Fat
	Lbs.	Lbs.	Lbs.
For maintenance	0.77	7.7	0.11
For 25 lbs. of 4 per cent milk	1.18	5.75	0.45
Total	1.95	13.45	0.56

In the above there is first set down the maintenance allowance for the 1000-lb. cow, increased by one-tenth because this cow weighs 100 lbs. more than the standard; this is 0.77 lb. crude protein, 7.7 lbs. carbohydrates, and 0.11 lb. fat, all digestible. The previous table shows the daily nutrient allowance for each lb. of 4 per ct. milk to be 0.047 lb. crude protein, 0.23 lb. carbohydrates, and 0.018 lb. fat, all digestible. Since this cow is yielding 25 lbs. of milk daily, the foregoing numbers multiplied by 25 are placed in the second line of the table. Thus it is shown that the production of 25 lbs. of 4 per ct. milk calls for 1.18 lbs. of crude protein, 5.75 lbs. of carbohydrates, and 0.45 lb. of fat, all digestible. Adding these nutrients to those for maintenance, we have practically 2 lbs. (1.95 lbs.) of digestible protein, 13.5 lbs. (13.45 lbs.) of digestible carbohydrates, and 0.6 lb. (0.56 lb.) of digestible fat as the quantity of digestible nutrients required daily to properly nourish a 1100-lb. cow when giving 25 lbs. of 4 per ct. milk daily.

V. Kellner's Starch Values and Feeding Standards.

Careful and laborious investigations, conducted by Kellner and Zuntz by means of a modern respiration apparatus and by Armsby by means of a respiration calorimeter, have shown that the total quantity of digestible nutrients in a feeding stuff is not the true measure of its feeding value, as is assumed in the Wolff-Lehmann feeding standards. These investigators have found that to determine the actual net value of any given feeding stuff to the animal it is necessary to deduct the energy expended in the work of mastication, digestion, and assimilation from the total available energy furnished by the digestible nutrients in the feeding stuff. (**70**)

141. Kellner's starch values.—As a result of his investigations concerning the net values of feeding stuffs to the animal, Kellner has formulated a feeding standard based upon what he calls "starch values."[1] He found that on the average 1 lb. of digestible starch fed to the ox in excess of maintenance requirements produced 0.248 lb. of body fat. (**85**) Taking 1 lb. of digestible starch as his unit, he gives the following starch values for the digestible nutrients in feeding stuffs, based on the amount of body fat these several pure nutrients will form if fed to the ox:

In 1 lb. of digestible	Starch value Lbs.
Protein	0.94
Nitrogen-free extract and fiber	1.00
Fat in roughage, chaff, roots, etc.	1.61
Fat in cereals, factory and mill by-products	2.12
Fat in oil-bearing seeds and oil meal	2.41

Kellner further found that the net nutritive value of certain concentrates, such as grains and seeds, oil cake, roots, and slaughter-house by-products, was the same as that obtained when the several pure nutrients in them were fed separately. If the amounts, in pounds, of the several digestible nutrients in 100 lbs. of feeds of this class are multiplied by the starch values of the respective nutrients they contain, and the products added, the sum will represent the starch value of 100 lbs. of such feeds. With other feeding stuffs the work of mastication and digestion materially reduces their actual net value. The following deductions should accordingly be made from the values found as before:

Class	Deduction Per ct.
Mill and factory refuse feed	5–30
Soilage crops	10–20
Silage	20–40
Hay	30–50
Straw	50–70

Kellner affirms that despite the vast amount of study given to the subject there are still many gaps in our knowledge of the actual net value of the different feeding stuffs. In his own case such values have been determined by actual experiments with only a limited number of typical representatives of the different classes of feeding stuffs when fed to the mature fattening ox. For the numerous other feeds, and especially for other classes of animals, the net starch values found by computation must be regarded only as approximations, which are helpful until the actual net values of such feeds to the different classes of animals have been found.

[1] Land. Kal., 1909, I, pp. 103–119; Ernähr. landw. Nutztiere, 1907.

142. Kellner's feeding standards.—Below are given the standard rations for the several classes of farm animals as formulated by Kellner:

The Kellner standards per 1000 lbs. of farm animal.

	Dry matter	Digestible nutrients	
		Protein	Starch values
	Lbs.	Lbs.	Lbs.
Maintenance of mature steer	15–21	0.6	6.0
Fattening steer	24–32	1.5–1.7	12.5–14.5
Milch cow, yielding 20 lbs. milk daily	25–29	1.6–1.9	9.8–11.2
Milch cow, yielding 30 lbs. milk daily	27–33	2.2–2.5	11.8–13.9
Milch cow, yielding 40 lbs. milk daily	27–34	2.8–3.2	13.9–16.6
Horse at light work	18–23	1.0	9.2
Horse at medium work	21–26	1.4	11.6
Horse at heavy work	23–28	2.0	15.0
Fattening swine, 1st period	33–37	3.0	27.5
Fattening swine, 2d period	28–33	2.8	26.1
Fattening swine, 3d period	24–28	2.0	19.8

In the Kellner standards the nutrients required are expressed in digestible protein and starch values; for example, a mature resting steer weighing 1000 lbs. requires for maintenance 0.6 lb. digestible protein and 6.0 lbs. starch values. Kellner holds that the amids have doubtful nutritive value, and therefore may be ignored in ordinary rations. Accordingly in his tables and standards the nitrogenous substance set forth is protein and not crude protein. (**5**)

The studies of Kellner, Zuntz, and Armsby are preparing the way for nutrition tables and feeding standards that in time may entirely supplant those of Wolff. The Kellner table of starch values is not here given, but instead Armsby's table of energy values, which is similar and will suffice in this elementary general presentation of the subject.

VI. The Armsby Feeding Standards.

143. The Armsby energy values.—Armsby[1] of the Pennsylvania Station is studying the nutrient requirements of the ox with the first and only respiration calorimeter used in the study of farm animals in America. From his own work and that of Kellner he has constructed the following table, which shows the net energy

[1] U. S. Dept. Agr., Bur. Anim. Indus., Buls. 51, 74, 101; Farmers' Bul. 346.

of feeding stuffs expressed in therms (**68**) in place of Kellner's starch values, and has also formulated feeding standards based thereon:

The Armsby Table of dry matter, digestible protein, and net energy values in 100 lbs. of various feeding stuffs.

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Green fodder and silage			
Alfalfa	28.2	2.50	12.45
Red clover	29.2	2.21	16.17
Green corn fodder	20.7	0.41	12.44
Corn silage	25.6	1.21	16.56
Rye fodder	23.4	1.44	11.63
Hay and dry coarse fodders			
Alfalfa hay	91.6	6.93	34.41
Red clover hay	84.7	5.41	34.74
Corn forage, field cured	57.8	2.13	30.53
Corn stover	59.5	1.80	26.53
Cowpea hay	89.3	8.57	42.76
Timothy hay	86.8	2.05	33.56
Straws			
Oat straw	90.8	1.09	21.21
Rye straw	92.9	0.63	20.87
Wheat straw	90.4	0.37	16.56
Roots and tubers			
Carrots	11.4	0.37	7.82
Mangels	9.1	0.14	4.62
Potatoes	21.1	0.45	18.05
Rutabagas	11.4	0.88	8.00
Grains			
Corn	89.1	6.79	88.84
Corn-and-cob meal	84.9	4.53	72.05
Barley	89.1	8.37	80.75
Oats	89.0	8.36	66.27
Rye	88.4	8.12	81.72
Wheat	89.5	8.90	82.63
By-products			
Dried brewers' grains	92.0	19.04	60.01
Buckwheat middlings	88.2	22.34	75.92
Cotton-seed meal	91.8	35.15	84.20
Gluten feed	91.9	19.95	79.32
Linseed meal, o. p.	90.8	27.54	78.92
Malt sprouts	89.8	12.36	46.33
Dried sugar-beet pulp	93.6	6.80	60.10
Wheat bran	88.1	10.21	48.23
Wheat middlings	84.0	12.79	77.65

The last column of the table does not show the total energy in the digestible portion of 100 lbs. of the various feeding stuffs, but only that energy which is finally available to the animal after deducting the losses occurring thru mastication, digestion, and assimilation.

The following table by Armsby sets forth the maintenance requirements of horses, cattle, and sheep, no table having yet been formulated for swine:

Armsby's maintenance standard for horses, cattle, and sheep.

Live weight	Horses		Cattle		Sheep		
	Digestible protein	Energy value	Digestible protein	Energy value	Live weight	Digestible protein	Energy value
Lbs.	Lbs.	Therms	Lbs.	Therms	Lbs.	Lbs.	Therms
150	0.30	2.00	0.15	1.70	20	0.023	0.30
250	0.40	2.80	0.20	2.40	40	0.05	0.54
500	0.60	4.40	0.30	3.80	60	0.07	0.71
750	0.80	5.80	0.40	4.95	80	0.09	0.87
1000	1.00	7.00	0.50	6.00	100	0.10	1.00
1250	1.20	8.15	0.60	7.00	120	0.11	1.13
1500	1.30	9.20	0.65	7.90	140	0.13	1.25

The table shows that a young, growing horse weighing 500 lbs., when neither gaining nor losing in weight, requires for its daily support 0.60 lb. of digestible protein and 4.40 therms of net digestible matter, the latter including the 0.60 lb. of digestible protein. When this growing horse reaches 1000 lbs., there is required for its maintenance 1 lb. of digestible protein and 7 therms of net digestible matter. Tho it has doubled in weight, the food requirement has not likewise doubled. When the horse reaches the weight of 1500 lbs., there is required a further increase of only 0.3 lb. of protein and 2.20 therms of net energy.

144. Standards for growing animals.—In the table which follows, Armsby sets forth the digestible protein and net energy requirements of growing cattle and sheep, no data as yet having been given for horses and swine. The figures include the maintenance requirements.

The Armsby standard for growing cattle and sheep.

Age	Cattle			Sheep		
	Live weight	Digestible protein	Net energy value	Live weight	Digestible protein	Net energy value
Months	Lbs.	Lbs.	Therms	Lbs.	Lbs.	Therms
3	275	1.10	5.0			
6	425	1.30	6.0	70	0.30	1.30
9				90	0.25	1.40
12	650	1.65	7.0	110	0.23	1.40
15				130	0.23	1.50
18	850	1.70	7.5	145	0.22	1.60
24	1000	1.75	8.0			
30	1100	1.65	8.0			

The table shows that a 3-months-old calf weighing 275 lbs. requires 1.10 lbs. of digestible protein and 5 therms of net energy value, the latter including the 1.10 lbs. of protein. When the calf has grown to 1100 lbs., or quadrupled in weight, it requires but 0.55 lb. more protein and 3 more therms than before. This relative lessening in feed requirement is due to the fact that the larger animal requires relatively less for maintenance, as explained elsewhere in the discussions on maintenance requirements. (**96, 123a**) For the 1000-lb. steer Armsby allows 1.75 lbs. of digestible protein, and but 1.65 lbs., or 0.10 lb. less, for the same animal when weighing 1100 lbs. This is because at the higher weight the steer has practically ceased muscular growth and therefore needs less protein than earlier in life. A comparison of the maintenance and growth requirements of animals, as here set forth, reveals the fact that a large portion of all the feed the animal consumes is used for the support of the body, and that the additional requirements for growth are not relatively large.

145. Standards for milch cows and fattening steers.—Armsby supplements the foregoing partial standards with the following:

1. For milk production, add to the maintenance standard 0.05 lb. of digestible protein and 0.3 therm for each pound of 4 per ct. milk to be produced.
2. For mature fattening cattle, add 3.5 therms to the maintenance standard for each pound of gain to be made.

For the **milch** cow Armsby provides additional food, both protein and therms, as noted in the foregoing, because milk is rich in complex protein compounds, and also contains carbohydrates and fat. Furthermore, the cow is usually growing a calf. For the fattening steer Armsby holds that, after providing the protein set forth in the **ration for growth,** the steer will fatten satisfactorily without any additional protein, provided there are supplied sufficient carbohydrates and fat to meet the standard. Hence there is no provision for additional protein during fattening as in the Wolff standards.

Armsby recommends that:

1. A 1,000-lb. ruminant should receive 20 to 30 lbs., or an average of 25 lbs., dry matter per day.
2. The horse should receive somewhat less dry matter than ruminants.

146. Ration for dairy cow.—The following illustrates the method of using the Armsby tables and standards in computing rations. The digestible protein in the tables is true protein; that is, it does not include the amids.

To form a ration for a dairy cow weighing 850 lbs. and yielding 20 lbs. of milk daily, suppose there are available field-cured corn forage, clover hay, corn meal, wheat bran, and gluten feed.

The maintenance requirements for an 850-lb. cow are approximately:

Digestible protein	0.45 lb.
Energy	5.60 therms

For the production of 20 lbs. of 4 per ct. milk there is needed in addition to the above:

Digestible protein (0.05 lb. × 20)	1 lb.
Energy (0.3 therms × 20)	6 therms

The total daily feed requirements are therefore as follows:

Feed requirements of an 850-lb. cow producing 20 lbs. milk daily.

	Digestible protein	Net energy value
	Lbs.	Therms
For maintenance	0.45	5.60
For milk production	1.00	6.00
Total requirement	1.45	11.60

For a trial ration we take 12 lbs. of corn forage, 6 lbs. of clover hay, 5 lbs. of corn meal, and 2 lbs. of wheat bran.

Calculations for trial ration for dairy cow.

Corn forage

	In 100 pounds	In 12 pounds
Dry matter	57.8 ÷100×12=	6.94
Dig. protein	2.13÷100×12=	0.26
Energy value	30.53÷100×12=	3.66

Clover hay

	In 100 pounds	In 6 pounds
Dry matter	84.7 ÷100×6=	5.08
Dig. protein	5.41÷100×6=	0.32
Energy value	34.74÷100×6=	2.08

Corn meal

	In 100 pounds	In 5 pounds
Dry matter	89.1 ÷100×5=	4.46
Dig. protein	6.79÷100×5=	0.34
Energy value	88.84÷100×5=	4.44

Wheat bran

	In 100 pounds	In 2 pounds
Dry matter	88.1 ÷100×2=	1.76
Dig. protein	10.21÷100×2=	0.20
Energy value	48.23÷100×2=	0.96

Arranging these results, we have:

First trial ration for an 850-lb. cow producing 20 lbs. milk daily.

Feeding stuffs	Total dry matter	Digestible protein	Net energy value
	Lbs.	Lbs.	Therms
Corn forage, 12 lbs.	6.94	0.26	3.66
Clover hay, 6 lbs.	5.08	0.32	2.08
Corn meal, 5 lbs.	4.46	0.34	4.44
Wheat bran, 2 lbs.	1.76	0.20	0.96
First trial ration	18.24	1.12	11.14
Standard requirement		1.45	11.60
Excess or deficit		−0.33	−00.46

This trial ration shows a deficiency in both digestible protein and energy value. To improve it we deduct 1 lb. of corn meal and add 2 lbs. of gluten feed, which is the richest in digestible protein of the available feeds. We then have:

Second trial ration for an 850-lb. cow producing 20 lbs. milk daily.

Feeding stuffs	Total dry matter	Digestible protein	Energy value
	Lbs.	Lbs.	Therms
Corn forage, 12 lbs.	6.94	0.26	3.66
Clover hay, 6 lbs.	5.08	0.32	2.08
Corn meal, 4 lbs.	3.56	0.27	3.55
Wheat bran, 2 lbs.	1.76	0.20	0.96
Gluten feed, 2 lbs.	1.84	0.40	1.59
Second trial ration	19.18	1.45	11.84
Standard requirement		1.45	11.60
Excess or deficit		0.00	+0.24

This ration agrees closely with the standard. Thus, according to the Armsby standard, a satisfactory ration for a dairy cow weighing 850 lbs. and producing 20 lbs. of 4 per ct. milk daily may be composed of corn forage, 12 lbs.; clover hay, 6 lbs.; corn meal, 4 lbs.; wheat bran, 2 lbs.; and gluten feed, 2 lbs.

VII. The Scandinavian Feed Unit System.

A system of feed equivalents, based mainly on the extensive experiments with milch cows and swine by Fjord and his successors at the Copenhagen Station, has been adopted in Denmark and other Scandinavian countries, especially by the cow-testing associations, for measuring the relative production economy of cows. This system is extensively used with cows, occasionally with pigs, and rarely with other animals. It has great merit, especially in coöperative efforts to improve dairy cattle and their feeding—lines in which the Scandinavian farmers are leaders.

147. The feed unit.—The feed unit of the Danish associations is 1 lb. of standard grain feed, such as corn and barley, or their equivalents in feeding value. In Sweden it is one kilo (2.2 lbs.) of mixed concentrates or their equivalent. All feeding stuffs are reduced to this standard in calculating the feed consumption of the animal. The Danish valuation table is as follows:

Danish valuation table of feeding stuffs.

	Feed required to equal 1 unit	
	Average	Range
For dairy cows	Lbs.	Lbs.
Indian corn, wheat, barley, palmnut meal, dry matter in roots—*the standard of value*	1.0	
Cotton-seed meal, peanut meal	0.8	
Linseed meal, rape-seed meal, sunflower meal	0.9	
Oats, wheat bran	1.1	
Malt sprouts, molasses feed	1.2	
Dried beet pulp and molasses	1.3	1.2–1.5
Whole milk	2.5	
Hay	2.5	2.0–3.0
Wet brewers' grains, potatoes, straw, and chaff	5.0	4.0–6.0
Skim milk and buttermilk	6.0	
Silage, green clover, and mixed green grasses	8.0	6.0–10.0
Mangels, rutabagas, carrots, beet pulp silage, and soilage crops other than clover and mixed grasses	10.0	8.0–12.0
Beet leaves and tops	12.0	10.0–15.0
Turnips and fresh beet pulp	12.5	10.0–15.0
Beet leaves, fresh	15.0	12.0–18.0
For pigs		
Indian corn, barley, wheat, oil cakes	1.0	
Rye, wheat bran	1.4	
Boiled potatoes	4.0	
Skim milk	6.0	
Whey	12.0	
For horses		
One lb. of Indian corn equals 1 lb. of oats or 1 lb. of dry matter in roots.		

It is shown in the table that 1 lb. of Indian corn, wheat, barley, palmnut meal, or the dry matter of roots is taken as the unit standard. On this basis 0.8 lb. of cotton-seed meal or 1.1 lbs. of oats has the same feeding value as the unit standard, 1 lb. of corn. Of the roughages, 2.5 lbs. of good hay or 8 lbs. of silage, green clover, or mixed fresh grasses counts as 1 unit. The grass consumed by a cow at pasture during 1 day is valued at from 10 to 16 units according to its quality and the production of the cow.

148. The Scandinavian feeding standard.—In the table which follows, Hansson has formulated the unit feed requirements for cows yielding different amounts of milk, based especially on the findings of the cow-testing associations in Southern Sweden.[1]

Scandinavian feeding standard for dairy cows.

	Required per day	
	Digestible protein	Feed units
	Lbs.	
When yielding 0-13 lbs. milk daily	1.10	11.0
When yielding 22.0 lbs. milk daily	1.65	14.5
When yielding 33.0 lbs. milk daily	2.20	18.3
When yielding 44.0 lbs. milk daily	2.75	22.0

The table sets forth that a cow yielding not over 13 lbs. of milk daily requires 11 feed units, containing 1.1 lbs. of digestible protein, while one yielding 44 lbs. of milk daily requires 22 feed units, containing 2.75 lbs. of digestible protein. The standard assumes that for maintenance the cow requires about 1 feed unit for every 150 lbs. of body weight, and 1 unit additional for each 3 lbs. of milk produced. The ration should contain not less than 0.065 lb. of digestible protein per 100 lbs. of live weight, and 0.045 to 0.05 lb. of digestible protein additional for each lb. of milk produced.

149. An example.—The following illustrates the Scandinavian method of comparing feed consumption and milk production:

If during a month a cow has consumed 240 lbs. of hay, 1000 lbs. of silage, 60 lbs. each of barley and ground corn, and 90 lbs. of linseed oil meal, the calculation based on the valuation table would be as follows:

Feed consumed		Lbs. for 1 unit		Feed units
240 lbs. hay	÷	2.5	=	96
1000 lbs. silage	÷	8.0	=	125
120 lbs. corn and barley	÷	1.0	=	120
90 lbs. oil meal	÷	0.9	=	100
Total feed units			=	441

[1] K. Lantbr. Akad. Handl. 47, 1908, parts I, II, p. 60; Fühling's Landw. Ztg., 57, p. 435.

It is shown that the cow consumed 441 feed units during the month. If in that time she yielded 850 lbs. of milk, containing 30.6 lbs. of fat, each 100 feed units produced $\frac{850}{4.41}$ = 193 lbs. of milk, containing $\frac{30.6}{4.41}$ = 6.9 lbs. butter fat. If the fat brought 30 cents per lb., 100 feed units would return 6.9 x $0.30=$2.07.

150. The Swedish Test Associations.—In what follows is shown some of the work of the Swedish Test Associations for the year 1906-7. The first table shows the feed units consumed per cow annually in the association having the poorest and the best returns, and the average of 96 associations. The second table shows the production per cow and per 100 feed units consumed.

Average feed units consumed annually per cow as found by the Swedish Test Associations.

	Concentrates			Roughages		Total
	Oil cakes	Bran and grains	Roots, beet pulp	Hay and straw	Soilage and pasture	
Association	Units	Units	Units	Units	Units	Units
showing poorest returns	900	581	900	1142	1397	4920
showing best returns	1056	878	1410	1078	1311	5733
Average of 96 associations	856	708	1166	1256	1294	5280

Average production per cow and per 100 feed units.

	Production per cow			Production per 100 units		
	Milk	Butter fat	Butter	Milk	Butter	Value of product
Association	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
showing poorest returns	6261	200.0	218.0	280.1	10.0	2.51
showing best returns	8650	295.2	327.1	332.1	12.5	3.17
Average of 96 associations	7429	239.9	265.3	309.5	11.0	2.85

The first table shows that the association with the poorest record fed each cow, on the average, 4920 feed units during the year. The association with the highest record fed 5733 units per cow, while the average for 96 associations was 5280 feed units.

The second table shows that the average cow in the poorest association gave 6261 lbs. of milk, while in the best association she gave 8650 lbs. The herds in the poorest association yielded about

200 lbs. of butter fat per cow, and those in the best over 295 lbs. The well-fed herds returned 66 cents more for each 100 feed units consumed than did the poorly-fed herds—a difference of over 22 per ct. in favor of the heavier feeding.

The Scandinavian system of using feed units for studying and comparing individual cows, herds, and associations, and the co-operative efforts of these associations toward betterment, merit the highest praise. This system is simple, easily understood, and capable of the widest usefulness. It should be adopted in the United States.

Part II.

FEEDING STUFFS.

CHAPTER IX.

LEADING CEREALS AND THEIR BY-PRODUCTS.

I. Indian Corn and its By-products.

Indian corn can be successfully grown in every state of the Union, tho it flourishes best in that great middle region of our country lying between the Appalachian Mountain chain on the east and the Rocky Mountain Plateau on the west. In the South the tropical corn stems, four or five months from planting, carry great ears burdened with grain so high that a man can only touch them by reaching high above his head. At the other extreme, the Mandan Indian in the country of the Red River of the North developed a race of corn which reached only to the shoulders of the squaw, with tiny ears borne scarcely a foot from the ground on pigmy stalks. Like the other leading cereals which grow *en masse*, the corn plant must likewise grow with others of its kind, but it requires more space, air, and sunlight. Because it requires thoro tillage and makes most of its growth during late summer and early fall, Indian corn stands in a class by itself among the cereals. (**16**) This requirement of thoro tillage brings many advantages to the soil not forced upon us in growing the other cereals. The corn grain is pre-eminently a carbohydrate bearer. Taking carbon from the air and water from the soil, it locks these together potentially thru the energy of the sun that shines with tropical fervor wherever this plant flourishes, for corn must have an average minimum temperature of at least 70° F. Starch is the great carbohydrate of corn, there being nearly 75 lbs. in every 100 of grain. Add to this 5 lbs. of oil, and we can understand why Indian corn among the cereal grains may be likened to anthracite coal among the fuels.

Corn is the great energizing, heat-giving, fat-furnishing food for the animals of the farm. Supreme in these qualities it is hardly possible that it should further prove ideal for nourishing young, growing animals. It fails in some measure to furnish the nutrients in proper proportion for bone and muscle building, since it is not rich in crude protein and mineral matter. No other grain that the farmer grows yields, on a given space and with a given expenditure of labor, so much animal food, both in grain and forage, as does the Indian corn plant. On millions of farms successful animal husbandry rests upon this imperial grain and forage plant. (**411, 521, 621, 744, 842**)

A possible explanation of the great fondness of farm animals for corn lies in the considerable amount of oil it carries. Again, on mastication the kernels break into flinty, nutty particles which are more palatable, for example, than meal from the almost oil-free wheat grain, which on crushing and mingling with saliva turns to a sticky dough in the mouth.

151. Races of corn.—Three races of corn—dent, flint, and sweet—are of interest to the stockman. In dent corn the starch is partly hornlike and partly floury, rendering the kernel easy of mastication. In flint corn the starch is mostly hornlike and flinty, making the kernel more difficult for the animal to crush. Both chemical analysis and experience oppose the assertion, often heard, that yellow corn is more nutritious than white, or the opposite. In fact, the coloring matter of yellow corn is so minute in quantity as to be unweighable. While a certain strain or variety of one may be superior to any particular strain or variety of the other in a given locality, there is no uniform difference between white and yellow corn in productiveness or feeding properties. In sweet corn the starch is hornlike and tough. Before hardening, the milky kernels of sweet corn carry much glucose, which is changed to starch as they mature into the shrunken grain. The sweetness of the immature grains of sweet corn, due to the glucose they then carry, adds to the palatability but not necessarily to their nutritive value, since glucose and starch have the same feeding value. Sweet corn has somewhat more crude protein and fat and less carbohydrates than the other races.

152. Corn cobs.—Well-dried dent ear corn of good breeding carries about 56 lbs. of shelled corn to 14 lbs. of cob. The proportion of cob to grain varies greatly according to race, variety, and dryness, ranging from below 20 to about 40 per ct., flint varieties having a larger proportion of cob to grain than does dent corn. The cobs carry about 30 per ct. of fiber, which at best is of low feeding value, and much of their nitrogen-free extract is in the form of pentosans. (**3, 82**)

153. Shrinkage of ear corn.—While the amount of water in old corn varies but little from 12 per ct., the Iowa Station[1] found as high as 36 per ct. in freshly husked ear corn. Corn carrying 20 per ct. or more of water will not usually keep if stored in any considerable quantity. Studies were conducted by the Kansas Station[2] with 3 lots of ear corn fairly dry when cribbed, by the Illinois Station[3] with 2 cribs, each containing 20,000 lbs., and by the Iowa Station[4] with 4 varieties. The results are given in the table:

Shrinkage of cribbed dent corn.

Station	Shrinkage during Nov. and Dec.	Shrinkage from Nov. to March	Shrinkage from Nov. to April	Shrinkage in 1 year	Shrinkage in 2 years
	Per cent	Per cent	Per cent	Per cent	Per cent
Kansas	----------	3.26	6.80	8.62	----------
Illinois	2.60	6.00	17.80	19.40	20.60
Iowa	8.34	14.08	19.26	----------	----------

The amount of shrinkage with ear corn depends upon the water content and maturity when husked, and the rate of shrinkage upon the variety, the maturity of the grain, and the air humidity.[5] When the water content of ear corn falls to 12 per ct., shrinkage practically ceases. The shrinkage in weight of ear corn is largely in the cobs, which usually form about one-fourth of the weight of the ears at husking and one-fifth of their cured weight. Twisting the ears slightly will fairly indicate the moisture contained. Loose grained, "sappy" ears carry 20 per ct. or more of water, while solid ones usually contain not much over 12 per ct. Seventy lbs. of dry dent corn of good varieties will make one bushel or 56 lbs. of shelled corn, but in early fall the buyers frequently demand 75 or 80 lbs., according to the estimated water content. Corn is stored mostly on the husked ear at the North, but at the South the husks are left on the ears because of the weevil, a beetle that lives in the kernels unless they are protected. Shelled corn does not keep well in bulk, especially in summer, and so the corn is always held in ear form as long as possible.

154. Soft corn.—Corn frosted before the grains mature contains too much water for storage or shipment, and can be best utilized

[1] Bul. 77.
[2] Bul. 144.
[3] Bul. 113.
[4] Bul. 77.
[5] Iowa Expt. Sta., Bul. 77.

by immediate feeding. When soft corn containing 35 per ct. of water was fed to cattle at the Iowa Station,[1] it was found that a lb. of dry matter in such corn equaled a lb. of dry matter in hard corn, and that the cattle fed soft corn finished as well as those fed hard corn. (**524, 843**)

155. The corn kernel.—Hopkins of the Illinois Station[2] separated the water-free kernels of an ear of average dent corn into their several parts, and analyzed each part with the results given below:

Location of nutrients in the water-free corn kernel.

Name of part	Lbs. of each part in 100 lbs. corn	Lbs. of each nutrient in 100 lbs. dry corn			
		Crude protein	Carbo-hydrates	Oil	Ash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Hull and tip cap	7.39	0.36	6.88	0.08	0.07
Hornlike gluten	8.51	1.89	5.88	0.59	0.15
Hornlike starch	47.08	4.80	42.05	0.11	0.11
Floury starch	25.49	2.00	23.36	0.06	0.07
Germ	11.53	2.28	4.09	4.02	1.14
Whole kernel	100.00	11.33	82.26	4.86	1.54

It is shown that in 100 lbs. of water-free corn the hulls and tip caps together amounted to 7.39 lbs., the hornlike layer of gluten just under the skin 8.51 lbs., and the flinty, hornlike starch at the sides and base of the kernel 47.08 lbs., or nearly one-half of the total weight. In each 100 lbs. of kernels the soft, floury starch in the middle portion of the kernel formed 25.49 lbs. and the germ 11.53 lbs. The last 4 columns of the table show the number of pounds of each nutrient contained in each of the several parts of 100 lbs. of water-free corn. It is seen that the hull and tip cap are largely carbohydrates, while the germ is heavily charged with crude protein and oil.

It is shown that 100 lbs. of water-free corn contains over 11 lbs. of crude protein. It further contains over 82 lbs. of carbohydrates, of which about 80 lbs. is starch, and the remainder, something over 2 lbs., comprises the fiber of the hulls and of the cell walls inclosing the starch grains. Of oil there is nearly 5 lbs., and of mineral matter only about 1.5 lbs. Thus it is shown that the corn grain is fair in crude protein, rather low in ash, rich in oil, and extremely rich in starch. It is because of the abundance of these latter two

[1] Bul. 75. [2] Bul. 87.

constituents in this highly palatable grain that corn excels as a fattening food.

156. Corn meal.—In preparing corn for human food the grain is ground to a rather coarse meal, and the bran or hulls of the kernels removed by bolting. The product is known as corn meal. The terms "corn meal" and "corn chop" as used by stockmen denote the entire ground grain. Since we have learned that it is often best not to grind corn at all when fed to stock, (**331-3, 523, 821**) the question whether this grain should be reduced to a coarse or a fine meal has lost much of the interest once taken in it. On grinding corn the oil it carries soon becomes rancid and gives to the meal a stale taste. Hence this grain should never be ground far in advance of use.

157. Corn-and-cob meal.—When ear corn is ground the product is called corn-and-cob meal. Because of the rubber-like consistency of the cobs, much power is required to reduce ear corn to meal. If the cob particles in corn-and-cob meal are coarse, the animal will not usually eat them, but, when finely ground, corn-and-cob meal proves satisfactory with most farm animals. Much evidently depends on the nature of the roughage fed with the meal. The Paris Omnibus Company found corn-and-cob meal more acceptable than pure corn meal to its thousands of horses, (**411**) and stockmen generally report favorably on its use. It has been suggested that corn meal when fed alone lies too compactly in the stomach to be readily attacked by the digestive fluids, while corn-and-cob meal forms a loose mass more easy of digestion. Where there is an abundance of cheap roughage, it is best to omit the cobs in grinding unless there is ample power at low cost. (**845**)

158. Starch and glucose by-products.—The following by Lindsey of the Massachusetts (Hatch) Station[1] shows, in outline, how corn is treated in the production of starch, which is used for many purposes, such as the manufacture of glucose. etc.:

"The corn is first soaked in quite dilute, warm sulfurous acid water. It is then ground by being passed with water thru mills to carry off the substance in suspension. Degerminating machinery removes the germs at this point. The germs are dried and crushed between rolls, and the oil pressed out, leaving the residue in cakes. It is exported as corn meal cake or sold in this country as germ oil meal. After degermination the suspended mass is bolted thru sieves separating the hull, bran, and some light-weight

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[1] Bul. 78.

and broken germs from the starch and gluten. These materials pressed and dried were formerly sold as chop feed, but are now known as fancy corn bran. The starch and gluten are run into concentrating tanks and then passed very slowly thru long shallow troughs. The starch settles down like wet lime in these troughs, while the hard, flinty portion or gluten floats off into receivers, is concentrated, and finally pressed in heavy filter cloths, run thru steam dryers, and appears as gluten meal.''

Gluten meal is one of the richest of concentrates in crude protein and fat, while fair in carbohydrates and low in mineral matter. It is a heavy feed and but little used in its original form. (**635, 846**) Gluten feed, composed of gluten meal and corn bran ground together, is now the largest common by-product of glucose and starch factories. It is rich in crude protein, fair in fat, and rather low in carbohydrates and mineral matters. It is a most valuable concentrate, especially in the ration of the dairy cow. (**636**) The experiment stations report samples of gluten feed showing acidity and artificial coloring matter. (**344**) The feeder should insist upon this product being free from both, for, while they may not be positively harmful, they detract from the palatability and general wholesomeness of this otherwise most valuable and satisfactory feed. Germ oil meal contains somewhat less protein and carbohydrates than gluten feed, but carries much more fat and a fair amount of mineral matter. (**638, 871**)

159. Hominy feed.—In the manufacture of hominy and brewers' grits, the hulls, together with some of the starchy matter of the corn grain, are left over as by-products. These combined compose hominy feed, a palatable, valuable concentrate of excellent quality, being fair in crude protein and mineral matter, and rich in carbohydrates and fat. (**637, 847**)

160. Corn a carbonaceous food.—Corn as a grain has a high percentage of starch with a rather low crude protein and ash content. Rich in starch and oil, it is plainly the function of this grain, when fed to farm animals, to produce heat, energy, and fat. No other grain equals corn for fattening, but because it is not rich in crude protein and ash, it is not eminently suited for producing bone and muscle in young and growing animals. (**115**) These deficiencies of corn are easily supplied in other feeds, so that on most American farms it ranks first in usefulness among all the grains.

II. Wheat and its By-products in Milling.

Since it costs more to produce wheat than corn, and since our population is steadily increasing, it is reasonable to suppose that wheat will never be used in any considerable amount for feeding stock in this country, as it was at one time. But the feeder should know both its absolute and relative value, for the low grades of wheat would better be fed to stock than sold.

161. Wheat as a feed.—Compared with corn, wheat carries slightly more carbohydrates in the form of starch, more crude protein, and much less fat. It also has somewhat more phosphorus and potash, and is therefore superior to corn for building bone and muscle in young and growing animals—a statement corroborated by the experience of feeders. Fed alone to fattening animals wheat yields about 10 per ct. less returns than corn, but when mixed with corn, oats, or barley the combination is superior to any one of these feeds. Wheat-fed steers and pigs have less fat and more bright-colored lean meat than those fed corn. Because the kernels are small and hard, wheat should be ground for all farm animals except sheep. Wheat flour and meal fed alone are unsatisfactory because they form a pasty mass in the animal's mouth, a condition which can be remedied by adding some material such as bran or corn meal. (**414, 527, 623, 746, 848**)

Those who raise wheat should sell only the best grades, retaining for their animals all shrunken and damaged grain, which at best has but a low selling value. (**526**) If only slightly charred or injured by smoke in elevator fires, wheat has very considerable feeding value. Several stations have fed frozen wheat to pigs with returns about equal to those yielded by marketable grain. (**848**)

162. Flour manufacture.—The wheat kernel proper is covered with three strawlike coats or skins. Beneath these comes the fourth, called the "aleurone layer," which is rich in crude protein, and which in milling goes with the other coats to form bran. The germ, or embryo plant, in each wheat kernel is rich in oil, crude protein, and mineral matter. The remainder of the kernel consists of thin-walled cells packed with starch grains. Among the starch grains are protein particles called "gluten," which give to wheat-flour dough that tenacity so essential in bread making. In producing flour the miller aims to secure all the starch and gluten possible from the wheat grains, while avoiding the germ and bran. He leaves out the germs because they make a sticky dough, and also because they soon turn dark and rancid, giving to flour a specked appearance. Nor does he use the aleurone layer, because it gives a brownish tint to the flour. In modern milling, flour is produced by passing the thoroly cleaned wheat again and again thru hardened steel rollers, the flour particles being taken out each time by bolting, until only the by-products remain.

In the manufacture of flour, from 25 to 33 per ct. of the weight of the wheat grain remains as bran, middlings, etc. Since the consumption of wheat in this country is about 4.5 bushels, or 270 lbs., for each person, the by-products of this grain amount to nearly 70 lbs. for each person, not including that resulting from the wheat milled for export.

163. Feeding bread.—An English writer[1] reports a cab proprietor in London feeding bread to horses with economy and success, the only trouble being that many loaves were consumed by the workmen. He further states that he has seen the coachmen of Paris feeding brown bread to their horses, and that this food is given to horses in countries where hay is dear. He recommends that, to prevent stealing, straw be mixed with the dough before baking. When available, the stale bread of the bakeries is used for feeding animals.

164. Low-grade flour.—"Dark feeding flour," "red dog flour," etc., usually contain the wheat germs and are rich in crude protein, carbohydrates, and fat. Such flours have a high feeding value, especially for young pigs, calves, and milch cows. (**479, 849**) McConnell of England[2] reports having fed American low-grade flour for 6 months, and is "rather surprised at the beneficial results."

165. Bran.—Bran is comparatively rich in digestible crude protein and carries a considerable amount of digestible carbohydrates and fat. It is light and chaffy, having a large amount of woody fiber for a concentrate, and is rich in mineral matter except lime. Hart and Patten of the Geneva (New York) Station[3] have shown that ordinary wheat bran contains from 6 to 7 per ct. of phytin. an organic compound containing phosphorus, magnesia, and potash. In the past the laxative effect of bran, one of its beneficial properties, was ascribed to the mild irritation produced by the chaffy bran particles on the lining of the intestinal tract. These chemists have found, however, that the laxative effect of bran is due to the phytin it contains.

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[1] The Field, England, July 15, 1893.
[2] Agricultural Gazette, 1893, p. 351.
[3] Bul. 250.

Phosphorus, an essential component of the bones and of milk, is abundant in bran, while lime, likewise needed in still larger amount, is only sparingly present. Horses heavily fed on wheat bran or middlings sometimes suffer from a form of rickets called "bran disease,"[1] which seriously affects their bones. To supply the lime which bran lacks, farm animals may either be fed lime in inorganic form—wood ashes, ground limestone, burned lime, or ground rock phosphate (floats), (**89, 90**) or they may be supplied lime in organic form by feeding lime-laden plants, such as the legumes, which include alfalfa, clover, vetch, cowpea, etc.

Knowing the properties of bran, one is in position to advantageously use this most valuable feed. The best grades of bran are of light weight, with large, clean flakes and no foreign matter. As bran is too valuable to be used as the sole concentrate for farm animals, it should be mixed with other concentrates to lighten the ration or add bulk while improving its nutritive qualities. Supplied to horses once or twice a week in the form of a "mash" made with scalding water, bran proves a mild, beneficial laxative. When used continuously, the animal system becomes accustomed to it and the laxative property is less marked. Hard-worked horses have neither time nor energy to digest feeds of much bulk, and hence their allowance of bran should be somewhat limited. It may be supplied more freely to colts, growing horses, brood mares, and stallions. (**420**) Because of its crude protein and phosphorus, it serves its highest purpose in giving virility and in helping to build bone and muscle without tending to fatten. Being light in character, it is most useful for combining with corn and other heavy feeds for fattening cattle. Bran is a most excellent feed for the dairy cow, being slightly laxative, giving bulk to the ration, and providing the crude protein and phosphorus so vital to the formation of milk. (**632**) It is equally satisfactory for breeding sheep and lambs. Tho too strawlike for young pigs, (**852**) it is valuable in giving bulk and nutriment to the ration for breeding swine and stock hogs when they are not getting legume pasture or hay. (**906**) Rationally used, bran is of great value in putting the body of the female farm animal in the best condition to bear her young.

166. Wheat middlings and shorts.—To some extent "middlings" and "shorts" are interchangeable terms. Flour wheat middlings are of higher grade than standard middlings and often contain considerable low-grade flour. Standard wheat middlings comprise

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[1] Law's Vet. Medicine, III, p. 572.

the finer bran particles with considerable flour adhering. Shorts too often consist of ground-over bran and the sweepings and dirt of the mills, along with ground or unground weed seeds. Middlings are highly useful with swine of all ages. They should not be fed separately, but should always be mixed with corn meal, barley meal, ground oats, or bran, therewith forming most satisfactory feed combinations. (**850**) Mixed with the various ground grains, middlings and shorts are helpful with dairy cows, since they add crude protein and phosphorus to the ration. (**633**) Middlings and shorts alone should never be fed to horses, since they are too heavy and pasty in character and are liable to induce colic. Like bran, both middlings and shorts are low in lime, a deficiency which should always be supplied by the other feeds in the ration.

167. Screenings.—In cleaning and grading wheat at the elevators and mills, great quantities of screenings remain, consisting of broken and shrunken wheat kernels having a high feeding value, and also weed seeds, many of which have value, while others are of little worth, and a few actually poisonous. Screenings have their place and use, tho, on account of their variable character, little of definite nature can be said concerning them. (**752**) Along with molasses and the by-products of the distilleries, breweries, flouring mills, oatmeal factories, etc., they are now largely absorbed in the manufacture of proprietary feeding stuffs.

III. Oats and their By-products.

Next to corn, oats are the most extensively grown cereal in America. In the southern portion of our country a bushel of oats often weighs only 20 lbs., while on the Pacific coast it may weigh 50 lbs. Southern oats have a larger kernel than the Northern grain. They bear an inflated husk carrying an awn or beard, which causes the grains to lie loosely in the measure. At the North the kernel is encased in a compact hull, usually not awned. The hulls of oats constitute from 20 to 45 per ct. of their total weight, the average being about 30 per ct. ''Clipped oats'' have had the hulls clipped at the pointed end, thereby increasing the weight per bushel. A hulless variety of oats, but little grown in this country, serves well for poultry and swine, while the varieties with hulls are preferable for other stock. The oat grain is higher in crude protein than is corn, and in fat it exceeds wheat and nearly equals corn.

168. Oats for horses.—Oats are the safest of all feeds for the horse, for the hull gives to them such volume that the animal rarely suffers from gorging. In this regard they resemble bran and are in strong contrast with corn. Whole oats are best for mature horses with good teeth and ample time for eating and digesting their food, but for hard-worked horses and foals the grain should be crushed or ground. Grandeau[1] states that the Paris Cab Company have used crushed oats in feeding its thousands of hard-worked horses getting but a limited amount of hay, with a decided saving.

The mettle or spirited action so characteristic of the oat-fed horse is never quite attained thru the use of any other feed. It has long been held that there is a stimulating principle in the oat grain, and tho all claims of the discovery of this principle have melted away on careful examination,[2] there yet remains the feeling that there is a basis for the claim. (**409**)

169. Oats for other animals.—For dairy cows there is no better grain than oats, but their use is restricted by their high price. Danish dairymen sow oats together with barley, and feed the two grains in combination. (**626**) Oats fed to beef calves at the South Dakota Station[3] returned but 26 cents per bushel. At both the Montana[4] and South Dakota[5] Stations oats proved inferior to corn, barley, or wheat for fattening lambs, doubtless because this grain tends to growth rather than fattening. (**747**) Ground oats with the hulls sifted out provide a most nourishing and wholesome feed for young calves and pigs. (**855**) For breeding swine, whole oats in limited quantity are always in place.

170. By-products.—At the grain elevators and oatmeal factories the light-weight oat kernels are screened out from the better grade and go out as feed for stock. The value of such grain depends on the proportion of kernel to hull. Light-weight oats of low feeding value are often mixed with corn and the ground product sold as ground corn and oats. Vast quantities of hulls are turned out by the oatmeal factories, and so completely are the kernels separated from the hulls that the chafflike material which remains has but a low feeding value. Oat hulls contain about 30 per ct. fiber, as Table I of the Appendix shows, and their feeding value can be but little, if any, above that of oat straw. If fragments of the kernels adhere, their value is of course thereby improved. Oat hulls are

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[1] Expt. Sta. Rec., XVII, p. 898.

[2] Agriculture in Some of its Relations with Chemistry, Vol. 2; Landw. Vers. Sta., 36, p. 299; Rpt. Me. Expt. Sta., 1891, p. 58, corr.; Centbl. Chem., 1884, p. 20.

[3] Bul. 97. [4] Bul. 47. [5] Bul. 86.

freely used as an adulterant of feeding stuffs, especially with ground corn, the combination then selling as ground corn and oats. In manufacturing oatmeal, after the kernels are hulled they are freed from the minute hairs which adhere to one end of the kernel. Small as these hairs are, they form with fragments of the kernels a product of great volume, known as oat dust, which has a feeding value between that of the hulls and oat middlings. Oat feed, oat shorts, and oat middlings are products ranging from low to high in feeding value.

IV. Barley and its By-products in Brewing.

Barley is the most widely cultivated of the cereals, growing as far north as 65° north latitude in Alaska and flourishing beside orange groves in California. Once the chief bread plant of many ancient nations, it is now used almost wholly for brewing, pearling, and stock feeding. Richardson[1] found that Dakota barley contained the highest per cent of crude protein, and Oregon barley the lowest. The closely adhering hull of the barley grain constitutes about 15 per ct. of its total weight. Besides the common barley there are varieties of barley without beards and still others without hulls. This grain has less digestible crude protein than oats, and considerably more than corn. The carbohydrates exceed those of oats and fall below those in corn, and the oil content is lower than in either of these grains.

171. Barley as a feed.—On the Pacific slope, where corn or oats do not flourish in equal degree, barley is extensively used as a feed for animals. The horses of California are quite generally fed on rolled barley, with wheat, oat, or barley hay for roughage. (**413**) Barley is the common feed for dairy cows in northern Europe. The Danes sow barley and oats together in the proportion of 1 part of barley to 2 of oats, the ground mixed grain from this crop being regarded as the best available feed for dairy cows and other stock. (**624**) At the Virginia Station[2] calves made excellent gains on barley and skim milk, but corn proved cheaper. At the Washington Station[3] steers made cheaper gains on wheat than on barley, and still cheaper on the two grains mixed. (**527-8**) In Great Britain and northern Europe barley takes the place of corn for pork production, leading all grains in producing pork of fine quality, both

[1] U. S. Dept. Agr., Div. of Chem., Bul. 9. [2] Bul. 172. [3] Bul. 79.

as to hardness and flavor. (**926**) The Iowa[1] and Nebraska[2] Stations used barley economically to supplement corn for hogs. (**854**)

Rain, fog, and dew at harvest time injure barley for brewing purposes without necessarily lowering its feeding value. Because barley meal, when finely ground, forms a pasty mass in the mouth of the animal, barley should be reduced by rolling, as is the common practice on the Pacific coast, rather than by grinding. (**768**)

172. Malt.—In making malt the barley grains are first steeped in warm water until they are soft. The grain is then held at a warm temperature until it begins to sprout, in which process a ferment or enzyme called "diastase" converts the starch into a form of sugar called "maltose." As soon as this change has occurred the sprouting grains are quickly dried. The tiny, dry, shriveled sprouts separated from the grains are called "malt sprouts," and the dried grains with their content of malt sugar form malt. In the manufacture of beer the brewer extracts the soluble malt sugar and some nitrogenous matter from the malt. The freshly extracted malt grains constitute wet brewers' grains, which on drying in a vacuum are called dried brewers' grains.

173. Malt for stock.—Lawes and Gilbert of the Rothamsted Station,[3] after experimenting with malt, conclude: "A given weight of barley is more productive both of the milk of cows and of the increase in live weight of fattening animals than the amount of malt and malt sprouts that would be produced from it. . . . Irrespective of economy, malt is undoubtedly a very good food for stock; and common experience seems to show that a certain amount of it is beneficial . . . to young or weakly animals, or in making up for exhibition or sale; that is, when the object is to produce a particular result, irrespective of economy." (**768**)

174. Wet brewers' grains.—Owing to their volume, their watery nature, and their perishable character, wet brewers' grains are usually fed near the brewery. In the hands of ignorant or greedy persons, cows have often been crowded into dark, illy-ventilated sheds and fed almost exclusively upon wet brewers' grains. Sometimes the grains have partially rotted before being fed, and the drippings getting under feed boxes and floors have on fermenting produced sickening odors. Under such circumstances it is not surprising that boards of health have been led to prohibit the sale of milk from such dairies. There is nothing, however, in fresh brewers' grains which is necessarily deleterious to milk. Sup-

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[1] Bul. 91. [2] Bul. 99. [3] Rothamsted Memoirs, Vol. IV.

plied in reasonable quantity, and fed while fresh in clean, water-tight boxes and along with nutritious hay and other roughage, there is no better food for dairy cows than wet brewers' grains. So great is the temptation to abuse, however, that wet grains should never be fed to dairy cows unless under the strict supervision of competent officials. If this cannot be done, their use should be prohibited.

175. Dried brewers' grains.—By removing practically all of the moisture from wet grains by means of the vacuum process, a concentrated product known as "dried brewers' grains" is obtained, which is no more perishable than wheat bran. Dried brewers' grains are rich in both crude protein and fat, with considerable fiber due to the barley hulls. They are low in carbohydrates, which in these grains are largely pentosans.[1] (**3, 82**) Dried brewers' grains are an excellent concentrate for dairy cows, ranking with bran and oil meal in palatability and general good effects. (**648**) The Massachusetts (Hatch) Station[2] found them cheaper than oats for horses and as satisfactory, especially for those at hard work and needing extra crude protein. From one-third to one-half of the concentrates in the ration for horses may consist of dried brewers' grains, and the remainder of either corn or oats. (**421**) Being high in fiber, dried brewers' grains are not satisfactory for pigs.

176. Malt sprouts.—The tiny, shriveled barley sprouts which have been separated from the dried malt grains are rather low in carbohydrates and fat, but carry about 20 per ct. of digestible crude protein, one-half or more of which is amids. (**5, 78**) Tho rich in crude protein they are not relished by stock, and should be given in limited quantity in combination with other concentrates. The Massachusetts (Hatch) Station[3] found that cows would not eat over 2 or 3 lbs. of malt sprouts daily. (**649**) They absorb much water and should be soaked several hours before feeding.

V. Rye and its By-products.

Rye, the principal cereal of the northern European countries, is not extensively grown in America. Tho it repays good treatment, this "grain of poverty" thrives in cool regions on land that would not give profitable returns with the other cereals. Since it furnishes about one-third of the people of Europe with bread,

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[1] Mass. (Hatch) Expt. Sta., Bul. 94. [2] Loc. cit. [3] Loc. cit.

we may conclude that rye must have nutritive value with domestic animals. Farm animals show no particular fondness for rye in any form, tho they take it willingly when mingled with other feeding stuffs, as it always should be. It has been charged that since ergot, a fungus having medicinal properties, grows on rye heads, this grain may prove dangerous to farm animals and even cause abortion—a charge that seems unwarranted in view of the extensive use of rye for human food.

177. Rye and its by-products.—In Germany[1] work horses are fed from 2 to 4 lbs. of rye daily with oats or other concentrates. (**415**) According to Böggild,[2] rye imparts a characteristic flavor to milk and may cause bitter butter. The Scandinavian Preserving Company of Copenhagen, which preserves butter in sealed cans for shipment to distant countries, prohibits the feeding of rye on the farms of its patrons. The limited use of rye with dairy cows should usually prove satisfactory. (**625**) Fjord's experiments with pigs show that rye has a feeding value about equal to barley, and that the quality of pork from rye-fed pigs is satisfactory. A combination of barley and rye was found superior to rye shorts alone. The pork from rye shorts was inferior, showing more shrinkage and being softer than that from mixed rye and barley. In one trial rye shorts caused sickness among the pigs. (**853**)

VI. Emmer.

178. Emmer as a feed.—Emmer, *Triticum sat.*, var. *dicoccum,* often improperly called "speltz," was introduced into America from Germany and Russia. It is a member of the wheat family, altho in appearance the grain resembles barley. Being drought resisting, emmer is especially valuable in the semi-arid regions of America, where it is now extensively and profitably grown. The adherent hulls of emmer represent about 21 per ct. and the kernels 79 per ct. of the grain, which weighs about 40 lbs. to the bushel. At the Kansas Station[3] emmer gave a heavier yield of grain than either oats or barley, and at the Western Nebraska Substation[4] it yielded 23 bushels per acre. In general the returns are from 20 to 40 bushels per acre. The South Dakota Station[5] found emmer

[1] Pott, Futterm., p. 395.
[2] Mälkeribruget i Denmark, 1st ed., p. 70.
[3] Bul. 123.
[4] Bul. 95.
[5] Bul. 100.

less valuable than barley for fattening sheep or for dairy cows. (**627**) A mixture of emmer and barley put larger gains on fattening lambs than emmer alone. (**749**) Thru emmer, kafir, milo, and certain millets, all relatively new plants with us, the possibilities of the great plains region of America for the maintenance of farm animals and the production of meat have been enormously increased. (**529, 530, 857**)

CHAPTER X.

MINOR CEREALS, OIL-BEARING AND LEGUMINOUS SEEDS, AND THEIR BY-PRODUCTS.

I. Rice and its By-products.

The production of rice is steadily increasing in Louisiana and Texas, where it already forms a most important industry. While, like wheat, this cereal is grown strictly for human food, nevertheless the waste and the by-products which remain in preparing it for the use of man have value and should be conserved for nourishing farm animals. Rice is the richest of all cereals in carbohydrates, while relatively low in crude protein and fat.

179. Rice and by-products.—According to Fraps of the Texas Station,[1] a sack of rice, weighing 162 lbs., yields the following products:

Clean rice	100.0 pounds
Rice polish	6.3 pounds
Rice bran	20.2 pounds
Rice hulls	32.1 pounds
Loss	3.4 pounds
Total	162.0 pounds

The Texas Station[2] found that after being ground damaged rice had about one-half the value of cotton-seed meal as a feed for fattening steers. Red rice, a pest in rice fields, equals the cultivated grain in feeding value. When true to name, rice meal is the most nutritious of rice feeds, containing a fair amount of crude protein and a large amount of fat. Rice polish is composed of the floury particles which result from polishing the kernels to produce a pearly luster. It has a feeding value equal to corn, but its use in the arts removes it largely from the list of farm feeding stuffs.

Dodson of the Louisiana Station[3] values ground whole rice at 7 and hulled rice at 16 per ct. more than corn. No ill effects have been known to follow feeding ground rough rice. Many farmers feed sheep rice. For a 1000-lb. horse a ration might be made from 8 lbs. of rice, 2 lbs. of cotton-seed meal, 10 lbs. of black strap molas-

[1] Bul. 73. [2] Bul. 86. [3] Louisiana Planter, 44, 6, p. 92.

ses, with pea-vine hay for roughage. He believes that rice is worth $2 per barrel for cattle fattening.

Rice bran is composed of the outside layer of the kernel proper, together with some of the germs, often adulterated with the hulls. Rice by-products, especially meal and bran, are frequently distasteful to animals, because the oil they contain soon becomes rancid. The Louisiana Station[1] employed rice bran successfully for one-half the concentrates in a ration for horses and mules. The North Carolina Station[2] found that, properly balanced with protein feeds, rice bran when not rancid was a valuable feed for cows. (**533, 863**)

The hulls of rice grains are tasteless, tough, and woody. They are also heavily charged with silica or sand, and have sharp, roughened flinty edges and needlelike points which do not soften in the digestive tract and so are irritating and dangerous to the walls of the stomach and intestines. The Louisiana Station[3] reports cases of vomiting and death with cattle fed rice hulls. Rice hulls should never be fed to farm animals, yet they have been extensively employed by unscrupulous dealers for adulterating commercial feeding stuffs. Such use should be prohibited by law, since rice hulls in any form are worse than worthless. (**863**)

II. Buckwheat and its By-products.

Tho rarely used for feeding stock, buckwheat has a fair value for such purpose, its nutrients running somewhat lower than those in the leading cereals. (**856**)

180. Buckwheat by-products.—The black, woody hulls of the buckwheat grain, *Fagopyrum esculentum*, have little feeding value and should be used to give bulk or volume to the ration only when it cannot be otherwise secured. On the other hand, that part of the kernel immediately under the hull, which on grinding and bolting forms middlings, is rich in crude protein and fat, with a correspondingly high feeding value. The miller, desiring to dispose of as much of the hulls as possible, mixes them with the middlings to form buckwheat bran. The intelligent purchaser will avoid the worthless hulls so far as he can, choosing instead the rich floury middlings. Buckwheat by-products are nearly always used for feedings cows, rightly having the reputation of producing a large flow of milk. The charge that buckwheat by-products make

[1] Bul. 77. [2] Bul. 169. [3] Bul. 77.

a white, tallowy butter and pork of low quality fails if they are not given in excess. Hayward and Weld of the Pennsylvania Station[1] conclude from feeding trials that for milk and butter production buckwheat middlings are equal to dried brewers' grains. (**634**) Buckwheat by-products may be successfully fed in limited amounts to other farm animals. When stored in bulk, buckwheat by-products are liable to heat unless first mixed with some other light feed like wheat bran.

III. Sorghums and Millets.

Numberless millions of human beings in India, China, and Africa rely on the sorghums and millets as their bread grain. Church[2] tells us that in India alone over 33,000,000 acres of land are annually devoted to growing the millets, including the sorghums, kafirs, milos, etc.—a greater area, he reports, than is devoted to wheat, rice, and Indian corn combined.

The sorghums, *Andropogon sorghum* or *Sorghum vulgare,* vars., may be divided into two classes—the saccharine sorghums, having stems filled with sweet juices, and kafir, milo, durra, and broom corn, whose pithy stems have little or no sweet juice. The Indian corn plant never gives satisfactory returns if once its growth has been checked. The sorghums, however, may cease growing and their leaves may shrivel during periods of excessive heat and drought. Yet when these conditions pass and the soil becomes moist again, they quickly resume growth. This quality gives to this group of grain-bearing plants great worth and vast importance in the southwestern semi-arid plains region of the United States, up to an elevation of 4,000 feet above sea level.

181. Sweet sorghums.—The sweet sorghums, which are used for forage production rather than for grain, can be grown almost anywhere in the United States. At the Wisconsin Station[3] the author secured amber cane seed at the rate of 32 bushels of 53 lbs. each per acre. Cook of the New Jersey Station[4] found amber cane seed about 10 per ct. less valuable than Indian corn for dairy cows. (**629**) Because of the value of the forage, both green and dry, and also of the seed, the sweet sorghums should be grown at the North to a far greater extent than at present. (**861**)

182. Broom corn.—In harvesting broom corn the heads are cut before the seed has fully matured, and the seed is removed from the

[1] Bul. 41.
[2] Food Grains in India, 1901.
[3] Rpt. on Amber Cane, 1881.
[4] Rpt. 1885.

brush before it is fully dry. This seed has considerable feeding value and may be saved by drying or ensiling. A test by Miles[1] shows that broom-corn seed can be satisfactorily ensiled in an earth-covered heap.

183. Kafir.—In Oklahoma, Kansas, and the semi-arid regions of the southwestern United States, kafir, introduced from eastern Africa, has proved of great importance both as a grain and a forage plant. The following table shows the yield of kafir and Indian corn at the Kansas and Oklahoma Stations:[2]

Relative yield of kafir and Indian corn.

	Red kafir		Indian corn	
	Grain per acre	Fodder per acre	Grain per acre	Fodder per acre
	Bushels	Tons	Bushels	Tons
Kansas Station, av. for 7 years	55.0*	4.7	39.1	2.4
Oklahoma Station, av. for 4 years	30.1	2.2	11.1	0.9

*Average for 6 years.

This table shows that red kafir gave materially better returns in both grain and forage than did Indian corn. Kafir grain weighs from 50 to 56 lbs. per bushel. The seed coat of the red kafir has an astringent principle which makes it less palatable than white kafir. Tho kafir ranks below Indian corn in palatability and feeding value, it is nevertheless a most valuable and important crop in the districts where it flourishes. Work horses may be fed either kafir heads or the threshed grain, (**416**) and idle horses, colts, young stock, and dairy cows thrive on kafir forage carrying the heads. Kafir should always be ground or soaked before feeding. Kafir meal is suitable for calves when supplementing skim milk. (**480**) Kafir grains moistened with water to stifle the dust may be fed whole to mature swine. (**858**) This grain is somewhat astringent in nature, and so is suited for feeding with alfalfa, clover, and other somewhat laxative feeds. (**531, 628**)

184. Milo.—The most successful of the durra sorghums is milo, now a staple crop over large portions of Texas, New Mexico, Colorado, and Oklahoma, at elevations ranging from 1500 to 4000 feet above sea level. Tests at Amarillo, Texas,[3] show a 5-year average of 40 bushels of milo per acre, weighing 60 lbs. per bushel. According to Ball,[4] milo is equal to or somewhat better than the kafirs as

[1] Country Gentleman, March 23, 1876.
[2] Cyc. Amer. Agr., Vol. II, p. 385.
[3] U. S. Dept. Agr., Farmers' Bul. 322.
[4] Loc. cit.

a feeding grain, and, unlike the kafirs, it has a beneficial laxative effect on the bowels. White and brown durra are grown in California under the name of Egyptian corn. The ripened seed of durra shatters easily, and the forage is less valuable than that of kafir. (**532, 859**)

185. Millet.—At the Massachusetts (Hatch) Station[1] Brooks produced millet at the rate of 74 bushels per acre, weighing 47 lbs. per bushel, but concluded that this grain cannot successfully compete with Indian corn in that state. Wilson and Skinner of the South Dakota Station[2] produced 30 bushels of hog or Black Veronesh millet, *Panicum miliaceum,* per acre. The ground grain proved satisfactory for fattening swine, tho for a given gain one-fifth more millet was required than wheat or barley. The carcasses of the millet-fed pigs were clothed with a pure white fat of superior quality. At the same Station[3] in the production of baby beef somewhat more millet than corn was required for a given gain. The millets are valuable and are growing in importance for grain production in the plains region of the United States, northward of the areas best suited to kafir and durra. (**433, 530, 751, 860**)

IV. Oil-bearing Seeds and their By-products.

186. Cotton seed.—The annual crop of the United States now amounts to over 12,000,000 bales of 500 lbs. each with not less than 6,000,000 tons of cotton seed as a by-product, since for each pound of fiber, or lint, there are 2 lbs. of seed. Previous to 1860 the seed of the cotton plant was largely wasted by the planters, who often allowed it to rot near the gin house, ignorant or careless of its worth, while meat and other animal products which might have been produced from it were purchased at high cost from northern farmers. The utilization of the cotton seed and its products as food for man and beast furnishes a striking example of what science is accomplishing for agriculture.

According to Burkett and Poe,[4] 1 ton of cotton seed yields approximately:

Linters, or short fiber	27 pounds
Hulls	841 pounds
Cake, or meal	732 pounds
Crude oil	280 pounds
Loss, etc.	120 pounds
Total	2000 pounds

[1] Bul. 18. [2] Bul. 83. [3] Bul. 97. [4] Cotton, its Cultivation, etc.

187. Cotton-seed cake and meal.—At the oil mills the dry, leathery hulls of the cotton seed, which are covered with short lint, are cut by machinery, and the oily kernels set free. These kernels are crushed, heated, placed between cloths, and subjected to hydraulic pressure in order to remove the oil. The residue is a hard, yellowish, boardlike cake about 1 inch thick, 1 ft. wide, and 2 ft. long. In this form it is shipped abroad as cotton-seed cake. For home trade the cake is reduced to meal by grinding, the product being called cotton-seed meal. Cotton seed is high in crude protein and fat, and cotton-seed meal is one of the richest in these nutrients of all feeds. The decorticated cotton-seed cake of the European markets is similar in composition to American cotton-seed meal. The undecorticated cake contains more hulls, and has a proportionally lower feeding value.

Cold-pressed cotton-seed cake is produced by subjecting the entire uncrushed, unheated seed to great pressure. In the residual cake there is a larger proportion of hull to meal than in normal cake, with correspondingly lower feeding value. In a trial with dairy cows Lee and Woodward of the Louisiana Station[1] found cold-pressed cotton-seed cake less valuable for milk and butter production than an equal weight of a mixture of two parts of meal and one of hulls. They conclude that the chemical composition of cold-pressed cotton-seed cake is a reliable indication of its feeding value. With cotton-seed meal at $30 per ton and hulls at $5 they estimate that cold-pressed cotton-seed cake is worth $21.65 per ton.

188. Feeding cotton seed.—Some cotton seed is still used in the South for feeding steers and dairy cows, tho most of it is now used for oil production. Trials at the Texas Station[2] showed that seed at $12 per ton was cheaper for fattening steers than meal at $20. Marshal and Burns of the same Station[3] secured larger daily and total gains with cotton seed than with cotton-seed meal. (**535**) Connell and Carson, likewise of the same Station,[4] found that boiled or roasted seed produced larger tho more expensive gains than raw seed, and was more palatable and less laxative.

189. Cotton-seed meal for horses.—Gebek[5] reports that draft horses do well on a ration containing 2 lbs. of cotton-seed meal. Judge Henry C. Hammond, Augusta, Georgia,[6] reports that for years he has fed about 1 lb. of cotton-seed meal daily to colts, brood

[1] Bul. 110. [2] Bul. 97. [3] Loc. cit. [4] Bul. 27. [5] Landw. Vers. Sta., 42, p. 294.
[6] Cotton-seed Meal as a Horse and Mule Feed; also, private correspondence.

mares, and driving and work horses. There has been no sickness among the horses, and their style, action, and health are all that can be desired. He attributes his unvarying success to the fact that the meal is never fed alone, but is always carefully mixed with some light concentrate. (**423**)

190. Cotton-seed meal for dairy cows.—Hills of the Vermont Station[1] found in a 6-months feeding trial with 20 cows that "cotton-seed meal seemed to possess a small tho measurable advantage over linseed meal as a milk and butter making by-product." Michels and Burgess of the South Carolina Station[2] write: "Cotton-seed meal and corn silage form by far the cheapest dairy feeds available to our dairymen. The cost of a ration is only slightly more than half as much as that of the common dairy ration now fed in this state." Moore of the Mississippi Station[3] found that for cows 1 lb. of cotton-seed meal was equal to 1.7 lbs. of cotton seed or 2 lbs. of corn-and-cob meal. (**641**)

The milk of cows heavily fed on cotton seed or cotton-seed meal yields a hard, tallowy butter, light in color and poor in flavor. If not over 3 lbs. of cotton seed or cotton-seed meal is fed, along with a generous allowance of other concentrates and of roughage, or if the cow is on good pasture, the quality of the butter is but little affected. The use of cotton-seed meal may prove helpful with cows whose milk produces a soft butter. (**619**)

191. Steer fattening.—Vast numbers of steers are fattened on cotton-seed meal at the cotton-oil mills of the South. At these establishments, starting with 3 or 4 lbs. of cotton-seed meal daily, the allowance is gradually increased to 6, 8, or even 10 lbs. per head along with all the hulls the steers will eat, which amount is about 4 lbs. for each lb. of meal. The feeding period lasts 90 to 120 days. Lloyd of the Mississippi Station[4] found that with fattening steers 1 lb. of cotton-seed meal proved equal to 1.6 lbs. of cotton seed or 1.9 lbs. of corn, while 1 lb. of cotton seed equaled 1.2 lbs. of corn. Soule and Fain of the Tennessee Station,[5] as the result of several steer-feeding trials, conclude that "A ration of silage, cotton-seed meal, and corn meal is probably better adapted for use on the average southern farm than any other."

McLean of the Mississippi Station[6] states that 2-year-old steers should not be fed over 7.5 lbs. and yearlings not over 6 lbs. of cotton-seed meal daily.

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[1] Rpt. 1908.
[2] Bul. 131.
[3] Bul. 60.
[4] Loc. cit.
[5] Vol. 15, 3.
[6] Bul. 121.

Swift & Company of Chicago informed the author that, while cotton-seed meal makes good beef, a still better quality is produced where the meal is fed with other concentrates. (**535-7, 556, 566**)

192. Effects of cotton seed on fat.—At the Texas Station[1] Harrington and Adriance found the kidney, caul, and body fats of steers fed raw, roasted, or boiled cotton seed had a higher melting point by 4.1°, 3.2°, and 8.7° C. respectively than the corresponding fats of corn-fed steers. The influence of cotton-seed feeding on butter and mutton suet was somewhat more marked than that produced on beef tallow.

193. Cotton-seed hulls.—Cotton-seed hulls, containing somewhat less digestible nutrients than oat straw, are extensively employed at the South as roughage for cattle feeding. Where broken kernels of seed adhere to the hulls their feeding value is considerably increased. Conner of the South Carolina Station[2] found that cotton-seed hulls have a little over one-half the feeding value of corn stover. Lloyd of the Mississippi Station[3] found that 1 lb. of hulls was equal to 1.6 lbs. of corn silage in steer feeding. Craig and Marshall of the Texas Station[4] showed cotton-seed hulls superior to sorghum or cow-pea hay with steers getting cotton-seed meal for concentrates. (**556, 566**) With corn or other concentrates rich in carbohydrates, instead of with cotton-seed meal, their value would have been lower. Michels of the North Carolina Station[5] found that dairy cows exhibited a strong dislike for cotton-seed hulls. (**671**)

194. The poison of cotton seed.—Practical experience and trials at the experiment stations unite in showing that cotton-seed meal is not a safe feed in all cases. After a period of about 100 days steers which have been closely confined and heavily fed on the meal often show a staggering gait, some of them becoming blind, death frequently ending their distress. The Iowa Station[6] reports the death of 3 steers, and others becoming blind, in a feeding trial in which a heavy allowance of corn-and-cob meal was fed with 2.5 lbs. of cotton-seed meal. Hunt of the Pennsylvania Station[7] reports the death of 2 calves out of 3 from feeding a ration of 1 lb. of cotton-seed meal with 16 lbs. of skim milk. Emery of the North Carolina Station[8] reports the death of 2 calves following the use of 0.25 to 0.5 lb. of cotton-seed meal daily with skim milk. Gips[9] reports the death of 3 out of 8 cattle from eating moldy cotton-seed cake.

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[1] Bul. 29. [3] Rpt. 1905. [5] Bul. 199. [7] Bul. 17.
[2] Bul. 66. [4] Bul. 76. [6] Bul. 66. [8] Bul. 109.
[9] Arch. Wis.. u. Prakt. Thierheilk, 14, 1886, p. 74.

Cotton-seed meal is particularly fatal to swine. Pigs getting as much as one-third of their concentrates in the form of cotton-seed meal thrive at first, but after 5 or 6 weeks, or sometimes earlier, they quite frequently show derangement and may die. Restricting the allowance of meal, keeping the animals on pasture, supplying succulent feeds, or souring the feed may help, but no uniformly successful method of feeding cotton-seed meal to swine has yet been found.

Numerous efforts have been made during the past 20 years to determine the cause of the poisonous action of cotton-seed meal. The harmful effects have been variously ascribed to the lint, the oil, the high protein content, to a toxal albumin or toxic alkaloid, to cholin and betain, to resin present in the meal, and to decomposition products. Recent investigations by Mohler and Crawford of the Bureau of Animal Industry, United States Department of Agriculture,[1] appear to prove conclusively that the chief poisonous principle in certain cotton-seed meals is a salt of pyrophosphoric acid. It was found that, while the seed from Upland cotton proved quite generally poisonous to animals, that from certain Sea Island cotton contained so small a quantity of the poisonous principle as to be practically harmless. The poisonous effect of Sea Island seed, however, was greatly increased by heating, indicating that if in the treatment of the seed at the oil mills the temperature rises high the poisonous principle is developed. Aside from avoiding too high heating of the crushed kernels in the manufacture of oil, no remedy for the poison has yet been suggested. Now that science has located the source of the trouble, it is reasonable to hope that a favorable solution of this most important matter will soon be reached.

195. Rational use of cotton seed and by-products.—Cotton seed and cotton-seed meal are among the richest and heaviest of feeds. When fed in limited quantity with a proper complement of other feeding stuffs, exceedingly satisfactory results can be secured with dairy cows and fattening cattle. Wet, moldy cotton seed, or that which has heated, should never be fed. Good cotton-seed meal has a bright yellow color and a pleasant taste. Meal of a dull color from exposure to the air, and that from musty or fermented seed, should not be used. Cotton-seed meal is not so well suited to the animal economy as linseed meal, yet it is so highly nutritious and so generally useful with cattle that it is of vast importance to the

[1] Expt. Sta. Rec., 22, 1910, pp. 501–505; Jour. Pharmacol. and Expt. Ther., 1, 1910, No. 5, pp. 519–548.

stock interests of this country, especially of the South. To the discredit of our live-stock interests, one billion pounds of cotton-seed cake are annually exported to other countries. (**574**)

196. Flax seed.—In 1909 about 25,767,000 bushels, each of 56 lbs., of seed from the flax plant, *Linum usitatissimum,* were produced in the United States.[1] The reserve building material is stored in the flax seed largely as oil and pentosans, instead of as starch, which most seeds carry, no starch grains being found in well-matured flax seeds. On account of the high commercial value of the oil it contains, flax seed is rarely used for feeding stock other than calves. (**574**)

The oil of the flax seed is either extracted by the old process, thru pressure, as in the production of cotton-seed oil, or it is dissolved out of the crushed seed with naphtha, the residue in either case being called linseed oil meal. In the United States nearly all the linseed oil meal is made by the old process.

According to Woll[2] in the manufacture of new-process oil meal the crushed and heated seed is placed in large cylinders or percolators, and naphtha poured over the mass. On draining out at the bottom the naphtha carries with it the dissolved oil. After repeated extractions steam is let into the percolator, and the naphtha remaining is completely driven off as vapor, leaving no odor of naphtha on the residue, which is known as "new-process" linseed oil meal.

197. The swelling test.—Woll[3] gives the following method of ascertaining whether oil meal is new- or old-process: "Pulverize a small quantity of the meal and put a level tablespoonful of it into a tumbler; then add 10 tablespoonfuls of boiling hot water to the meal, stir thoroly, and leave to settle. If the meal is new-process meal, it will settle in the course of an hour and will leave half of the water clear on top." Old-process meal will remain jelly-like.

198. Old- and new-process oil meal.—By artificial digestion trials with old- and new-process oil meal Woll[4] found that 94 per ct. of the crude protein in the old-process and 84 per ct. of that in the new-process oil meal was digestible. The lower digestibility of the new-process meal is doubtless due to the use of steam for driving off the naphtha, since cooking lowers the digestibility of many crude protein-rich foods. Despite its somewhat lower factor of digestibility, new-process oil meal contains rather more digestible crude pro-

[1] U. S. Dept. Agr. Yearbook, 1909.
[2] Rpt. Wis. Expt. Sta., 1895.
[3] Loc. cit.
[4] Loc. cit.

tein than old-process oil meal because the oil is more completely extracted.

199. Value of oil in linseed oil cake.—To determine the value of oil in linseed oil cake, Cooke[1] of England conducted a test with 2 lots of 30 sheep each. To the first was given cake containing from 6 to 7 per ct. oil, and to the second lot cake containing from 15 to 16 per ct. oil. The roughage was the same for both lots. During the 16 weeks of the trial the sheep fed on the cake rich in oil gained nearly 5 lbs. more per head and also brought a higher price than those fed cake low in oil. The conclusion was, "Weight for weight, linseed oil to the extent of 16 per ct. in a cake has a much higher feeding value than the other constituents which in the absence of oil replace it."

200. Linseed oil meal as a feed.—There is no more healthful feed for limited use with all farm animals than linseed oil cake or oil meal, with its rich store of crude protein, slightly laxative oil, and its mucilaginous, soothing properties. Its judicious use is soon apparent in the pliable skin, the sleek, oily coat, and the good handling quality of the flesh of animals receiving it. A very limited quantity, 0.5 to 1.5 lbs. daily, of oil meal may be fed to horses with advantage, but its heavy use makes a soft flesh. (**422**) For dairy cows 1 to 2 lbs. daily will improve almost any ration. (**640**) For fattening sheep one-fourth or one-third of a lb., (**754**) and for steers 2 to 3 lbs., (**538-9**) can be given daily with advantage, the meal tending to regulate the system and ward off any ill effects from the continued use of heavy concentrates. For calves ground flax seed or oil meal is quite generally used by progressive dairymen. (**480**) A handful of oil meal in each feed of the growing pig will advertise itself in the sleek coat and improved appearance. (**871**)

Unfortunately the American farmer insists that oil cake be ground to a meal. He should adopt the wiser practice of European farmers, who buy oil cake in slab form and reduce it in cake mills to the size of hickory nuts or smaller just before feeding. In such form this feed is more palatable, and there is no chance for adulteration.

201. Soybean, *Glycine hispida.*—The soybean is one of the most important agricultural plants of northern China and Japan. So great is the production of this seed or grain in Manchuria that already that country is annually exporting hundreds of thousands of tons to Europe, and the western coast of America is gradually becoming a

[1] Jour. Roy. Agr. Soc., 1889.

market for this product. The bean-like seeds of the soybean, which carry from 16 to 21 per ct. of oil, are used for human food and for feeding animals. The oil is used for human food and in the arts, and the resulting meal from which the oil has been extracted is employed as a feed for animals and for fertilizing the land. The yield of the soybean per acre varies from 12 to 20 or more bushels of 60 lbs. each, this plant yielding as well as corn on poor soil in the Gulf States. No other plant in the United States grown so little at this time as the soybean is so full of promise to agriculture, especially to animal husbandry. Clover, alfalfa, and vetch are legumes that give us most valuable protein roughage. The Canada field pea, soybean, and cowpea furnish protein-rich concentrates with roughage secondary. Hence a combination of one or more from each class will go far toward freeing the feeder from purchasing costly feeding stuffs.

Humphrey and Fuller of the Wisconsin Station[1] found ground soybeans from 8 to 10 per ct. more valuable than wheat middlings for pig feeding. They recommend feeding 1 part of soybeans with 2 parts of corn. Duggar of the Alabama Station[2] found soybean pasture next in value to peanut pasture for fattening pigs. (**868**) Humphrey and Kleinheinz of the Wisconsin Station[3] found equal parts of soybeans and shelled corn superior to equal parts of oats and shelled corn for lambs, the soybeans producing larger gains for a given amount of feed and a much heavier clip of wool. (**753**) Butter from soybean meal is softer than that from cotton-seed meal. (**643**) Soybean meal should always be used in combination with other grains, and the meal from which the oil has been expressed should prove superior to the ground seeds.

202. Peanut, *Arachis hypogaea.*—The peanut, or earth nut, is of growing importance as feed for stock in the Southern States. The underground seeds or nuts of the peanut are quite commonly harvested by turning swine into the fields when the seeds are ripened, and allowing them to feed at will. The vines with the nuts attached are often gathered and cured into a nutritious, palatable hay useful with all kinds of farm stock. Both the entire nuts and the peanut waste of the factories are useful if fed to swine in moderate quantity, while a heavy allowance produces soft fat and inferior meat. The famous Smithfield hams and bacons come from pigs fed partially on peanuts. (**870**)

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[1] Rpt. 1906. [2] Bul. 143. [3] Rpt. 1905.

The peanut quickly becomes rancid if taken from the shell and exposed to the air. The by-product in the manufacture of oil from the peanut is used in various European countries for stock feeding. Peanut meal is one of the richest known feeds in the amount of crude protein it yields. Voelcker[1] states that peanut cake proved on trial to be a useful feeding material for cattle, having a value about equal to beans. The worthless peanut hulls which accumulate in great quantities at the factories are sometimes ground and used for adulterating feeding stuffs.

203. Sunflower seed cake, *Helianthus annuus.*—The sunflower is grown in Russia on a commercial scale, one variety with small seeds producing an oil which serves as a substitute for other vegetable oils. The large seeds of another variety are consumed as a dainty by the people.

The average of 5 experiments conducted by the North Carolina Station[2] in as many parts of the state showed a yield of 65 bushels of sunflower seed per acre. Mammoth Russian sunflower seed weighed 26.7 lbs. per bushel, with 21.5 per ct. oil, and Black Giant seed weighed 32 lbs. per bushel, with 20.8 per ct. oil. Bartlett of the Maine Station[3] concludes that "With the same cultivation, corn produces a third more protein and twice as much carbohydrates as sunflower heads."

204. Cocoanut meal, *Cocos nucifera.*—The residue in the manufacture of oil from the cocoanut is known as cocoanut or cocoa meal. It is used to some extent by dairymen in the vicinity of San Francisco. Cocoanut meal has a reputation for producing fine butter of considerable firmness and is therefore recommended for summer feeding to dairy cows. It may be used with advantage for swine and sheep, serving also as a partial substitute for oats with working horses. (**642**)

V. Oil-free Leguminous Seeds.

205. The Canada field pea, *Pisum sativum.*—The common field or Canada pea succeeds best where the spring and summer heat is moderate, as in Canada, the Northern States, and in several of the larger Rocky Mountain valleys. No other widely known grain plant of equal possibilities has been so generally neglected by the farmers of the northern United States. According to Shaw[4] the province of Ontario, Canada, produces about 14,000,000 bushels of peas annually, averaging over 19 bushels per acre.

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[1] Jour. Roy. Soc., 1892.
[2] Bul. 90b.
[3] Rpt. 1895.
[4] U. S. Dept. Agr., Farmers' Bul. 224.

The field pea is particularly rich in crude protein, a part of which is of the same chemical composition as the casein of milk. It also has a high phosphorus and potash content. Combined with corn, peas may form as much as one-half the concentrates for dairy cows. They are eminently suitable for sheep and lamb feeding, and their culture forms the basis for an important sheep-feeding industry in Colorado. (**750, 805**) With ground corn or wheat bran, peas form an excellent ration for brood sows and growing swine, proving especially useful for building the framework and preparing them for fattening. (**115, 866**)

206. Cowpea, *Vigna Catjang.*—The cowpea, a bean-like plant from India and China, now holds an important place in southern agriculture because of the large amount of forage and grain it yields. The early varieties grow fairly well as far north as New Jersey and Illinois. The seed pods of the cowpea ripen unevenly, necessitating hand gathering. For this reason the crop is mostly used for hay, silage, and grazing. Duggar of the Alabama Station[1] fed cowpeas to fattening pigs with excellent returns, finding more lean meat in their bodies than in those of pigs fed corn meal. (**869**) Lloyd of the Mississippi Station[2] grazed pigs on ripe cowpeas with no additional feed. Thin hill land gave 350 lbs. and better land 483 lbs. of gain, live weight, for each acre grazed. (**897**)

207. The common field bean, *Phaseolus vulgaris.*—Many varieties of the common field bean are grown in this country for human food. Beans damaged by wet are used for animal feeding. Shaw and Anderson of the Michigan Station[3] estimate the cull beans of Michigan at about 100,000 bushels annually. Cull beans are fed whole in large quantities to sheep, producing a solid flesh of good quality. For swine, beans should be cooked in salted water and fed in combination with corn, barley, etc., as when fed alone they produce soft pork and lard with a low melting point. (**867**)

208. Horse bean, *Vicia Faba.*—The horse bean is used in England for feeding stock, especially horses. This legume grows fairly well in some parts of Canada, but has never proved a success in the United States.

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[1] Bul. 82. [2] Rpt. 1905. [3] Bul. 243.

CHAPTER XI.

THE GRASSES INCLUDING INDIAN CORN—SORGHUMS—THE SMALLER GRASSES—HAY-MAKING—STRAW.

I. Indian Corn and the Sorghums.

Indian corn, maize, is the imperial agricultural plant of America. This giant annual grass reaches a height of from 7 to 15 feet in 4 or 5 months' growth, producing under favorable conditions from 30,000 to 50,000 lbs. of green forage per acre, containing from 5,000 to 9,000 lbs. of dry matter. When grown in a dense mass but little seed forms, and we have a rank grass which cures into a bright, nutritious, coarse hay. If the plants grow some distance apart, a large yield of grain results, with excellent forage as a secondary product.

Were a seedsman to advertise Indian corn by a new name, recounting its actual merits while ingeniously concealing its identity, either his words would be discredited or he would have an unlimited demand for the seed of this supposed novelty. The possibilities of American farms in the live stock they may carry and the animal products they may turn off are restricted only by the quantity of corn and of clover or other legumes which the land will produce, and this, under good management, seems almost unlimited.

In Chapter I the classic study of Ladd on the composition of the Indian corn plant is given at length to helpfully illustrate and fix in mind the manner in which plants grow and elaborate food for animals. The student should turn to that most helpful presentation and carefully review what it teaches. This done he is in position to proceed with the further study of the maize plant as here set forth.

209. Definitions.—The term *fodder corn* or *corn fodder* is applied to stalks of corn, green or dry, which have been grown primarily for forage, and from which the ears or "nubbins," if they carry any, have not been removed. *Stover* or *corn stover* denotes the dry stalks of corn from which the ears have been removed. Fodder corn or corn fodder, then, is the fresh or cured corn plant which has been grown for forage, with all the ears, if any, originally produced. Stover is cured shock corn minus the ears.

210. Thickness of planting.—After studying the results of thick and thin seeding for three seasons at the Illinois Station,[1] Morrow and Hunt reached the conclusions summarized in the table below. In these trials dent corn was planted at distances varying from 1 kernel placed every 3 inches in the row, to 1 every 24 inches, the rows being 3 feet 8 inches apart.

Results of planting corn kernels various distances apart in rows.

Thickness of planting		Yield per acre		Digestible substance per acre			Stover per acre	Stover for each lb. of corn
Distance between kernels in row	Kernels per acre	Good ears	Poor ears	Stover	Grain	Total		
		Bu.	Bu.	Lbs.	Lbs.	Lbs.	Tons	Lbs.
3 inches	47,520	13	46	3,968	2,250	6,218	4.8	3.6
6 inches	23,760	37	39	3,058	2,922	5,980	3.7	1.9
9 inches	15,840	55	22	2,562	2,977	5,539	3.1	1.5
12 inches	11,880	73	16	2,480	3,113	5,593	3.0	1.3
15 inches	9,504	63	11	2,398	2,782	5,180	2.9	1.4
24 inches	5,940	49	6	2,066	2,141	4,207	2.5	1.5

We observe that on rich soil with the kernels 3 inches apart in the row, or 47,520 per acre, there were 13 bushels of sound ears and 46 bushels of poor ears or nubbins per acre. Poor as are these returns from the standpoint of grain production, we gather the interesting and exceedingly important fact that thick planting gave the largest returns in total digestible nutrients per acre. Over 6,000 lbs. of digestible dry matter was secured in the nearly 5 tons of stover and corn harvested. With this thickness of seeding there were 3.6 lbs. of stover for each lb. of grain. The largest yield of sound ear corn was secured by planting the kernels 12 inches apart in the row, or about 12,000 kernels per acre. From this the returns were 73 bushels of sound and 16 bushels of poor ears per acre, with only 600 lbs. less digestible matter than was returned from planting the kernels 4 times as thick.

Morrow maintains that for Illinois conditions, with a rich soil, 10,000 good stalks of corn per acre, secured by planting about 12,000 kernels, give the best returns in grain. The lesson from the above table, confirmed by the work of other stations, teaches that when the stockman is seeking the greatest amount of nutrients possible from the corn crop he will plant the seed so thickly as to choke the ears to about half their natural size. If, on the other hand, he aims to produce grain, with stover secondary, he will then plant

[1] Bul. 13.

the kernels at such distance apart as will allow each individual plant to produce full-sized ears. No rule can be given which is applicable to all cases as to the amount of seed to be planted per acre. This varies greatly and is determined by local conditions. One must know accurately the capacity of his land for corn, and seed accordingly, bearing in mind that thick seeding gives the most total nutrients, largely as roughage, while thinner seeding gives the most sound grain.

211. Distribution of nutrients.—Armsby of the Pennsylvania Station,[1] studying the returns of the corn crop reported by experiment stations in four states, found the yield of ears and stover to be as follows:

Yield of corn ears and stover per acre at 4 stations.

Experiment station	Race of corn	Yield per acre	
		Ears	Stover
		Lbs.	Lbs.
New Jersey	Dent	4774	4041
Connecticut	Flint	4216	4360
Wisconsin	Dent	4941	4490
Pennsylvania	Dent	3727	2460

The above shows that in the northern states somewhat more than half the total weight of the corn crop when grown for grain is found in the ears. The following table, arranged from Armsby's study, shows the location of the digestible nutrients:

Location of the digestible nutrients in a crop of corn.

	Crude protein	Carbohydrates	Fat	Total digestible nutrients
	Per cent	Per cent	Per cent	Per cent
In ears	75	61	85	63
In stover	25	39	15	37

The table shows that in a crop of ripened corn about 75 per ct. of the digestible crude protein is found in the ears and 25 per ct. in the stover. Of the total digestible nutrients, about 63 per ct., or two-thirds, appears in the ears, and 37 per ct., or one-third, in the stover. These figures should not be regarded as rigid, for the ratio of grain to stalk will vary with the crop and section of the country.

[1] Rpt. 1887.

Southern corn with its large stalks will have less of the total nutrients in the ear and more in the stalks.

The last column in the table, which shows that one-third of the digestible nutrients of the corn crop is in the stover or corn straw, is most significant and should be carefully considered by the corn grower. While literally correct, the figures do not mean that in all cases one-third of the value of the corn crop for feeding purposes is in the coarse parts. Much more energy is required to digest a given weight of stover than the same weight of ears and consequently less net energy remains in the case of the stover after both have been passed thru the digestive tract. For fattening animals, those giving milk, and for those at hard work the stover has a smaller value than here given. For animals at light work, those fattening slowly or giving only a small quantity of milk, and for maintaining animals in winter when much heat for warming the body is required, the stover then approximates the value here expressed. (**70**, **96**, **403**)

212. Pulling fodder.—At the South the tops of the ripening corn stalks are quite commonly cut off just above the ears, leaving the tall butts, each with an unhusked ear at its top. Next, the leaves are stripped from the butts, and these together with the severed tops are cured into a nutritious, palatable fodder, which is extensively employed for feeding horses and other stock. Ladd's study of the ripening corn plant shows the folly of this practice. During the last stages of its life the corn plant is busiest in gathering crude materials from air and soil and elaborating them into nutritious food. Removing the top and leaves, at once stops all this work of food making. Stubbs of the Louisiana Station[1] found that pulling fodder caused a shrinkage of from 15 to 20 per ct. in the yield of grain.

213. Losses in field curing.—Losses of nutrients in corn fodder after it has been gathered into shocks (stooks) are known to occur thru weathering, but there are also large losses which are unexplained. During 4 years' study at the Wisconsin Station, Woll[2] determined the dry matter and crude protein in a crop of corn at the time of cutting and again after the shocks had been exposed to the weather for several months. It was found that under Wisconsin conditions well-made shocks of corn which stand in the field for a few months lose about 24 per ct. of their dry matter, the crude pro-

[1] Bul. 22 (old series); also Bul. 104, North Carolina Sta.
[2] A Book on Silage.

tein content suffering to the same extent. Cooke has shown that in the dry climate of Colorado[1] heavy losses likewise occur in shock corn. At the South the corn forage, maturing early, melts away to almost nothing in a comparatively short time. The substances lost thru such wasting are crude protein, sugar, starch, etc.—the most valuable portions of the plant. Nor is it possible to entirely prevent these losses by placing the cured fodder under cover or in stacks, for Woll found losses even under such conditions. Losses of this nature are probably due to fermentations which slowly but steadily waste the substance of the forage. Sanborn[2] writes: "Many trials with fodder . . . make it certain that 15 per ct. is the minimum loss to be expected with dry storage, while the loss may rise to 20 per ct. or even more in ordinary practice." (**348**)

214. Fodder corn for soilage.—On farms lacking summer silage, feeding corn forage in the green stage should become general, for the reason that during the late summer and early fall the pastures are often scant, and animals forced to subsist upon them suffer from lack of sufficient food and cannot do their best. An acre of ripening corn fed in early fall to steers or dairy cows which are otherwise on poor feed may so advance their condition as to return double the value it would yield were it held over until winter and fed at a time when there is often a plethora of the same material.

215. Shocking (stooking) corn.—The loss from weathering which shock corn suffers can be lessened by making large shocks. In corn shocks the stalks stand almost vertical, and as the leaves wilt there is ample room for the upward passage of air currents, which rapidly dry the interior and check molds and fermentations. When shock corn is pronounced dry by the farmer, it still carries more water and consequently less dry matter than hay, a fact which should not be overlooked when feeding this forage.

216. Shock corn.—Mumford of the Illinois Station,[3] when feeding steers clover hay, found shock corn supplemented with ear corn and oil meal superior to shelled corn and oil meal. (**523**) This result, substantiated by common experience, shows that corn need not be husked for the best results in steer feeding, and in somewhat less measure this is true with the dairy cow. An ear of corn wrapped in its husk possesses aroma and palatability which is in part lost after it has been exposed to the air for a time. Whoever has watched a cow eagerly searching a bundle of stover for a possible ear or nubbin which the would-be thrifty farmer had overlooked,

[1] Colo. Expt. Sta., Bul. 30. [2] Cyc. Am. Agr., Vol. II, p. 569. [3] Bul. 103.

must be impressed with the folly of him who so carefully performed his work. It is true that when fed in this manner some corn passes thru the animal unbroken, but feeding trials have shown that, despite such waste, there is often little or no profit in husking the ear and reducing it to meal. Part of the shock corn can be husked to furnish the extra forage required by the cattle. A little study will determine the amount of grain the shocks carry, so that the feeder can properly adjust the ratio of grain to roughage. Because our ancestors laboriously husked corn and afterwards divided with the miller for grinding, is no reason why in these days of high-priced labor we should continue husking corn for cattle, when these animals have all day in which willingly to perform the work.

217. Dry fodder corn.—Corn grown and cured as forage constitutes a coarse hay of high feeding value, since only a portion of the nutrients has gone into the ear. Dry fodder corn is more palatable and nutritious than stover, which has lost much of its substance to the grain produced. Thickly seeded corn bears small, palatable ears which are easily masticated. When grown for coarse hay and carrying some grain, corn possesses a feeding value not as yet appreciated by most stockmen. Overlooking its splendid qualities as a hay plant, we have become accustomed to growing this grass for the grain it yields, and using the roughage as a sort of straw to be eaten or wasted as accident determines. (**435, 664**)

218. Corn stover.—The forage which remains after removing the ear from shock corn has a higher feeding value than is usually conceded. Stover produced in the northern portion of the corn belt is superior in nutriment and palatability to that grown at the South. As soon as fairly well cured and freed from external moisture, stover should be placed under cover or stacked, rather than left to deteriorate in the field. Waters of the Missouri Station[1] found as the average of experiments covering 4 years that moderately thin yearling steers lost only 33 lbs. each when wintered on whole corn stover alone. This shows that whole corn stover will nearly furnish a maintenance ration for such animals. (**436, 545, 665, 764**)

219. Shredded stover.—When shock corn is husked by machinery the stover is usually shredded at the same operation. Shredded corn forage is easy to handle, and the waste is in better shape for bedding and manure. At the Missouri Station[2] Waters found shredded stover slightly inferior to whole stover for steer feeding. It is probable that shredding stover or running it thru a feed cutter will pay

[1] Bul. 75. [2] Loc. cit.

better at the North than at the South, because the northern-grown cornstalks are more palatable and less woody. (**341**, **500**)

220. Corn forage for silage.—Indian corn is the only common farm plant in America that experience has shown to be entirely satisfactory for silage. Its use for this purpose has revolutionized farm practice in many sections. Thru the aid of the silo the entire plant is economically used without waste, and a succulent feed, greatly relished by cattle, is produced. (**360**)

221. The new corn product.—The pith of the cured corn stalk is used as a packing between the walls of vessels to prevent the entrance of water should the hull be pierced. It has been found that for each lb. of pith suitable for such purpose there are 15 lbs. of blades, husks, and parts of stalks which remain as a by-product. This waste, ground to a powder, has been named "the new corn product." At the Maryland Station[1] Patterson found the new corn product somewhat more digestible than whole stover in feeding trials with steers and equal to hay for horses.

222. The sorghums, *Sorghum vulgare.*—While the sorghums can be grown over most of the United States they are at their best in the southwestern plains region, reaching from Nebraska to Texas. The saccharine sorghums, with their juicy stalks rich in sugar, are grown for both forage and grain, principally the former. The non-saccharine sorghums—kafir and milo—are grown for grain, with forage second in importance. In 1907 Kansas[2] grew 378,000 acres of sweet sorghum and 508,000 acres of kafir for grain and forage, the 2 crops having a value of over $8,000,000. Conner[3] of the United States Department of Agriculture, reporting for Northwest Texas, states that sorghum, milo, and kafir yield from 5 to 6 tons of dry forage per acre in average seasons. When grown in drills, not too thickly, the sorghum stalks are coarse and much seed is produced. It is then usually harvested into shocks, the same as Indian corn. Thickly-sown sorghum becomes a coarse grass which may be cut with the mower and cured in cocks, the same as the meadow grasses. The leaves of the sorghum plant are quite free from dust and very palatable, making with the sweet, juicy stalks a desirable roughage for stock, especially horses.

The merits of sorghum as silage are but little known. When ensiled, sorghum usually makes a sourer silage than corn. Soule of the Tennessee Station[4] has found, however, that well-matured sorghum properly ensiled makes sweet silage.

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[1] Buls. 43, 51.
[2] Qt. Rpt. Kan. St. Bd. Agr., Dec. 1907.
[3] Texas Exp. Sta., Bul. 103.
[4] Bul. Vol. XVII, No. 1.

The common variety at the North, known as Amber Cane, should be more extensively used for soilage, and especially as a dry forage, since it is highly palatable and greatly relished by horses, cattle, and sheep. (**434**, **551**, **765**, **900**)

II. The Smaller Grasses.

The great grain-bearing plants—Indian corn, wheat, rye, barley, oats, rice, and the sorghums—are all members of the grass family, being annuals and requiring careful cultivation. The smaller grasses are nearly all perennials, thriving without cultivation and producing roughage of high grade. In the humid regions Nature everywhere spreads a carpet of soft, green grass that beautifies the landscape and furnishes an abundance of palatable food for animals. Even in the desert the grasses struggle for existence and yield rich nutriment, tho in meager amount. For recuperating the soil and binding it together and for furnishing food to man and the domestic animals, the grasses are of supreme importance. In summertime in those regions where grasses flourish, the animals of the farm largely care for themselves, and meat, milk, and wool are produced at the minimum cost for labor.

223. Blue-grass, *Poa pratensis.*—Kentucky blue-grass, or June grass, is the common carpet grass of the northeastern United States, easily ranking first for lawn and pasture. By its persistence it often drives red clover, timothy, and other grasses from the meadows and pastures, tenaciously holding its own against all claimants. Table III of the Appendix shows this grass to be the richest in the list in digestible crude protein and fat, which helps to explain the fondness for it shown by stock.

Blue-grass ripens in early summer, having largely gathered the necessary food material from air and soil during the preceding late summer and fall. With the coming of spring it pushes forward so vigorously that early in May the fields wear a thick, nutritious carpet of grass, and a little later the seed heads show. With seed bearing late in May, the plant's energies have been exhausted, and blue-grass enters a period of rest which lasts several weeks. During this time there is little growth, and if a midsummer drought occurs the plants turn brown and appear to be dying. They quickly revive with the coming of the fall rains, and again the pastures are green and growing. They have had their rest, and each plant is once more busy gathering nourishment for the coming season's seed bearing. The observant stockman soon learns that it is not wise to rely on blue-grass pasture for a steady and uniform feed supply for his cattle thruout the whole season. Accordingly he understocks the pasture in spring so that the excess of herbage during May and June remains to be drawn upon during the midsummer dormant period, or he fully stocks it and makes up the later shortage by partial soilage. In some districts it has been found profitable to graze blue-grass pastures lightly, or not at all, in summer, and allow the self-cured herbage to stand for winter grazing. Kentucky blue-grass is primarily a pasture grass and should be so regarded. (**327**)

224. Timothy, *Phleum pratense.*—The well known grass called timothy, or herd's grass, yields a large part of all the hay used on the farms of the northeastern United States and probably three-fourths of all that marketed in the cities. Timothy seeds, large and easily recognized, are produced in abundance and long retain their vitality. The grass cures easily into hay, and a field seeded to timothy is quickly established and usually holds well. These points of merit make it a favorite with the farmer. Timothy hay from nearly ripened grass is usually bright, quite free from dust, and much liked by driving horses, which get most of their nourishment from oats or other grains. (**429**) These qualities satisfy the city buyer. But timothy hay is not desirable as the sole forage crop on well managed farms, because the yield is not particularly large and there are other and better plants which, in part, may take its place. Fodder corn, hay from the cereals—oats, wheat, rye, or barley,—mixed clover and timothy hay, or pure clover hay are all available and desirable substitutes in many cases. (**540**, **664**)

Red or alsike clover should always be sown with timothy, for the combination furnishes more and superior hay, even for horses. Grown together, the hay of the first season will consist largely of clover. With the close of the second season most of the clover disappears and the decaying clover roots will nourish the timothy which remains, so that a much larger yield of that grass is thereby obtained. The largest returns of timothy hay are secured by delaying harvest until the grass is nearly mature. (**238**) Late-cut hay is usually quite free from dust and is satisfactory for horses and fattening cattle, while early-cut timothy is superior for cows, young stock, and sheep. Timothy hay grown at the Minnesota Station[1] on manured soil contained 25 per ct. more crude protein than that from the same soil without manure. (**546**, **547**, **554**)

[1] Bul. 101.

225. Red top, *Agrostis vulgaris.*—This grass, widely disseminated and of several species, is especially valuable on damp lowlands, where it forms a close, well-knit, smooth turf, ranking next to blue-grass in this particular. It furnishes excellent pasture and yields a palatable hay of fine stems and numerous leaves. Red top is often indigenous in northern meadows and should be more generally grown. Tracy of the Mississippi Station[1] found no better grass than red top for marshy lands and seepy hillsides.

226. Orchard grass, *Dactylis glomerata.*—This grass starts early in the spring and ripens about two weeks in advance of timothy. For this reason it may well be grown with red clover. It succeeds well in partial shade, but forms an irregular, uneven sod, and should always be sown with other grasses and with clovers. The hay from orchard grass is inclined to be harsh, woody, and lacking in aroma, and is not particularly relished by stock. These defects can be partially overcome by early harvesting.

227. Mixed grasses.—No matter how valuable, no single variety of grass should be grown in meadows or pastures, but always a mixture of several kinds in combination with the clovers. At the North a combination of red top, timothy, and orchard grass, together with alsike and medium red clover, will yield a larger tonnage of aromatic, palatable hay than is possible from any single variety. Unless indigenous, white clover should be sown in pastures with all the above. There are other varieties of grass that thrive in certain districts, and the stockman should experiment freely with the more promising ones in order that he may discover those best suited to his particular farm. In this connection it must be remembered that the presence or absence of sufficient plant food—nitrogen, phosphoric acid, potash, and lime—determines and regulates, in a large degree, the species or varieties of grass and clover found in any given field.

228. Brome grass, *Bromus inermis.*—For the eastern edge of the northern plains region, stretching from South Dakota to Saskatchewan, brome is the most important perennial hay and pasture grass, flourishing there as do timothy and blue-grass further east. Ladd and Shepperd of the North Dakota Station[2] found brome the best grass for permanent pasture, yielding twice as much protein and no more fiber than timothy. During a 5-year test, brome grass yielded an average of 2 tons of hay at the Manitoba and 1.25 tons at the Saskatchewan Station.[3] (**431**, **749**)

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[1] Bul. 20. [2] Bul. 47. [3] Canada Expt. Farms, Rpts. 1902–6.

229. Millet, *Setaria Italica* and *Panicum, spp.*—The millets, which are annual grasses, are of many races and varieties mixed in hopeless confusion. German millet and Hungarian grass are the varieties commonly grown for hay in the northern states. Sown in early summer, frequently as catch crops, they thrive remarkably in hot and even dry weather, reaching the harvest period late in August or September. For millet hay of fine quality heavy seeding should be practiced. Millet grass designed for hay should be cut as soon as the blossoms appear, to prevent the formation of the hard, indigestible seeds. Thickly-seeded, early-cured millet hay is useful for cattle and sheep feeding. (**501, 764**) Since millet hay is sometimes injurious to horses, it should be fed sparingly and under close supervision. (**433**)

230. The cereals as grasses.—At the North, fall-sown rye and wheat and spring-sown barley and oats furnish quick, excellent, short-time pasture or soilage, or, if harvested when nearly mature, dust-free, palatable hay. Barley is the best cereal grass for late summer seeding, since the young plants do not rust as readily in early fall as do the others. Sown in August at the North, and still later at the South, barley will grow to nearly or quite full height before cold weather, and will furnish much nutritious pasture or green forage for soilage. At the Alabama (Canebrake) Station[1] a fall-seeded barley field yielded over 11 tons of green forage per acre by the following March. It was found in southern Kansas that fall-sown wheat pastured by cows during mild weather in winter gave a grass flavor to winter butter. The bad flavor which green rye imparts to milk may usually be avoided by grazing the cows thereon for but two or three hours immediately after milking. In the northern states the cereal grain plants are not as extensively used for hay and pasture as they should be.

A field sown to rye, wheat, oats, or barley for temporary pasture may be changed to a permanent one by sowing clover and grass seed thereon early in spring in the usual manner. The grass and clover plants will then soon begin growth under shelter of the young grain plants. Stock should be turned into such pastures to graze on the cereal plants regardless of the young grasses and clovers, but the animals should be kept off the field immediately after rains while the ground is soft. The cattle will tramp out some of the tiny grass plants, but will do no permanent harm. The young grass and clover plants will grow rapidly, and as the cereal plants

[1] Bul. 9.

die will spread until they form a dense, permanent sod. Such double seeding gives the earliest possible summer pasture of rye, wheat, barley, or oats, followed by the more permanent one of mixed grasses and clovers.

231. The cereals for hay.—Barley is the common hay grass of the Pacific slope, and there is no reason why this plant, as well as the oat and wheat, should not be used for hay production in other parts of the country. When intended for hay, the cereal grasses should be cut while the grains are in the early milk stage, at which time the stems and leaves may be cured into bright, dust-free hay of good quality. In many cases a field of wheat or other cereal grains which has lodged badly because of overrich soil or excessive rainfall may be advantageously converted into hay. (**430**)

232. Bermuda grass, *Cynodon Dactylon.*—This grass is to the cotton belt what Kentucky blue-grass and timothy combined are to the northeastern United States. Bermuda grass furnishes a dense sod covering the southern fields with a carpet of summer green as pleasing to the eye of the stockman as it is to the animals grazing thereon. Spillman[1] reports that the best Bermuda pastures will support 2 head of cattle per acre from April until late October. The Louisiana Station[2] grazed 30 head of cattle of all ages on 17 acres of Bermuda grass pasture mixed with other grasses and some Lespedeza, with no other feed from March to November. According to Spillman,[3] Killebrew states that on the best alluvial soils 1 acre of Bermuda pasture will graze 10 sheep for 8 months. Bermuda pastures are best utilized by subdividing them and turning the stock from one lot to the other. On rich soil Bermuda grass yields as much as 4 tons of hay in 2 cuttings, fully equal in quality to timothy. At the Oklahoma Station[4] hardy Bermuda grass yielded 4 tons of hay per acre in 3 cuttings. (**432, 669**)

233. Johnson grass, *Andropogon Halepensis.*—Johnson grass, the worst weed of the South, is capable of yielding from 3 to 5 tons of excellent hay in 3 or more cuttings. It spreads from seeds as well as by its vigorous creeping rootstocks. This coarse grass is not suitable for pasture, but for soilage it may be cut once each month during the summer season. (**668**)

234. Miscellaneous southern grasses.—For winter pasture and soilage as well as for hay, a long list of grasses is available for the southern states, only a few of which can be here mentioned. The

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[1] Farm Grasses of the United States.
[2] Bul. 72.
[3] Loc. cit.
[4] Rpt. 1906.

cereals—oats, wheat, barley, and rye—furnish large quantities of useful forage. Bell[1] reports that at Jackson, Mississippi, 15 acres of winter rye furnished one-half the pasturage for 25 cows. Tracy[2] states that in Florida and the Texas Gulf country 1 acre of Guinea grass, *Panicum maximum*, will carry 4 head of cattle thru the entire season by soilage, or 3 head by grazing. Stubbs of the Louisiana Station[3] reports teosinte, *Euchlaena Mexicana,* a giant grass resembling sorghum, as yielding over 50 tons per acre. This plant is too tropical in character to have value outside a belt bordering the Gulf of Mexico.

235. The abuse of pasturage.—It is a fact which cannot escape the attention of students of agricultural economics, that our stockmen rely too blindly upon pastures for the maintenance of their cattle during half the year. But a few centuries ago the inhabitants of Great Britain trusted to the growth of natural herbage for the support of their stock not only in summer but thruout the entire year. If their animals, foraging for themselves as best they could, survived the winter, all was well; if they died from starvation, it was an "act of God." We have abandoned the crude practices of our ancestors, and now carefully store in barns abundance of provender for feeding flocks and herds during winter's rigor. We are amazed that our ancestors were so improvident as to gather no winter feed for their cattle, while for ours great barns are built and stored with provender. By turning cattle to pasture in spring and letting them forage as best they may until winter we show that all the barbaric blood has not yet been eliminated from our veins. If the summer rains are timely and abundant the cattle are well nourished on these pastures; if drought prevails they suffer for food as surely, and often as severely, as did the live stock of England in winter, ages ago. To suffering from scant food there is added the heat of "dog days" and the ever-present annoyance of blood-sucking flies. Our stockmen will never be worthy of their calling, nor their flocks and herds yield their best returns, until ample provision is made against drought-ruined pastures in summer. Every argument in favor of storing provender for stock in winter holds with equal force for providing feed to make good any possible shortage of pastures in summer.

III. Hay-making.

236. The quality of young grass.—At the Michigan Station[4] Crozier cut growing timothy grass 8 times from one plat, while on

[1] U. S. Dept. Agr., Farmers' Bul. 147.
[2] U. S. Dept. Agr., Farmers' Bul. 300.
[3] Bul. 19.
[4] Bul. 141.

another it was cut and cured into hay after making full growth. The hay from the grass which was frequently cut was nearly 3 times as rich in crude protein as that from the nearly mature grass cut once, but the latter had the largest total amount of crude protein and nearly 4 times as much total dry matter. This teaches that the short, tender grass, such as is gathered by grazing animals, is percentagely much richer in crude protein, which goes to build muscle, than the same grass when allowed to mature. To get the largest returns of total nutrients, however, grass must make full growth before it is cut.

237. Dried green grass.—At the Pennsylvania Station[1] Armsby tested the feeding value of dried and fresh grass in the following manner: Short grass on the college lawn was cut with a lawn mower and divided into 2 portions, one of which was fed fresh to a cow, the other half being dried over a steam boiler and in turn fed to the same cow. Armsby had previously conducted a similar experiment at the Wisconsin Station with grass cut when 9 or 10 inches high. Half was fed fresh, and the other half carefully dried in the sun and later given to the same cow. The yields of milk and butter fat in the 2 trials were as follows:

Average daily yield of milk and fat from cows fed green and dried grass.

	Product from—			
	Green grass		Dried grass	
	Milk	Fat	Milk	Fat
	Lbs.	Lbs.	Lbs.	Lbs.
Trial at Pennsylvania Station	26.01	1.08	25.27	1.06
Trial at Wisconsin Station	16.98	0.92	17.81	1.00
Average	21.5	1.00	21.54	1.03

These results show that perfectly dried grass yields as much nutriment as when fed in the fresh condition. In actual hay-making, however, more or less of the finer portions of the plants is always lost. Exposure to the sun reduces the palatability by bleaching and causes a loss of aromatic compounds, dew works injury, and rain carries away the more soluble portions. (**48**) Thus, while the dried grass may theoretically equal the fresh forage, in practice it falls short.

Stöckhard[2] cured one sample of meadow hay in 3 days and left another in the field for 13 days in alternate wet and dry weather. Analysis showed that the weathered hay had lost 12.5 per ct. of its

[1] Rpt. 1888. [2] Wolff, Farm Foods, Eng. ed., p. 155.

total dry substance, representing one-fourth of its original nutritive value. Märcker[1] found the loss in meadow hay exposed to a prolonged rain to be 18.4 per ct. of the dry substance. This heavy withdrawal of the soluble portions of the hay leaves proportionally more woody fiber and indigestible matter in what remains.

238. Changes in ripening grass.—Hunt of the Illinois Station[2] conducted extensive studies of the changes which occur in maturing grasses, securing the following data relative to the timothy plant:

Yield of one acre of timothy cut at different stages.

Stage of growth when cut	Dry matter	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Full bloom	3287	224	240	1056	1602	165
Pollen and ½ anthers shed	3423	228	225	1155	1663	152
Seed in dough	4021	273	246	1380	1960	153
Seed nearly ripe	4064	239	253	1377	2058	137

The table shows that between full bloom and the ripe-seed stage the acre of timothy gained nearly 800 lbs., or over 23 per ct., in dry matter. There was but little increase in crude protein or ash, and a small decrease in fat. In carbohydrates the increase in woody fiber, which is low in feeding value, was over 300 lbs., and the gain in nitrogen-free extract, which is valuable in feeding, was over 450 lbs. By referring to Ladd's study of the maturing corn plant, (**16**) it will be seen that timothy resembles corn in storing great quantities of food material, especially carbohydrates, after the bloom period. In this marked way the grasses differ from the clovers, since the latter, as Hunt has also shown, (**250**) practically close their work of food building with the bloom period.

239. Time to cut grass.—For dairy cows, young stock, and sheep grass should be cut early, since these animals do not relish hay that is woody and lacks aroma, as does most late-cut hay. For horses and fattening cattle late cutting is favored. These animals subsist mostly on concentrates, and the hay they eat serves more for "filling," as horsemen say. In any case the harvest should not be too long delayed, however, lest the grass become tough and stringy and the seeds shatter. In trials with early- and late-cut timothy for fattening steers, Sanborn[3] found that late-cut hay gave better returns.

[1] Loc. cit. [2] Bul. 5. [3] Rpt. N. H. Board of Agr., 1880.

The author, in an unpublished duplicate experiment conducted many years ago, reached the same conclusion.

240. Making hay.—The widely varying character of grass crops, the dampness or dryness of the soil of the meadows, the humidity of the atmosphere, and the intensity and continuity of sunlight and heat, are all modifying factors that combine to keep the curing of grasses into hay one of those arts which cannot be very helpfully discussed in books. However, some interesting and important points bearing on the subject will be considered here, drawn largely from Storer's classic work on agriculture.[1]

Tho an unweighable quantity, the aroma of grass has real value in rendering hay palatable. When the sun dissipates the dew from the grass drying in the meadow, we detect the escaping aroma, because the dew in rising carries some of it into the atmosphere. This is one reason why hay should not remain scattered over the meadow at night. When new-mown hay lies in the sunlight, the bleaching which we observe indicates that harmful chemical changes are taking place within the grass stems and leaves. Green-colored, sweet-smelling hay is really the best, and prudent stockmen will not overlook such seemingly small points as preserving the aroma and preventing bleaching. Grass stems remain alive for some time after they have been severed by the mower, and the leaves, so long as they remain succulent and green, continue to exhale moisture. If grass with the leaves still fresh is gathered into bundles or cocks, the leaves will continue drawing water from the stems, thereby ridding them of moisture and hastening the drying grass toward the condition of hay. In this fact we have an explanation of one of the advantages of curing grass in cocks or bundles rather than by spreading it thinly in the hot sun. Hay cocked in the afternoon entraps much warm air, and the mass remains in a condition favorable to the transpiration, or giving off, of moisture during the night. The heat yielded by the plant in still carrying on its life functions and the warm air entrapped by grass gathered in the afternoon should not be confused with the heat which may develop in partially cured or damp hay thru fermentation. When hay that has been cocked for a time is exposed to the air in flakes, the moisture, which has been evenly diffused thruout the mass of stems and their leaves, is yielded up rapidly and such material is soon dried. While hay can be made without sweating in the cock, it is much better for having undergone such action.

[1] Agriculture in Some of its Relations with Chemistry.

Hay put into the barn when so dry that it will not pack well, is not in first class condition. It should be mowed away with just that amount of moisture which allows it to settle compactly when treaded down. Salt and lime scattered over hay when put into the mow tend to prevent fermentation and check the growth of molds and mildews. Salt also renders it more palatable. These materials are not essentials, but are helpful, especially when storing partially cured hay during bad weather. Damp hay may be improved by placing it in alternate layers with dry straw. The straw absorbs moisture as well as aroma from the hay so that cattle the more readily eat both straw and hay. Hay from second-growth grass, or aftermath, is rich in nutrients, but it is made at a time when the ground is often damp, the days short, and the heat of the sun weak. This combination renders the curing of aftermath difficult, and the product is usually of less value than first-crop hay. Cured under favorable conditions, aftermath hay is excellent for winter feeding.

New-made hay is laxative and should not be fed to horses, since it makes soft flesh. Not until the sweating process has been completed in the mow and the mass cooled off can new-crop hay be fed with entire safety.

241. Measurement and shrinkage.—Woll[1] states that 420 cubic feet of timothy or 500 of clover hay in the mow equals 1 ton. Wheeler and Adams of the Rhode Island Station[2] found that field-cured, mixed red top and timothy hay, containing from 25 to 29 per ct. water when placed in the barn, showed a shrinkage of from 15 to 20 per ct. of the original weight when later removed. Jordan of the Pennsylvania Station[3] found that timothy hay stored in the mow shrank on the average 22 per ct. and red clover 37 per ct. Wilson of the Arizona Station[4] found the shrinkage of stacked alfalfa hay to range from 11 to 23 per ct. Sanborn of the Missouri Station[5] estimates that a hay stack 12 ft. in diameter has 33 per ct. of its contents in the surface foot where it is more or less exposed to the weather. A stack of second-crop clover lost 30 per ct. in weight between early August and the following March, 17 per ct. being water and 13 per ct. dry matter.

IV. Straw and Chaff.

With our steadily increasing population and the gradual exhaustion of the fertile lands of the Northwest, the pioneer stage of wheat

[1] Handbook for Farmers and Dairymen.
[2] Bul. 82.
[3] Bul. 5.
[4] Rpt. 1907.
[5] Bul. 25, 1st series.

growing in the United States is drawing to a close. Instead of burning vast quantities of straw and wasting many other roughages as is now done, all these will soon be used along with silage, roots, grains, and the by-products of the flouring mills for feeding dairy cows, fattening cattle, and sheep in order to supply the ever-increasing wants of a vast population.

242. Straw and chaff.—Straw is poor in crude protein and fat, and rich in woody fiber or cellulose, a carbohydrate that requires much energy for its digestion and disposal. Accordingly straw should be used but sparingly, at most, with animals at hard work, fattening rapidly, or giving a large flow of milk. For animals at light work, fattening slowly, or giving only a little milk some straw can often be advantageously used. Straw is particularly useful in winter with horses that are idle and cattle that are being carried over without materially gaining in weight. Heat is one of the principal requirements of such animals, and the large amount of energy expended in masticating, digesting, and passing straw thru the body finally appears as heat which helps warm the body. The stockman who understands the nature and properties of straw will usually be able to make large use of it. (**71, 73, 403**) In Europe straw is extensively used for fattening cattle. Oat straw with its soft, pliable stems is the most nutritious, followed by barley straw. Wheat straw, being coarse and stiff, is not so readily eaten by cattle. Rye straw is harsh and woody and is best suited for bedding. In Canada and Europe pulped roots and meal are mixed with straw, and the moist mass allowed to soften and even to ferment slightly, after which it is readily consumed in large quantities by cattle and sheep with satisfactory results. The chaff of wheat and oats contains more crude protein than does straw, and forms a useful roughage for stock. All such roughage will be wisely utilized when a rational system of feeding is followed. (**73, 403, 437-8**)

While not especially desirable, flax straw may be fed with advantage when better roughage is scarce. The statement that the stringy fiber of flax forms indigestible balls in the stomachs of farm animals is unwarranted, since it is digested the same as other fibrous matter, such as the lint of cotton and the pith of corn stalks, for example.

CHAPTER XII.

LEGUMINOUS PLANTS FOR GREEN FORAGE AND HAY.

The cereal grain plants—corn, wheat, oats, barley, etc.—and the grasses—timothy, red top, etc.—serve mainly for furnishing carbohydrates for the nourishment of animals. The legumes—alfalfa, clover, vetch, soybean, cowpea, etc.—comprise the great group of food-bearing plants characterized by their high nitrogenous or crude protein content. While the first named group primarily furnishes the animal with energy and fat, the last group serves especially for building all the muscular tissues and all the various organs of the body, as well as a part of the skeleton.

Heretofore we have ascribed the great usefulness of the legumes in nourishing farm animals to their high content of crude protein. We must now give to these plants another value—that of furnishing an abundance of lime to animals. Farm animals need a large supply of lime for building the skeleton and replacing the lime which is used up in the metabolic processes or changes which are constantly going on within the body. Pregnant animals store much lime in the skeleton of the fetus, and animals giving milk undergo a steady loss of lime. Each 100 lbs. of milk the cow produces carries off 0.75 lb. of mineral matter, a considerable portion of which is lime.

Many of the concentrates, such as corn, wheat, bran, middlings, gluten meal, etc., and the roughages, such as corn stover, corn silage, hay, straw, etc., range from poor to fair in their content of lime. Of all the plants widely grown by the farmer, the legumes are, as a class, richest in crude protein and lime. When to these vitally important facts we add the great basic one, that the generous and continuous growing of legumes is absolutely essential to the economical maintenance of soil fertility, then, and only then, do we begin to appreciate the importance of this beneficent group of plants in husbandry. (**89**, *Appendix, Table V*)

I. Alfalfa.

243. Alfalfa, *Medicago sativa.*—The alfalfa plant is at its best in the great semi-arid plains region covering the western half of the United States, where the alkaline soil is usually rich and deep, with perfect drainage. On such land, amply watered by irrigation and energized by the tropical sun of summer, alfalfa furnishes from 2 to 5 cuttings each season, yielding from 2 to 5 tons annually of nutritious hay per acre. Within the humid region, experience and tests are developing districts from Louisiana to Maine where alfalfa can also be profitably grown. That good crops of alfalfa can be produced in the East when conditions are favorable is shown by Voorhees of the New Jersey Station,[1] who reports the following returns from a well-established alfalfa field:

Green alfalfa and total nutrients from one acre of alfalfa.

Cuttings	Green forage	Dry matter	Ash	Crude protein	Carbohydrates		Fat
					Fiber	N-free extract	
	Tons	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First cutting	9.0	3,060	346	657	820	1,116	121
Second cutting	7.7	3,613	348	629	1,113	1,388	135
Third cutting	4.9	2,533	212	442	643	1,131	105
Fourth cutting	2.8	1,666	147	299	389	771	61
Fifth cutting	2.2	913	92	301	143	327	50
Total	26.6	11,785	1,145	2,328	3,108	4,733	472

It will be observed that 1 acre yielded over 26 tons of green alfalfa, containing over 11,000 lbs. of dry matter which held over 2,300 lbs. of crude protein. Voorhees estimates that this acre of alfalfa yielded as much crude protein as is contained in 7.5 tons of wheat bran. These exceptionally large returns are given to show what is possible in the eastern states from alfalfa grown by experts.

At the Colorado Station,[2] Cooke compared a crop of dent corn from 1 acre of land with the returns from an adjoining acre plat of alfalfa 3 years seeded, as shown below. The alfalfa acre was cut 3 times, yielding a total of 5.6 tons of hay.

Comparative acre yields of corn forage and alfalfa hay.

	Total yield		Digestible matter	
	Corn	Alfalfa	Corn	Alfalfa
	Lbs.	Lbs.	Lbs.	Lbs.
Crude protein	405	1,602	296	1,198
N-free extract	3,263	4,782	2,186	3,114
Fiber	1,472	2,800	1,060	1,198
Fat	84	246	63	101
Ash	315	829		
Total	5,539	10,259	3,605	5,611

[1] Forage Crops. [2] Bul. 26.

It will be seen that alfalfa yielded nearly twice as many pounds of dry matter as the corn, with the digestible nutrients far in the lead. The digestible crude protein of the alfalfa was about 4 times that of the corn.

244. Alfalfa hay making.—Experience teaches that alfalfa should be cut when about 0.1 of the plants reach the blossom stage, since after that time there is little increase of nutrients, and early cutting materially aids the next crop. The Ottawa Experimental Farms[1] found that 4 cuttings of alfalfa yielded more nutrients than 2 cuttings.

Concerning the making of alfalfa hay, Cottrell of the Kansas Station[2] writes: "There is practically no difficulty in curing any but the first crop. When the conditions for curing the first crop are unfavorable, we have usually found the most practicable method to be to cut the alfalfa in the morning, after the dew is off, allow it to barely wilt in the swath, then rake, and before night put in narrow, tall cocks. After the dew is off the next morning and the surface of the ground has become dry, we open these cocks carefully, so as not to shatter off the leaves. If the weather is favorable the hay may be stacked in the afternoon; if not, we recock carefully, and repeat treatment until the hay is properly cured."

In the humid regions, where more time is required for curing alfalfa, muslin hay caps will be found particularly useful. Headden of the Colorado Station[3] found that from 40 to 60 per ct. of the weight of the alfalfa plant is in its leaves, which carry four-fifths of the crude protein and over half of the nitrogen-free extract and fat. Three-fourths of the fiber, or woody portion, is in the alfalfa stems. Headden further found that, in the dry climate of Colorado, with all conditions favorable, for every ton of alfalfa hay taken off the field not less than 350 lbs. of leaves and stems was wasted, and with unfavorable conditions and careless handling there was a loss of as much as 3,000 lbs. One hundred lbs. of fresh alfalfa yields from 27 to 29 lbs. of cured hay. In one instance alfalfa injured by a succession of showers, aggregating 1.75 inches of water, lost one-third of its protein and one-seventh of the nitrogen-free extract, leaving the per cent of fiber, or woody portion, increased by 12 per ct. Forty per ct. of the nutrients of alfalfa hay can be extracted with tepid water. Cooke of the Colorado Station[4] found that stacked alfalfa loses in an average season one-fifth of its feeding value, a loss which would be largely avoided by storing under cover.

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[1] U. S. Dept. Agr., Farmers' Bul. 215.
[2] Bul. 109.
[3] Bul. 110.
[4] Bul. 57.

245. Alfalfa hay as a feed.—No other roughage on the farm is possible of wider use than alfalfa hay. For road horses it is not of much value, being too laxative and causing the animals to sweat freely. However, it can be used with all classes of horses to some extent, and largely with those at slow, steady work. (**440**) When fed to fattening steers alfalfa hay tends to the more rapid laying on of fat, thereby reducing the quantity of concentrates required for a given gain. (**548, 553**) For the dairy cow there is no better feed, for alfalfa hay is rich not only in crude protein but in mineral matter—prime requisites in milk production. (**672-5**) For sheep feeding alfalfa hay leads the roughages, (**762-6**) and it can be used to a limited extent with fattening hogs, and largely employed in maintaining shotes and breeding swine during winter. (**903**)

Understanding the composition and nature of alfalfa hay the stockman can feed it to all farm animals with economy and satisfaction. On every farm where stock is kept there should be an effort made to grow alfalfa. If the attempt results in failure, recourse should be had to red clover or some other legume.

At the New Jersey Station[1] it was found that while alfalfa hay is one of the richest of roughages and approximates bran in crude protein content, its fiber and coarse, bulky nature prevent its entirely taking the place of such concentrates as bran, cotton-seed meal, etc., with cows giving a large flow of milk. Cows fed alfalfa hay in place of all the concentrates lost flesh, and their coats were less smooth and glossy than those getting some meal as a part of their ration. When alfalfa was used to furnish as much as 60 per ct. of the crude protein usually furnished to the cows in the form of bran, cotton-seed meal, etc., there was some shrinkage in milk flow, but a financial saving of over 25 per ct. in the cost of producing the milk. (**675**)

Cottrell of the Kansas Station[2] reports that heifers wintered on alfalfa hay alone made an average gain of 1.2 lbs. per head daily, returning 104 lbs. increase for each ton of hay fed. (**501**)

Alfalfa feeding has revolutionized the sheep fattening industry at the West. In several districts by combining beet pulp from the sugar factories with alfalfa hay, vast flocks of western range lambs and sheep are economically fattened. (**759**)

Cottrell[3] reports that brood sows which lived thru the winter on alfalfa hay with no grain farrowed large, healthy litters of pigs in the spring. Numerous trials at the western stations have established

[1] Bul. 204. [2] Bul. 114. [3] Ibid.

the value and importance of a limited amount of alfalfa hay in the ration of fattening swine. (**903**)

246. Pasturing alfalfa.—Alfalfa is primarily a hay and not a pasture plant, and while it may be grazed with some success in the arid regions, this practice means almost certain failure in the Eastern States. Sheep are particularly severe on alfalfa pasture because they graze so closely. The loss from bloat with animals grazing regularly on alfalfa is small, tho in some cases it reaches 5 per ct. per annum. Stock should not be turned on alfalfa pasture for the first time until the dew is off, and only after they have been so well filled with other feed that they are not hungry and will not overeat. Even tho pigs may injure alfalfa pastures, on account of the high value of the succulent, nitrogenous feed furnished, it is often most profitable to set aside areas of limited size for their use. Hitchcock[1] reports a case where pigs weighing from 30 to 60 lbs. gained 100 lbs. each during the season when turned on alfalfa pasture. At the Kansas Station[2] pigs on alfalfa pasture were given corn in addition. After allowing for the corn, the alfalfa pasture returned 776 lbs. of pork per acre. (**895-6**)

247. Alfalfa for soilage and silage.—Wherever it can be grown in the East, alfalfa will prove the most valuable of all soiling crops, fitting admirably into the soilage system. Voorhees of the New Jersey Station[3] reports that the first cutting is ready about the last of May or the first of June, with 3 cuttings following at intervals of from 4 to 6 weeks. Alfalfa furnishes a more nearly continuous supply of summer forage than any other crop. Voorhees recommends feeding dairy cows from 35 to 40 lbs. of fresh alfalfa forage daily at first, and gradually increasing the allowance to 50 lbs., which will furnish nearly 2 lbs. of digestible crude protein. At the New Jersey Station[4] Voorhees and Lane found that for 3 years alfalfa yielded annually per acre an average of over 18 tons of green forage, or 4.5 tons of hay. Alfalfa is primarily a soilage and hay plant, and while it can be made into silage it is less satisfactory for that purpose than Indian corn, and should only be ensiled when it cannot be successfully cured into hay. (**360**)

248. Alfalfa meal.—Ground alfalfa hay and alfalmo, the latter a mixture of alfalfa meal and beet molasses, are products brought to public notice by the high prices ruling for concentrates. In view of the great palatability of well-cured alfalfa hay and the satisfac-

[1] U. S. Dept. Agr., Farmers' Bul. 215.
[2] Bul. 114.
[3] Forage Crops.
[4] Bul. 148.

tion with which it is eaten, the stockman cannot ordinarily afford to bear the heavy expense incident to grinding and mixing these products and placing them on the market. Where ground feed of rather coarse nature is desired, and in special cases, alfalfa meal may be found profitable. (**673**)

II. Red Clover.

Red clover, *Trifolium pratense,* is found on every well-conducted farm in the northeastern United States, where with grasses it stands prominent in rotation with corn and the cereals, serving for pasture and hay production and for the maintenance of soil fertility.

249. Yield.—At the Wisconsin Station[1] Woll, cutting clover 3 times during the season, secured the results given below:

Yield of three cuttings of red clover.

Date of cutting	Green clover	Dry matter	Dry matter
	Lbs.	Per cent	Lbs.
First crop, May 29	29,220	8.2	2,402
Second crop, July 16	16,020	22.5	3,599
Third crop, September 1	7,221	27.5	1,986

The table shows a total yield per acre of over 26 tons of green forage, equal to 4 tons of hay per acre. From one-half to two-thirds this amount may be relied upon by the stockman as a fair crop under practical conditions. In this case the first crop of clover, carrying but 8.2 per ct. of dry matter, contained more water than is found in skim milk. This crop was cut while lush and green, long before it had reached the proper condition for making hay. The figures are of interest in showing why green clover, when used for soilage, so often proves unsatisfactory. It shows that, cut too early, such forage is mostly water, and the cattle cannot consume enough of it to secure the nourishment they require.

250. Development of nutrients.—Hunt of the Illinois Station[2] has arranged the results of studies of the medium red clover plant, made by himself and Jordan of the Pennsylvania Station, portions of which are given on the next page.

We learn from these studies that the fiber, or woody matter, which is the least valuable carbohydrate of the plant, increased up to the time the blossom heads were dead. On the other hand, the protein, fat, and ash, as well as the nitrogen-free extract, which contains the

[1] Rpt. 1889. [2] Bul. 5.

more valuable carbohydrates, reached their maximum at the time the plants were in full bloom, and diminished in amount after that period. The loss after blooming was probably largely due to the withering and dropping off of the lower leaves on the clover stems. This shrinkage of valuable nutrients in the clover plant after the bloom period is in strong contrast with their continued increase up to full ripening in Indian corn and other grasses, as previously shown. (**16, 238**)

Yield and nutrients in an acre of medium red clover.

Stage of growth when cut	Yield of 1 acre of hay	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Illinois, Hunt						
Full bloom	3,600	217	400	660	1,052	197
Heads three-fourths dead	3,260	196	379	672	1,024	156
Pennsylvania, Jordan						
Heads in bloom	4,210	260	539	1,033	1,731	116
Some heads dead	4,141	226	469	1,248	1,379	106
Heads all dead	3,915	208	421	1,260	1,378	94

The table clearly points to full bloom as theoretically the best date for cutting clover hay. Practical experience, however, places the time somewhat later, or when about one-third of the heads have turned brown. This is because at any earlier date the plant is so soft and sappy that only with difficulty can it be cured into good hay. Delaying until all the heads are dead makes haying still easier, but means poor, woody, unpalatable hay.

251. Methods of haying.—Three methods, each of which has its advantages and its disadvantages, are followed in making clover hay. Under the first system the clover is mown as soon as the dew is off in the morning, and by frequent tedding and turning, aided by bright sunshine, it is housed before 5 o'clock in the afternoon, at which time the gathering dew shuts off further operations. To secure good results under this system the clover must be somewhat past its prime for the best hay, the ground dry and warm, and the weather favorable.

The second system differs from the first only in cutting the clover late in the afternoon so that the dew will not materially affect the plants during the night, as they will then have wilted but little. The following day, with the aid of the tedder, operations should proceed as rapidly as possible, and the crop be placed under cover before night.

By the third method the clover is cut in the forenoon after the dew is off, and remains untouched in the swath until afternoon, when it is raked into loose windrows, and from these bunched into large well-made cocks or miniature stacks before the dew falls. The cocks stand for several days, the clover undergoing a sweating process which is essential in making the finest quality of hay. After sweating and when the weather is favorable, the cocks are carefully opened in large flakes to avoid shattering the leaves. These flakes rapidly give off their moisture, and the material is soon ready for the barn. Hay cured in cocks is sometimes protected by muslin covers or caps to keep off the rain. Whatever the system adopted, great care should be exercised to preserve the leaves and blossom heads, which are easily wasted, leaving only the coarse, woody stems. Under any system of hay making the clover plant should never be placed in barn or stack when carrying moisture from either dew or rain.

252. Losses by faulty curing.—According to Wolff,[1] from 25 to 40 per ct. of the dry substance of clover hay can be extracted by means of cold water. Ritthausen cured one sample of clover hay quickly and allowed another to lie a fortnight in the rain with the results shown below:

	Not rained upon	Rained upon
Water	16.0 per cent	16.0 per cent
Crude protein	14.6 per cent	15.8 per cent
Fiber	25.3 per cent	37.4 per cent
N-free extract and fat	36.1 per cent	23.4 per cent
Ash	8.0 per cent	7.5 per cent

The table shows that rain decreased by one-third the content of nitrogen-free extract and fat, which have high feeding value, while percentagely the woody fiber, of low feeding value, was materially increased, and the crude protein slightly augmented. Rain not only injures hay by washing out the soluble portions, making it more woody, but also destroys the aroma and favors the growth of molds and mildew. (**213**)

253. Spontaneous combustion.—It is now generally conceded that spontaneous combustion may occur in partly dried clover or grass. Hoffmann[2] states that when hay heats, oxygen is taken from the air, and organic matter is transformed into carbon dioxid and water. The water thus formed further moistens the hay, which then ferments, owing to the presence of bacteria. The first fermentation

[1] Farm Foods, Eng. ed., p. 160.

[2] Exp. Sta. Rec., 10, p. 880.

may cause a temperature of 133° F., and this leads to a higher one of about 194° F. When this temperature is reached, the hay heats still more and charring goes on rapidly. All these processes together destroy at least half of the material present. According to tests, clover hay will ignite at 302° to 392° F. Therefore the temperature may become sufficiently high for spontaneous combustion, which is indicated by the hay becoming darker in color and finally black, by sooty odors, and by smoke. It is probable, tho not certain, that spontaneous combustion does not occur in partially dried clover or grass even if quite damp, provided it carries only its own natural moisture. Spontaneous combustion generally, and possibly always occurs in stored or stacked hay that carries external moisture in the form of dew or rain. The trouble is best avoided by never placing hay material in stack or barn when it carries excessive moisture or is wet with dew or rain. When curing hay heats dangerously high it should be compacted and covered with other material and all other possible means taken to shut out the air. Rarely are the arrangements for putting out fires by water sufficient or available.

254. Use of clover.—Clover hay is successfully and economically used in many cases with both farm and city horses. Mr. T. B. Terry,[1] the well-known farmer-writer, maintained a team of farm horses for several years on clover hay with no grain allowance of any kind. There are instances of successfully managed livery stables feeding clover hay to driving horses. Only the best grades should be used and the animals gradually accustomed to this roughage. (**439**)

No investigations of the experiment stations in cattle feeding have been more helpful than those showing the great value of the legumes, including clover hay, for fattening cattle. By adding clover hay to the ration the grain required by the fattening steer can be materially reduced and the fattening period shortened—both matters of great importance in these days of high-priced concentrates. (**546-7, 554**)

For the cow, clover hay is one of the best of all roughages. It furnishes the large amount of crude protein so essential to milk production, and is palatable and much relished. Clover hay is unusually rich in lime, which is needed by the cow in large quantity, and is often otherwise supplied in but meager amount in her feed. Where well-cured clover hay furnishes one-half or two-thirds of the roughage, the dairyman is able to cut down the allowance of

[1] Our Farming.

concentrates and materially reduce the cost of the ration. (**665**) For sheep, calves, and young stock generally, clover or other legume hay is all-important. (**501, 764**) Chaffed clover hay, or, better, the leaves and finer parts which shatter from it, when softened with water and mixed with their slop, serve a useful purpose with swine, especially breeding stock. (**902**)

Clover pasture is helpful and important for all farm animals. For pigs it furnishes about sufficient food for maintenance, so that all the grain fed goes for gain. Clover-pastured pigs are healthy and have good bone and constitution—points of special importance with breeding stock. (**899**) To forestall bloat or hoven, cattle and sheep should not be turned on clover pasture for the first time while hungry or before the dew has risen. As a preventative, dry forage, such as hay or straw, should be placed in feed racks in the pasture. To these cattle and sheep will resort instinctively when bloat threatens.

Clover is particularly valuable for soilage, ranking next to alfalfa among the legumes available for that purpose. By cutting clover early, it at once starts growth again if the weather is favorable, and will furnish three or four cuttings annually. In a few cases clover has made fair silage, but so many failures have occurred that this plant cannot be recommended for such purpose except where weather conditions prevent its being properly cured into hay.

III. Other Clovers and Leguminous Forage Plants.

255. Mammoth clover, *Trifolium medium.*—The distinctive characteristics of mammoth clover are its rank growth, coarse stems, and blooming two or three weeks later than the medium variety. Since it yields but one cutting during the season, this clover is frequently pastured for several weeks in the early spring. After the stock is removed the plants shoot up and are soon ready for the mower. Wallace[1] recommends that for pasture medium and mammoth clover seed be sown in equal proportions, together with grasses, holding that since the mammoth variety blooms later there is more nearly a succession of good forage than is possible with only one variety.

256. Alsike clover, *Trifolium hybridum.*—This variety of clover has weak stems which fall to the ground unless supported by attendant grasses. Well-made alsike hay ranks with the best, tho the

[1] Clover Culture.

yield is not large. At the Illinois Station[1] Hunt and Morrow secured 1.2 tons of alsike hay per acre against 2.1 tons of medium clover. Alsike flourishes on land that is too acid or too moist for other clovers, tho it will not grow in really wet soils. While red clover usually dies out the second year, alsike often lives for several years, a feature which greatly increases its value for pasture.

257. Crimson clover, *Trifolium incarnatum.*—This plant grows best in the region south of New York and east of the Mississippi river, flourishing in the middle Atlantic seaboard states. It has proved vastly helpful to agriculture in Delaware and Maryland. Crimson clover is an annual, thriving best when sown in the fall, in which case it blossoms the following spring, and, producing seed, dies by early summer. While its main use has been to enrich the soil, it furnishes green forage, and makes hay of fair quality when cut early. Garrison of the South Carolina Station[2] reports a yield of over 7 tons of green and 1.75 tons of dry crimson clover per acre. (**676**)

The blossom heads of crimson clover are covered with minute barbed hairs, which become rigid as the heads ripen. Coville of the United States Department of Agriculture[3] writes: "If overripe crimson clover is fed to horses, the bristly hairs (of the heads) will accumulate in the stomach or intestines in spherical balls, which are increased in size by repeated additions of the same matter to their surfaces, the whole mass tending to become more compact because most of the hairs, upwardly barbed, are constantly pushing toward the center, base foremost. When a ball has reached sufficient size, . . . it acts as a plug in the intestines, interfering with the vital functions, and finally, after a few hours of intense suffering, the horse dies." This trouble can be averted by cutting and curing crimson clover at the proper stage. Hay from overripe crimson clover and the refuse chaff left when seed is threshed should not be fed to horses.

258. Japan clover, *Lespedeza striata.*—This plant has proved most helpful to southern agriculture because it adds nitrogen to the soil, binds it together, prevents washing, and furnishes a nutritious food for stock. On sterile land it grows freely but yields pasture only, while under favorable conditions it reaches a height of from 20 to 30 inches, furnishing in extreme cases as much as 3 tons of hay per acre, which, according to Tracy,[4] is equal to the best clover hay.

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[1] Bul. 15.
[2] Bul. 123.
[3] Div. of Botany, Cir. 8.
[4] Miss. Expt. Sta., Bul. 20.

259. The common field-pea vine.—The common field pea, *Pisum sativum,* var. *arvense,* is grown in Canada and the northern states for seed, for human food, and to some extent for forage. A combination of peas and oats, if cut early, forms a forage of high nutritive quality much appreciated by farm stock, especially sheep and dairy cows. In the grain which this plant furnishes and the hay which it is possible to secure from it, the stockman located far north has a fair compensation for the corn crop which he cannot grow. (**805**)

260. Pea-cannery refuse.—The bruised pea vines with exuding rich juices should never be wasted. If piled in well made stacks, the decaying exterior will preserve the mass within, which becomes silage. Pea-vine silage is useful with all farm animals, especially dairy cows, fattening cattle, and sheep. Crosby[1] reports a lot of 442 western wethers which were fattened on corn and pea-vine silage for 50 days topping the Chicago market. Breeding ewes can be maintained on 5 or 6 lbs. of pea-vine silage and 2 lbs. of alfalfa hay daily.

Where weather conditions are favorable, the pea vines from the cannery can be quickly and economically cured into hay. The vines should be drawn directly from the viner to a clear, airy place where the grass is short, such as a pasture lot or meadow, and there spread out thinly. The hot sun quickly dries the bruised stems and leaves with their exposed juices, and the result is a most palatable, nutritious legume hay, worth, according to Crosby, 20 per ct. more than clover hay.

261. Cowpea vine, *Vigna Catjang.*—This is one of the most important legumes of the South, furnishing grain for humans and animals, as well as soilage and hay. In the Piedmont region of North Carolina cowpeas are planted with sweet sorghum, tho more generally with Indian corn. Under favorable conditions the yield is from 2 to 3 tons of nutritious hay per acre. Duggar of the Alabama Station[2] found that the leaves formed 30 per ct. of the weight of cowpea hay, and were about twice as rich in crude protein as the coarse parts. This is one of the most difficult of plants to cure satisfactorily into hay. Duggar advises wilting the crop, placing it in small cocks and covering with hay caps, to remain until cured. At the South the cowpea vine should assume vastly greater importance than it has as yet done. It should be extensively used with

[1] U. S. Dept. Agr., Bur. Plant Indus., Cir. 45. [2] Bul. 118.

corn forage as a silage crop, thereby greatly reducing the cost of a properly balanced ration.

In a feeding trial with dairy cows at the New Jersey Station[1] the substitution of cowpea hay for wheat bran and dried brewers' grains caused a shrinkage of 7 per ct. in the milk flow, but reduced the cost of the ration 30 per ct. In a feeding trial with dairy cows at the Alabama Station,[2] substituting cowpea hay for wheat bran effected a saving of 23 per ct. in the cost of the ration. Cowpea hay may be successfully substituted for at least half the concentrates in the ration for cows and fattening steers. (**442, 554, 557-8, 678, 766, 897**)

262. Hairy vetch, *Vicia villosa.*—The hairy vetch is a legume of increasing importance, attaining special prominence in Washington and Oregon, where it flourishes to a surprising degree. The seed should be sown in the fall with rye, the stems of which will support the weak vetch vines, the latter being from 4 to 10 feet long. Vetch can be used to a limited extent for pasture or extensively as soilage, and finally it may be cured into a nutritious, useful hay. At the South Carolina Station[3] hairy vetch yielded 1.5 tons of hay per acre. French of the Oregon Station[4] reports a yield of 19 tons of green vetch per acre. Pigs grazing on vetch at that station gained 0.68 lb. per head daily, proving it to be one of the most valuable of forage plants for swine, ranking with alfalfa. Spillman of the Washington Station[5] reports a yield of 1 ton of straw and over 14 bu. of seed per acre. (**680**)

263. Velvet bean, *Mucuna pruriens,* var. *utilis.*—The tropical velvet bean plant flourishes south of a line drawn from Savannah, Georgia, to Austin, Texas. The vines, which sometimes run 75 ft., are difficult to cure into hay, and are used mostly for grazing. Scott of the Florida Station[6] reports a yield of 20 to 30 bushels of 60 lbs. each of shelled beans per acre and that 3 lbs. of beans in the pod are equal to 1 lb. of cotton-seed meal for milk production. Tracy[7] reports that 20 acres sown to velvet beans in Florida furnished half the daily grazing for 30 cows during 27 days in winter, after which 10 tons of beans in pod were harvested. Eighty acres of velvet beans in southern Georgia furnished grazing for 100 head of cattle for 4 months. Seventy days' grazing on velvet-bean pasture was sufficient to put steers in marketable condition. (**555**) Scott of the

[1] Bul. 174.
[2] Bul. 123.
[3] Bul. 123.
[4] Bul. 35.
[5] Bul. 41.
[6] Bul. 102.
[7] U. S. Dept. Agr., Farmers' Bul. 300.

Florida Station[1] states that the fat of pigs fed on velvet beans has a dark, dirty appearance and a disagreeable odor and taste, which may be avoided by feeding corn, cassava, etc., with a limited quantity of beans. The charge that velvet beans cause abortion among cattle and swine and blind staggers with horses is substantially without foundation. If exclusively fed on velvet-bean hay, horses may suffer from kidney trouble, but all danger may be averted by feeding equal parts of velvet-bean and crab-grass hay.

264. Peanut-vine, *Arachis hypogaea.*—Newman of the Arkansas Station[2] reports hay of the peanut vine close in value to that from alfalfa and clover. Hay from the entire peanut plant was found rather superior to a ration composed of ordinary hay and corn as a feed for horses and mules. The yield is from 1 to 3 tons per acre. (**557, 900**)

265. Beggar weed, *Desmodium tortuosum.*—This legume is used both for green forage and for hay production in the sub-tropical regions of our country. Garrison of the South Carolina Station[3] reports a yield of over 11.5 tons of green and 2.25 tons of dry forage from 1 acre. Smith[4] states that on rich lands yields of from 4 to 6 tons of hay are not unusual.

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[1] Bul. 102.
[2] Rpt. 1905.
[3] Bul. 123.
[4] Yearbook, U. S. Dept. Agr., 1897.

CHAPTER XIII.

MISCELLANEOUS FEEDING STUFFS.

I. Roots and Tubers.

266. Yield of root crops.—The Cornell Station[1] secured the following yields of fresh and dry matter per acre with various root crops during three years of field trials. Potatoes are added for comparison:

Yield, water, and dry matter per acre in various root crops.

Root crop	Yield	Water	Dry matter
	Tons	Per cent	Lbs.
Sugar beet	23.8	85.1	7,090
Half sugar mangel	26.6	88.9	5,880
Mangel	23.6	89.1	5,155
Rutabaga (swede)	23.0	88.6	4,331
Carrot	12.6	87.6	3,134
Parsnip	8.1	80.7	3,130
White turnip	12.9	89.6	2,680
Potato (200 bushels)	6.0	79.1	2,508

267. Sugar beet, *Beta vulgaris,* var.—This root has been marvelously developed for the single purpose of producing sugar. Because it sets deep in the ground the sugar beet is more expensive to cultivate and harvest than most other roots. If liberally fed, this root is liable to produce scouring because of its high sugar content. Farmers patronizing sugar factories should utilize cull beets as well as the tops. (**656**, **757**, **873**)

268. The mangel, *Beta vulgaris,* var.—Tho the most watery of all roots except the white turnip, the mangel has a high total dry matter content because of its enormous yield. As the large roots stand well out of the ground, the mangel is easily cultivated and harvested. Tho it yields less dry matter per acre than the sugar beet, only half the labor is required to harvest the mangel, and furthermore this root keeps better than the sugar beet. The mangel is useful for all kinds of farm stock except possibly the horse. Day of the Ontario College[2] found that equal weights of pulped mangels and grain caused pigs to fatten faster and on less dry matter than

[1] Bul. 243. [2] Rpt. 1901.

did grain alone. The bacon from the root-fed pigs was superior to that from pigs getting grain only. The danger to sheep of calculi or stones in the kidneys and bladder from mangel feeding has been pointed out by the Iowa Station. (**563, 567, 660-1, 758, 874**)

269. Rutabaga, *Brassica campestris.*—The rutabaga or swede ranks next to the mangel in ease of cultivation and harvesting. Sheep prefer it to all other roots. Like other turnips, the rutabaga may taint the milk of cows, and for this reason should be fed immediately after milking. This root is of vast importance to the stock interests of Great Britain and is likewise a favorite with stockmen of Canada, where it is extensively grown. (**444, 567, 768**)

270. Flat turnip, *Brassica rapa.*—This watery root yields less nutriment than the rutabaga, and is not so satisfactory for stock feeding. Sown as a catch crop, large yields are often secured at small cost. It is used mainly for sheep, but can be fed to cattle.

271. Parsnip, *Pastinaca sativa.*—The parsnip is a favorite root with the dairy farmers on the islands of Jersey and Guernsey. Since it contains more nutriment than most roots, and is easily grown, its use should be more general.

272. Carrot, *Daucus Carota.*—This root is relished by horses of all ages and conditions. Being watery, it cannot be fed in quantity to hard-worked or driving horses. Carrots also serve well for other stock, especially dairy cows. Hills of the Vermont Station[1] writes: "Carrots far surpassed beets in feeding value." (**444**)

273. Potato, *Solanum tuberosum.*—Despite the relatively poor showing made by the potato in the foregoing table, it often happens that the farmer has large quantities of these tubers which should be fed to stock rather than forced on a profitless market. According to Fjord's experiment, 400 lbs. of potatoes are worth 100 lbs. of mixed grain for pig feeding. Trials by the author showed that 445 lbs. of potatoes, when cooked, were equal to 100 lbs. of corn meal for pigs. Potatoes should be cooked and mixed with meal for pigs, and for sheep and cattle they should be sliced. The heavy feeding of raw potatoes induces scouring. Hills of the Vermont Station[2] found the butter from cows fed a heavy potato ration to be salvy and poor. (**444, 875**) In Germany potatoes are sometimes dried and ground to a meal for stock feeding, 3.8 tons of raw potatoes making 1 ton of the dessicated or dried product.[3]

274. Jerusalem artichoke, *Helianthus tuberosus.*—Goessmann of the Massachusetts Station[4] reports artichokes yielding at the rate

[1] Rpt. 1907.
[2] Rpt. 1896.
[3] Daily Cons. and Trade Rpts., 1910, 3716.
[4] Rpt. 10.

of 8.2 tons per acre. Artichokes may be harvested in the same manner as potatoes, or hogs may be turned in the field to root out the tubers. At the Oregon Station[1] 6 pigs confined to one-eighth of an acre of artichokes gained 244 lbs., consuming 756 lbs. of ground wheat and oats in addition to the tubers. Allowing 500 lbs. of grain for 100 lbs. of gain, we find that an acre of artichokes was worth 3700 lbs. of mixed wheat and oats. The pigs made but little gain on artichokes alone. No individual or community seems to continuously grow and make use of the artichoke—a significant fact. (**444**, **876**)

275. Use and value of roots.—Roots may be regarded as watered concentrates high in available energy for the dry matter they contain. The extensive feeding trials of the Danes show that for the dairy cow a pound of dry matter in roots has the same feeding value as a pound of corn, wheat, barley, or oats.

Roots of some kind are helpful with all domestic animals, their effect being tonic as well as nutritive. Breeders and feeders of exhibition animals find them invaluable. They are usually chopped or sliced before feeding, and should not be fed alone, but always with some dry forage, since they carry much water. The daily allowance of roots may vary from 25 to 50 lbs. per thousand lbs. of animal, according to the dry concentrates and roughage fed. It is usual to put the cut roots into the feed box and sprinkle meal over them. In feeding cattle in Canada and England, roots are quite commonly pulped and spread in layers several inches thick, alternating with other layers of cut or chaffed hay or straw. After being shoveled over, the mass is allowed to stand several hours before feeding, to moisten and soften the chaffed straw or hay. In this manner great quantities of straw may be successfully utilized. (**567**, **768**)

276. Root crops costly.—Despite the advice of agricultural writers during these many years urging the use of roots in the United States, and the example of English and Canadian feeders, who rely so largely on this crop, roots are no more generally grown in this country than they were 50 years ago. The reason is thus stated by Storer:[2] "The well nigh universal cultivation of Indian corn in this country has, practically speaking, done away with the need of growing roots as cattle food. . . . Occasionally a few roots are grown among us, here and there, to be fed out as a relish to animals; but now that the method of preserving corn fodder in silos has become generally understood, it seems improbable that roots can

[1] Bul. 54.

[2] Agriculture, Vol. III, p. 315.

anywhere hold way with Indian corn in places proper for the growth of the latter."

277. Roots v. corn silage.—Grisdale of the Ottawa Station[1] found rutabagas more expensive and not much more effective than corn silage as a milk-producing food. Sugar beets proved the best of the root crops, but were more expensive than corn silage. (**656**) Shaw and Norton of the Michigan Station[2] found that the addition of roots to a balanced ration containing silage increased the yield of milk and fat to a limited extent, but such addition was not economical. They state that some roots may be advantageously employed in feeding cows for records. Hills of the Vermont Station[3] found the dry matter in potatoes less valuable for milk production than an equal weight of dry matter in corn silage.

278. Roots modify the carcass.—At the Utah Station[4] Sanborn, after feeding trials with roots, wrote: "(1) The live weight gain for cattle and sheep was greater, and for hogs less, when fed on roots. (2) The dressed weight of cattle, sheep, and hogs showed in every case greater shrinkage for those fed on roots. (3) The root-fed animals contained more blood and necessarily more water in the blood. (4) The root-fed steers had heavier vital organs. (5) The fat was always less for the root-fed animals." Thus we learn that roots cause a more watery carcass than do dry feeds. May not this be a point of value and importance with breeding stock and animals in the early stages of fattening? The shote pastured on clover or rape likewise has watery tissues, yet it afterwards fattens most economically. Grass-fed steers are in the best possible body condition to make rapid gains when changed to more solid feed. A steer fed roots during part or all of the fattening period should remain more vigorous and make better gains for feed consumed than one held on dry feed from start to finish. There is no doubt that, for breeding stock, less tense and more watery flesh, a natural sequence of root feeding, is more conducive to vigorous young at birth and to their hearty maintenance after birth than is the condition of hard, dry flesh produced by feeding only dry forage thru our long winters. The dairy cow takes kindly to succulent feed. Whenever by the use of dry feed alone we can produce beef cattle and mutton sheep equal to those of Great Britain, where roots are so generally used, and cows so universally good as those of Jersey, where kale, cabbage, and roots are liberally fed, then and not until then may we say that there is no place for roots or other succulent feeds during

[1] Rpt. 1904. [2] Bul. 240. [3] Rpt. 1896. [4] Bul. 17.

winter on American stock farms. Admitting that the corn crop is superior to the root crop over much of our country, stockmen should watch lest, failing to make the proper use of the one, they also neglect the other.

II. Fruits and Forage Plants.

279. Apple, *Pyrus malus.*—Withycombe of the Oregon Station[1] fed 3 shotes all the apples they would eat, 897 lbs. of apples producing 38 lbs. of gain in 14 days. During the second period of 15 days, 1,119 lbs. of apples gave only 3 lbs. of gain. In another trial lasting 79 days 3 sows showed a gain of 36 lbs., or 1 lb. of increase for each 64 lbs. of apples fed. Clark of the Utah Station[2] found that: ''Apples fed to pigs in 2 experiments with skim milk and shorts had a value ranging from nothing to 18 cents per cwt. In one trial apples were only equal to grass pasture.''

From trials with dairy cows at the Vermont Station,[3] Hills concludes that apples have about 40 per ct. of the feeding value of corn silage. Lindsey of the Massachusetts (Hatch) Station[4] concluded that 4 lbs. of apple pomace equals 1 lb. of good hay for cows. From 15 to 30 lbs. of pomace may be fed daily to cows with advantage. (**657**)

280. Pumpkin, *Cucurbita Pepo.*—As a result of several trials, Hills of the Vermont Station[5] found that 2.5 tons of pumpkins, including seeds, was equal to 1 ton of corn silage for dairy cows. French of the Oregon Station[6] found that 200-lb. pigs, when daily consuming 26 lbs. of cooked common yellow field pumpkins and a small allowance of wheat shorts, gained 1.5 lbs. daily. (**880**) There is a tradition among farmers that pumpkin seeds increase the kidney excretions and should be removed before feeding. The United States Dispensatory states that the pumpkin seed is a vermifuge, with no reference to any other property. The seeds contain much nutriment and should not be wasted.

281. Cabbage, *Brassica oleracea.*—On rich ground, cabbage gives as good returns of palatable forage as do root crops. It is highly prized by shepherds when preparing stock for exhibition. Gill of England[7] states that cabbage is superior to swedes (rutabagas) for milk production and does not give an unpleasant flavor to the milk.

282. Rape, *Brassica Napus.*—Largely thru the instrumentality of our experiment stations rape is now extensively grown by stockmen

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[1] Bul. 80.
[2] Bul. 99.
[3] Rpt. 1901.
[4] Rpt. 1904.
[5] Rpt. 1908.
[6] Bul. 54.
[7] Jour. Brit. Dairy Ass'n, 1898.

thruout the United States. This member of the turnip family stores its nutriment in the numerous leaves and stems, the parts eaten by stock. The Dwarf Essex variety should be sown, bird-seed rape being worthless. While rape can be used for soiling, it is best to let stock harvest the crop. Rape is too watery for silage. The seed may be sown from early spring until August at the North and later at the South, either broadcast, in drills and cultivated, or finally with corn just previous to the last cultivation. In from 8 to 12 weeks after seeding the crop is large enough for use. Zavitz of the Ontario College[1] reports a yield of 27 tons of rape forage per acre from 2 lbs. of seed sown in drills 27 inches apart, the crop having been cultivated every 10 days.

Cattle which during the fall months have the run of a rape field, together with pasture, will go into winter quarters in high condition. To avoid tainting the milk, rape should be fed or grazed directly after milking only. Swine having the run of a rape field, along with clover or blue-grass pasture and grain, find in the rape both succulence and nutriment. Rape alone will, however, cause pigs to put on but little gain. Pigs, especially the white breeds, running in rape when the leaves are wet, may suffer from a skin affection. (**895, 899**) Rape has its largest use on sheep farms, and, since the sheep gather the crop, its cost is insignificant compared with the returns. Cabbage, rape, turnips, etc., like all cruciferous plants, have an unusually high content of sulfur, which may explain in part their high value with sheep. (**760, 761**) Access to clover or blue-grass pasture when on rape is highly advantageous to all stock, besides preventing bloat or hoven. When feeding grain to rape-pastured stock, the rape will about support the animal, leaving the grain to go wholly for making gain. The stockman, familiar with the value, uses, and methods of growing rape, will prize this easily grown crop.

283. Spurry, *Spergula arvensis.*—The dairy farmers of Holland and other European countries cultivate spurry to some extent. The plant has, however, proved of little value in this country and should be let alone.

284. Prickly comfrey, *Symphytum asperrimum.*—This plant, occasionally exploited by advertisers, has little merit in comparison with the standard forage plants. When carefully cultivated it gives quite large returns of forage which at first is not relished by

[1] Rpt. 19.

cattle. Woll of the Wisconsin Station[1] found that red clover returned 23 per ct. more dry matter and 25 per ct. more crude protein than the same area of carefully cultivated prickly comfrey.

285. Purslane, *Portulaca oleracea.*—The succulent weed of the garden, purslane, can often be used to advantage with swine. Plumb of the Indiana Station[2] fed brood sows 9 lbs. of purslane each daily, along with wheat shorts and hominy meal, and secured fair daily gains.

286. Acorns.—In some portions of the South and in California, acorns, the fruit or nut of the oak, *Quercus,* spp., are of importance in swine feeding. Carver of the Tuskegee (Alabama) Station[3] reports the successful feeding of acorns and kitchen slop to 400 pigs, allowing about 5 lbs. of acorns to each pig, daily. Acorns make a soft, spongy flesh and an oily lard, which can be overcome by feeding corn for 2 or 3 weeks before slaughtering time.

287. Tree leaves and twigs.—The small branches and leaves of trees are regularly fed to farm animals in the mountain regions of Europe where herbage is scarce, and in case of the failure of pastures or the hay crop they have been extensively used elsewhere. Tree leaves are more digestible than twigs, and the better kinds compare favorably with ordinary hay in feeding value. Leaves of the ash, birch, linden, and elder are valued in the order given. They are eaten with relish, especially by goats and sheep. These statements apply only to leaves gathered at the right stage and cured substantially as is hay from the grasses. Leaves which turn brown and drop from the trees in autumn are worthless for feeding farm animals.

III. Underground Forage Available at the South.

Pork production has great possibilities at the South where various underground crops which can be cheaply grown may be gathered by pigs. This line of opportunity is worthy of considerate attention by southern farmers, since it means not only greatly increased meat production but also improvement of the soil.

288. Sweet potato, *Ipomaea Batatas.*—Duggar of the Alabama Station[4] states that an acre of sweet potatoes yields from 10 to 15 times as many bushels as does a corn crop grown on the same quality of land. Both the vines and the roots are used in stock feeding. In a feeding trial with pigs at the above station sweet potatoes gave

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[1] Rpt. 1889. [2] Bul. 82. [3] Bul. 1. [4] Bul. 93.

only fair returns, yet their common use on many southern farms warrants the conclusion that pigs can gather this crop with profit. (**877**) Conner of the Florida Station[1] found that sweet potatoes can be successfully substituted for half the corn in the ration of work horses, 3 lbs. of sweet potatoes replacing 1 lb. of corn. Scott of the same station[2] found that for dairy cows 100 lbs. of sweet potatoes was as useful as 150 lbs. of corn silage. While more valuable, sweet potatoes were also far more expensive to produce than the corn silage. (**565**, **877**)

289. Cassava, *Manihot utilissima.*—This plant, resembling the castor bean in leafage, grows in Florida and along the Gulf Coast. Cassava roots, which are fleshy like those of the sweet potato, yield from 5 to 6 tons per acre, carrying from 25 to 30 per ct. of starch. They are used for the manufacture of starch and for cattle and swine feeding. At Muscogee, Alabama,[3] 200 steers and 100 hogs were fattened by using 1600 lbs. of cassava roots daily in place of grain. The roots appear to be about as useful as corn for swine feeding, and, because of the heavy yield, this plant is full of promise to stockmen in the far South. The cassava waste of starch factories should be dried for feeding. (**565**)

290. Chufa, *Cyperus esculentus.*—The chufa sedge, frequently a weed on southern farms, produces numerous small edible tubers which are relished by pigs. Chufas grow best on light sandy soils, yielding from 100 to 150 bushels per acre. Like artichokes they remain in the ground uninjured thru the winter. Duggar of the Alabama Station[4] hurdled young pigs on a chufa field, giving them corn and cowpea meal additional. The average of 2 trials showed that, after due allowance was made for the grain fed, the chufas produced pork at the rate of 307 lbs., worth over $15, per acre. (**879**)

291. Peanuts, *Arachis hypogaea.*—The yield of peanuts runs from 40 to 100 bushels per acre. Duggar of the Alabama Station[5] has carefully studied the possibilities of the peanut for pork production. In one trial pigs turned into a peanut field made 100 lbs. of gain from 190 lbs. of corn and 140 lbs. of peanuts, together with the vines. The yield in this case was estimated at 63 bushels per acre. The pork returned over $18 per acre against $10 or $12 from the same area planted to cotton. Duggar reports various trials in which peanuts returned from 225 to 432 lbs. of pork per acre when fed in combination with corn, skim milk, etc.. allowance being made

[1] Bul. 72.
[2] Bul. 101.
[3] U. S. Dept. Agr., Farmers' Bul. 167.
[4] Bul. 122.
[5] Buls. 93, 122.

for these feeds. He found the lard from peanut-fed pigs so soft as to be solid only in the coldest weather, but otherwise satisfactory. Finishing off on corn will largely remedy this defect. When consideration is given to the fact that the peanut crop is easily grown, that pigs can harvest it, that the vines are useful for forage, and that, being a legume, the plant greatly improves the soil, the possibilities of this plant in advancing the animal industries of the South become apparent. (**878-9**, **900**)

IV. Plants of the Desert.

Sagebrush, saltbush, and greasewood flourish on the plains of Western America where alkali and common salt shut out many or even all of the ordinary forage plants.

292. Sagebrush.—Writing of the Red Desert of Wyoming, Nelson[1] says: "The amount of sagebrush, *Artemisia,* spp., consumed in the desert is simply amazing. . . . Whole bands (of sheep) will leave all other forage and feed on sagebrush for a day or two at a time. After that they will not touch it for some days, or even weeks."

293. Saltbush, *Atriplex,* spp.—Many species of the saltbush, both annual and perennial, furnish forage to range animals on the Western plains. The Australian saltbush, introduced into California and Arizona, will under favorable conditions produce 15 to 20 tons of green forage per acre, or 3 to 5 tons of dry, coarse hay which has about the same digestibility as oat hay. Peacock of New South Wales[2] reports that sheep fed saltbush in pens lost 3 lbs. in weight per head, but remained healthy during a period of a year. Others getting grass, hay, and saltbush made substantial gains. Saltbush mutton was dry and tough, but had a good flavor.

294. The greasewoods, *Sarcobatus,* spp.—The shrubby greasewoods likewise flourish on the plains and are browsed by range animals. Forbes and Skinner of the Arizona Station[3] report an analysis of greasewood which compared favorably with alfalfa in the amount of crude protein and other nutrients contained. Such forage is readily eaten.

295. Russian thistle, *Salsola kali,* var. *tragus.*—The introduced Russian thistle now grows over great areas of the plains east of the Rockies. It is used to some extent for pasture and hay. The mature

[1] U. S. Dept. Agr., Div. Agros., Bul. 13.
[2] Agr. Gaz. N. S. Wales, 1906.
[3] Rpt. 1903.

plants are woody and loaded with alkali. It should be cut when in bloom and quickly stacked.

296. Cacti.—In western Texas, New Mexico, and Arizona, various cacti, principally prickly pear, *Opuntia*, spp., growing wild on the ranges, are used for feeding cattle, especially during periods of drought. Cacti grow but slowly unless the soil is good and there is reasonable rainfall during some part of the year. Because of its peculiar structure and habits this plant can survive protracted drought, tho it makes little or no growth at such times. Under favorable conditions the prickly pear may be harvested about once in 5 years. In Texas Mexican teamsters make free use of the pear for feeding their work oxen, and some rangemen have fed large quantities along with sorghum and cotton seed or cotton-seed meal to their fattening cattle. Cacti may be fed where they grow by first singeing off the spines with a gasoline torch, after which the cattle eat them with apparent satisfaction. Under favorable conditions a man can singe the spines from 6 to 12 tons of standing "pears" per day. In some cases the pears are gathered in wagons and put thru machines which chop them in such manner that the spines are rendered more or less harmless.

The prickly pear ranges in value from one of the least valuable of feeds to about the equal of the mangel beet. The full-grown steer requires from 125 to 200 lbs. of the pear daily, and the dairy cow should have from 40 to 70 lbs., along with some other more nutritious feed, for she cannot maintain a flow of milk on the pear alone. Cotton seed, cotton-seed meal, and sorghum hay go well with the pear. Griffiths[1] found that cactus-fed steers made an average gain of 1.75 lbs. each per day, requiring 55 lbs. of pear and 2.5 lbs. of cotton-seed meal for each lb. of gain. When fed with rice bran and cotton-seed meal, about 6 lbs. of fresh pears equaled 1 lb. of dry sorghum hay in feeding value for the dairy cow.

Spineless cacti have long been known and grown in Mexico. These cacti cannot survive on the range because cattle will graze and destroy them. On the other hand, in its wild state the prickly cactus is able to grow and hold its own on the ranges of the Southwest. When pasture is reasonably abundant the animals do not feed on the cacti, so that when serious droughts come on, this forage is available and proves most valuable. It seems reasonable to hold that in

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[1] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 91.

most cases there are other more refined and productive agricultural plants which will serve the cattlemen of the plains better than cacti, if plants which require protection and cultivation are to be grown.

V. Cow's Milk and its By-products.

From its nature and purpose it is reasonable to hold that normal milk contains all the nutrients necessary to sustain the life of young animals and that these are arranged in proper proportion. For this reason milk is of peculiar interest to the student of animal nutrition. The solids of milk are 98 per ct. digestible, exceeding all other common feeding stuffs in digestibility.

297. Colostrum.—The first milk yielded by the mother for her young, called colostrum, is thick and viscous and differs from ordinary milk in being rich in protein and ash, that of the cow being low in fat and milk sugar. The following table shows the average composition of colostrum and normal milk of various farm animals:[1]

Composition of colostrum and normal milk.

Animal and character of milk	Water	Protein	Fat	Sugar	Ash	Nutritive ratio
	Per cent	Per cent	Per cent	Per cent	Per cent	
Cow, colostrum	75.1	17.2	4.0	2.3	1.5	1:0.7
Cow, normal	87.3	3.4	3.7	4.9	0.7	1:3.9
Ewe, colostrum	61.8	17.1	16.1	3.5	1.0	1:2.3
Ewe, normal	80.8	6.5	6.9	4.9	0.9	1:3.1
Sow, colostrum	70.1	15.6	9.5	3.8	0.9	1:1.6
Sow, normal	84.1	7.2	4.6	3.1	1.1	1:2.0

The high protein content of colostrum is largely due to its excess of albumen, which causes such milk to clot on heating. Colostrum is laxative and highly important for cleansing the alimentary tract of accumulated fecal matter and properly starting the work of digestion. During the week following birth the yield of milk usually increases and its composition gradually changes to the normal.

298. Milk sugar.—Cow's milk contains from 4 to 5 per ct. of milk sugar or lactose. Commercial milk sugar is a white powder of low sweetening power and is much less soluble than cane sugar, which it resembles in chemical composition. It has about the same feeding value as the same weight of starch. When milk sours, some of the sugar is changed to lactic acid, which curdles the casein. When

[1] König, Chem. Nahrungs-und Genussmittel, Vol. I, 1903.

about 0.8 of 1 per ct. of acid has developed, this fermentation ceases, so that sour milk may still contain milk sugar.

299. Milk fat.—Cow's milk contains from about 3 to above 5 per ct. of fat, the amount varying with the breed, individual, etc. The percentage of fat varies greatly between the first and last milk drawn at each milking, as the following table by Babcock of the Wisconsin Station[1] shows:

Composition of first and last milk from the cow.

	Water	Solids	Fat
	Per cent	Per cent	Per cent
First milk drawn	88.73	11.27	1.07
Strippings	80.37	19.63	10.36

It will be seen that the last drawn milk contained about 10 times as much fat as that first drawn. (**597**)

300. Ash.—One hundred lbs. of cow's milk supplies about 0.20 lb. of phosphoric acid, 0.17 of lime, and 0.17 of potash.

301. Whole milk.—With rare exceptions whole milk is too valuable for feeding to stock, tho one should never hesitate to supply it when required by very young or valuable animals. Young stock being prepared for exhibition can be forced ahead rapidly by the judicious use of unskimmed milk. (**123**, **473**, **492-4**, **881**)

302. Skim milk.—Because of the protein and ash it carries skim milk is of high value in building the muscles and bony framework of young animals. While great care and good judgment are necessary in feeding skim milk to calves, it serves its highest purpose when so used. According to Pott,[2] the horses of the Coöperative Association of Hamburg are fed large quantities of skim milk and buttermilk. (**474-6**) For pigs, from 5 to 6 lbs. of skim milk has the feeding value of 1 lb. of corn. It should always be fed in combination with corn, barley, or other carbohydrate-rich feeds. (**882-5**)

303. Buttermilk.—This by-product has substantially the same composition as skim milk, tho it is usually somewhat richer in fat. In eastern Prussia suckling foals are fed buttermilk and sour skim milk. Some feeders use buttermilk successfully in rearing calves, tho most efforts are failures. (**477**) Tests at the Massachusetts Station[3] show that buttermilk has the same feeding value as skim milk for pigs. (**886**) Creameries often dilute buttermilk with water, thereby re-

[1] Bul. 18. [2] Futtermittel, p. 645. [3] Buls. 13, 18.

ducing its value. If allowed to ferment in dirty tanks it may become a dangerous food.

304. Whey.—Whey is a poor feed for calves and can be used only in a limited way at best. (**478**) For pigs it has about half the value of skim milk. It should be fed in combination with wheat middlings, corn, linseed oil meal, etc. At the Ontario Agricultural College,[1] Day secured as good results with whey, somewhat soured, as with sweet whey. The feeder should not conclude from this that decomposing whey held in filthy vessels is a suitable feed for stock. (**887**)

305. Spreading tuberculosis.—Since milk from different farms is mixed at the creamery or cheese factory, the germs of bovine tuberculosis may be widely spread from a diseased herd in the skim milk, buttermilk, or whey. The careful farmer will insist that these products be first pasteurized at the factory, as is successfully done in Denmark.

VI. Slaughter-house, Sugar-factory, and Distillery By-products.

306. Flesh waste.—The slaughter houses now furnish to the feeder great quantities of by-products, such as meat meal, beef meal, tankage, dried blood, etc. These are usually extremely rich in protein, and those carrying bone are also rich in lime and phosphorus. Farm animals rarely object to these feeding stuffs and they are highly digestible. Owing to the high prices which such feeds command, the feeder should understand their nature and know how to compound them with other feeding stuffs in order to make the most of them. Shaw of the Michigan Station[2] found that tankage could successfully take the place of skim milk in pig feeding from weaning time on, a fact of importance to many stockmen. (**888-891**) According to Wolff,[3] meat meal has been found satisfactory in cattle feeding. For cows and oxen a limited quantity should at first be supplied, the amount being gradually increased until each animal receives 2 or 3 lbs. daily. Sheep digest meat meal as completely as do pigs, and thrive on it.

La Querriere[4] states that boiled meat meal mixed with hay and straw is excellent for horses. The Arabs feed their horses camel's flesh mixed with other feed in the form of cakes. Scheurer[5] has shown that meat scrap, mixed with ground grain and baked into a bread, can be kept 7 years without deterioration. English army horses

[1] Rpt. 1896.
[2] Bul. 237.
[3] Farm Foods, Eng. ed., p. 204.
[4] Milchzeitung, 1881, p. 753.
[5] Loc. cit.

fed American meat, made into biscuits with oats, showed superiority over those fed in the ordinary way. Meat biscuits have been recommended for feeding race horses. Dried blood, the richest of all these products, is particularly useful with young pigs and calves. (**485**)

Since tankage is in part produced from the carcasses of diseased animals, the question arises whether it may not carry disease to animals fed on it. Mohler and Washburn,[1] who have studied the matter, write: "As tankage is thoroly steam-cooked under pressure it comes out a sterilized product, and owing to its dryness there is little danger of infection." None of the many stations that have fed tankage have reported any trouble of such nature.

307. Dried fish.—Along the coasts of Europe the waste parts of fish, as well as entire fishes not used for human food, are fed in dried form to animals. Speir of Scotland[2] reports no bad influence on milk when reasonable quantities of dried fish are fed to dairy cows. Nilson[3] found that 80 parts of herring cake could replace 100 parts of linseed cake in the ration for cows. The better grades of dried fish meal should be used for feeding farm animals.

308. Bone meal and ground rock phosphate.—Trials at the stations have shown that pigs fattened largely or entirely on corn will profit greatly by the addition of bone meal or ground rock phosphate to the ration. The production of milk makes a steady drain on the cow for lime, phosphorus, etc., which often causes a depraved appetite, shown by eating horse manure, chewing old bones, etc. This craving can often be satisfied by adding bone meal or probably ground rock phosphate to the ration. Colts and growing horses may likewise be benefited by such addition to their rations. (**90, 892**)

309. Wet beet pulp.—This by-product, of great volume at the beet factories, contains about 90 per ct. water and 10 per ct. solids. The dry matter of wet beet pulp is equal to that of roots in feeding value, and the pulp can be used in the same manner as are roots for feeding farm animals. The Colorado Station[4] found that 1 ton of wet beet pulp had about the same feeding value as 200 lbs. of corn for fattening lambs. The wet pulp is relished by dairy cows and produces a good-flavored milk. For fattening steers alfalfa or clover hay should be combined with the pulp, but no concentrates should at first be fed. On this combination the animal will for some time gain rapidly in weight, tho the flesh will be soft and watery. After a time such concentrates as corn, barley, etc., should be gradually sub-

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[1] U. S. Dept. Agr., Bur. Anim. Indus., Cir. 144.
[2] Trans. Highl. & Agr. Soc., 1888, pp. 112–128.
[3] Kgl. Landtbr-Akad. Handl., 1889, p. 257.
[4] Bul. 76.

stituted for a part of the wet pulp, so that 6 weeks prior to the close of the feeding period no pulp is fed, but concentrates instead.[1] Because the beet pulp ferments quickly it is usually sour when fed. Fortunately the soured pulp is best liked by stock.

310. Beet pulp silage.—Maercker[2] found that, owing to fermentation, ensiled wet beet pulp lost rather more than one-fourth of its total nutrients. Such heavy losses teach that, where possible, the pulp should be dried. Where it cannot be dried it may be ensiled the same as corn forage. It keeps quite well if merely piled in large heaps, as the outside mass on rotting protects the interior. The pulp may be better preserved, with or without alternate layers of beet leaves, in shallow, well-drained pits dug in the earth. The pitted mass, extending several feet above ground, should be covered with straw and earth to keep out air and frost. (**360**)

Steers are annually fattened by thousands and sheep by ten-thousands on wet soured beet pulp at the western beet sugar factories. Owing to the high prices of concentrates, and the favor with which the dried pulp is being received by stockmen, the factories are gradually being equipped for drying the pulp. (**541, 644, 759**)

311. Dried beet pulp.—Dried beet pulp is now a by-product of large volume and of increasing importance. Shaw of the Michigan Station[3] found that dried beet pulp compared favorably with corn meal for fattening sheep and steers. It produced larger gains with growing animals, while corn meal put on more rapid gain with fattening animals nearing the finishing period. From German investigations Ware[4] concludes that 1 lb. of dried pulp is equal to 8 lbs. of wet pulp in feeding value. The New Jersey Station[5] secured the best results by softening the dried pulp with water before feeding to dairy cows. (**542, 645, 755**)

312. Beet molasses.—The molasses of the beet sugar factories is a bitter, purging substance containing considerable nitrogenous matter of low nutritive value, together with a large amount of sugar and alkaline mineral matters. European investigators have taxed their ingenuity to utilize beet molasses for feeding farm animals. As one result, it has been found possible to combine molasses with peat dug from the marshes. The dried peat neutralizes the alkali of the molasses and renders it harmless to animals. Clausen and Friderichsen[6]

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[1] Loc. cit.
[2] U. S. Dept. Agr., Bur. Chem., Bul. 52.
[3] Buls. 220, 247.
[4] Cattle Feeding with Sugar Beets, Sugar and Molasses, etc.
[5] Bul. 189.
[6] New Rational Method for the Utilization of Blood, Copenhagen, 1896.

of Denmark have shown that fresh blood will not putrefy when there has been added to it the proper amount of beet molasses, containing 50 per ct. sugar. By adding the blood-molasses mixture to corn meal or other cereal products and drying, a palatable, highly nutritious feed is obtained. Beet molasses may be directly fed in a limited way with chopped straw, hay, or the various concentrates. (**426, 544**) Much of the beet molasses is now utilized by combining it with beet pulp and drying. Molasses-beet pulp is somewhat more palatable than the dried pulp and has about the same feeding value. (**646, 755**)

313. Beet leaves.—At harvest an acre of sugar beets will usually yield about 4 tons of fresh leaves and 1 ton of the severed upper portion of the beet roots. The leaves have about half the feeding value of the roots. Ware[1] reports that the German farmers ensile beet leaves and the tops of the roots in pits about 6 feet deep with rounded corners and slanting sides, 5 inches of leaves alternating with 4 inches of straw. Seven lbs. of salt are used with each ton of leaves. The mass, which extends 3 or 4 feet above the ground level, is covered with straw and earth. As fresh or ensiled leaves tend to purge the animals, they should always be fed in a limited way with such dried roughages as corn stover, straw, or hay.

314. Cane molasses.—Craig and Marshal of the Texas Station[2] describe cane molasses, or black strap, as follows: "It is a thick black mass, having somewhat the color of coal tar, but a pleasant odor and sweet taste." It averages about 50 gals., or 600 lbs., to a barrel and runs on the average 12 lbs. to a gallon or 170 gals. to the ton. The Texas factories produced in 1904 a crop of 32,500 bbls. of this molasses, of which amount 3,000 bbls. were sold to cattle feeders of the state.

The composition of cane and beet molasses is as follows, according to Browne[3] of the Louisiana Sugar Experiment Station:

	Louisiana cane molasses	Beet molasses
Water	20.93 per cent	23.70 per cent
Cane sugar	30.73 per cent	46.70 per cent
Other sugars	29.67 per cent	0.60 per cent
Ash (salts)	8.85 per cent	13.20 per cent
Organic non-sugar	9.82 per cent	15.80 per cent

Unlike beet molasses, that from the cane plant is bland, extremely palatable, and much relished by farm animals. It may be rated equal to the same weight of corn in feeding value. Cane-sugar mo-

[1] Cattle Feeding with Sugar Beets, Sugar and Molasses, etc.
[2] Bul. 86.
[3] Breeder's Gazette, 47, p. 471.

lasses is not only appetizing, but according to Patterson of the Maryland Station[1] tends, when fed in moderation, to increase the digestibility of the other feeding stuffs. Investigations by the Louisiana Station[2] show that the planters of that state use cane-sugar molasses extensively, feeding as much as 10 lbs. daily to each mule. They hold that its use reduces the cases of colic and other digestive ailments, increases the capacity for work, keeps the animals in better flesh, and effects a saving of 15 to 20 per ct. in the cost of maintenance. Marshal and Burns of the Texas Station[3] after several trials conclude that 1 gallon of cane-sugar molasses per head daily is the maximum profitable allowance for fattening steers. (**425, 543**)

Lindsey of the Massachusetts Station,[4] as the result of feeding trials and in view of the high price which cane-sugar molasses commands in many of the northern markets, writes: "No advantage is to be gained by northern farmers from the use of molasses as a feed for dairy stock, pigs, or horses in the place of corn meal and similar carbohydrates, except as an appetizer for animals out of condition and for facilitating the disposal of unpalatable and inferior roughage." Molasses is quite commonly used in preparing animals for shows or sales. Fed in large quantity it is said to be deleterious to breeding animals, leading to sterility, especially with males.

315. Molasses mixtures.—Cane and beet molasses are now extensively used in combination with a wide range of materials, good and bad, to render them more palatable with farm animals. Cocoa waste, peanut hulls, worthless weed seed, as well as the useful screenings and by-products of elevators, flouring mills, breweries, etc., after being sweetened with molasses and dried, are sold under various trade names. Molasses can properly and legitimately be used to improve feeding stuffs of low to fair feeding value. Unfortunately it is often employed to conceal or disguise material having little or no feeding value. Because of the widespread fraud in molasses feeds, they should only be purchased after one has consulted with the feed-control station of his state.

316. Sugar.—Tho sugar has the same nutritive value as an equal weight of starch, the great fondness for it shown by farm animals renders it helpful in some cases. Owing to heavy internal taxes laid upon sugar for human consumption in France and Germany, it is sometimes denatured by mixing it with vermouth powder, lamp black, salt, peat, etc., after which it is used for feeding to animals.

[1] Bul. 117. [2] Bul. 86. [3] Bul. 97. [4] Bul. 118.

317. Dried distillers' grains.—In the manufacture of alcohol, the corn, rye, etc., after grinding are treated with a solution of malt to convert the starch into sugar, which is next converted into alcohol by the action of yeast. This is distilled off and leaves a watery residue, known as distillers' slops or slump. Formerly the slump was fed to fattening steers at the distillery; now it is largely dried in vacuum and the product placed on the market as a cattle feed under various proprietary names. In 1904 Lindsey of the Massachusetts (Hatch) Station[1] placed the annual output of dried distillers' grains at 60,000 tons. Until recently, most of this product was exported to Germany. Dried distillers' grains are rich in digestible crude protein and fat, with a fair content of carbohydrates. Corn makes the richest and rye the poorest dried distillers' grains.

Plumb of the Indiana Station[2] found that horses did not relish dried distillers' grains. At the Kentucky Station[3] May found a combination of dried distillers' grains and corn the most economical of the several rations tested for fattening steers. Lindsey,[4] in a trial with dairy cows, found the grains rather superior to Buffalo gluten feed in nutritive value and in no way objectionable. He recommended that dairy cows receive from 2 to 4 lbs. daily mixed with other concentrates. He valued the grains at 50 per ct. more than wheat bran. Hills of the Vermont Station[5] found that a mixture containing dried distillers' grains produced more milk than one containing dried brewers' grains. (**540, 647, 754, 862**)

VII. Poisonous Plants.

Only the briefest mention can be made of the leading plants poisonous to stock. One in trouble should send suspected specimens to his State Experiment Station or the United States Department of Agriculture.

318. Loco poisoning.—Great numbers of horses, cattle, and sheep have been lost on the great ranges of Western America thru "loco" poisoning brought about by eating various plants, mostly legumes. The loss from this cause in Colorado alone has been estimated at a million dollars annually.[6] "Locoed" animals have a rough coat and staggering gait, carry a lowered head, and show paralytic symptoms—in general, going "crazy." Until recently the source of this plague has eluded solution. The studies of Marsh and Crawford[7] seem to

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[1] Bul. 94.
[2] Bul. 97.
[3] Bul. 108.
[4] Mass. Expt. Sta., Bul. 94.
[5] Rpt. 1903.
[6] U. S. Dept. Agr., Bur. Plant Indus., Bul. 121, Pt. III; Farmers' Bul. 380.
[7] Loc. cit.

show that the poisoning is due to the presence of barium salts in certain legume plants. Barium does not generally exist in the soil, so the dangerous plants are found only in certain districts. Loco poisoning is most prevalent in springtime when the ranges provide scant feed, and the emaciated animals are forced to subsist largely on plants which they would ordinarily reject Well-nourished animals are rarely affected.

319. Plants carrying Prussic acid.—Prussic acid, a most deadly poison, has been found in over 200 species of plants. It is present in the wild cherry, laurel, locust, vetch, Java bean, flax, etc. The leaves of the wild cherry, especially when wilted, are particularly fatal to cattle. Peters and Avery of the Nebraska Station[1] have shown that when sorghum and kafir are stunted by drought, Prussic acid may develop in such quantity as to bring death to cattle browsing upon them, the affected animals often dying soon after eating a few mouthfuls of the poisonous forage. While normal plants are entirely harmless, authorities advise caution in the use of the sorghums, kafirs, Johnson grass, etc., growing on rich soil, as well as in the use of second-growth and stunted plants. The poison is not found in wilted or cured kafir or sorghum, which are therefore always safe for feeding.

320. Cornstalk disease.—A mysterious ailment in the West at times attacks cattle turned into the stalk fields during fall and winter after the corn ears have been removed. All efforts to determine the cause have thus far proved futile. Alway and Peters of the Nebraska Station[2] investigated the losses from cornstalk disease in one county in Nebraska in which 404 farmers lost 1,531 head of cattle during a single fall. They state that no precaution and no feed or combination of feeds has so far been found to prevent or mitigate the losses from this disease. They further conclude that farmers in districts in which the disease is prevalent, unless they are to lose the valuable forage of their corn stalks, must choose between two alternatives: (1) Cutting the stalks when the corn ripens, shocking them in the field and feeding the fodder, thus avoiding all trouble. (2) Pasturing the standing stalks with the knowledge that they are liable to lose as many as one-twentieth of their cattle in an unfavorable season.

321. Ergot.—The seeds of rye and many grasses are sometimes attacked by a fungus which produces enlarged black, sooty masses,

[1] Bul. 77.

[2] Press Bul. 27.

known as ergot. Occasionally hay or straw bearing the fungus severely injures cattle which are continuously fed thereon during winter. Ergot acts on the nervous system, depressing heart action and thereby restricting the blood circulation. In advanced cases the ears, tail, and lower parts of the limbs of affected animals lose warmth and sensibility, dry gangrene sets in, and the diseased parts finally slough away. Animals showing symptoms of this trouble should have their feed changed to remove the cause, and also be warmly housed and liberally supplied with nourishing food.

322. Corn smut.—At the Wisconsin University[1] the author fed 2 milch cows on well-cleaned corn smut mixed with wheat bran, starting with a few ounces and increasing until 32 ounces of smut was supplied daily to each cow. At this point one refused her feed, but the allowance of the other was increased until 64 ounces, or 1 peck, was fed daily. This cow seemed to thrive on the smut and was growing fat, when she suddenly sickened and died. Smith of the Michigan Station[2] fed 4 cows on well-cleaned corn smut until each was eating from 1 to 10 lbs. daily. Only one cow showed any indisposition, and she recovered. In experiments by the Bureau of Animal Industry,[3] United States Department of Agriculture, corn smut was fed to heifers without harmful effect. It is reasonable to conclude that corn smut is generally harmless to cattle, tho animals becoming fond of it and eating inordinately may suffer harm.

323. Castor bean.—The castor bean and the pomace remaining after the oil has been extracted contain a deadly poison. Castor beans or pomace accidentally getting into feeding stuffs sometimes cause mysterious deaths. Carnivan[4] reports that exposing castor oil cake to the air for 5 or 6 days or cooking the seeds or cake for 2 hours destroys the poison.

324. Saltpeter.—Mayo of the Kansas Station[5] reports losses of cattle from eating corn forage carrying quantities of saltpeter in and on the stalks. The dangerous forage had been grown on land previously used as feed lots where the soil was excessively rich.

325. Miscellaneous poisonous plants.—The common horsetail, water hemlock, poison hemlock, death camas, several species of larkspur, cockle bur, and many other plants are more or less poisonous to farm animals.

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[1] Rpt. of Regents, 1881.
[2] Bul. 137.
[3] Bul. 10.
[4] Ann. Soc. Agr., Lyon, 1887.
[5] Bul. 49.

CHAPTER XIV.

SOILAGE—THE PREPARATION OF FEED—STOCK FOODS—FEEDING STUFFS CONTROL.

I. Soilage.

*Soilage** means supplying forage fresh frcm the field to animals in confinement. It was first brought to public attention in this country by Josiah Quincy, whose admirable essays, printed in the Massachusetts Agricultural Journal in 1820, were later gathered into a booklet entitled "The Soiling of Cattle," long since out of print. Soilage is one of the most advanced forms of husbandry, and is especially helpful where it is desirable to concentrate labor and capital in maintaining farm animals on a relatively small area of land. Partial soilage with dairy cows is already widely practiced in this country, and exclusive soilage is growing in favor in the vicinity of large cities.

326. Soilage v. pasturage.—Quincy points out six distinct advantages from soiling: First, the saving of land; second, the saving of fencing; third, the economizing of food; fourth, the better condition and greater comfort of the cattle; fifth, the greater product of milk; and sixth, the attainment of manure.

According to this author there are six ways in which farm animals destroy the articles destined for their food. First, by eating; second, by walking; third, by dunging; fourth, by staling; fifth, by lying down; and sixth, by breathing on it. Of these six, the first only is useful; all the others are wasteful.

Quincy reports his own experience where 20 cows, kept in stalls, were fed green food supplied 6 times a day. They were allowed exercise in an open yard. These 20 cows subsisted on the green crops from 17 acres of land where 50 acres had previously been required. (**663**)

The disadvantages of soilage are: The greater expenditure for labor, seed, and fertilizer in providing the crops and for labor in

* So far as known to the author the word "soilage" was used for the first time in an editorial in the New York Independent of March 11, 1909, by E. P. Powell, the helpful, charming writer on rural topics. It is in a class with the words "leafage," "herbage," "forage," "pasturage," and "silage," and is here adopted as a valuable accession to our all too brief distinctively agricultural vocabulary.

cutting and carrying them to the animals, pasturage costing the minimum for labor. During wet spells the palatability of the forage is reduced, and it is difficult to harvest and cart the food to the animals without injury to the land. On the other hand, pastures also suffer while wet.

327. Blue-grass pasture v. soilage.—At the Wisconsin Station[1] the author kept 3 cows during summer on an excellent blue-grass pasture. During the same period 3 other cows were maintained in stable and yard by soilage. The pastured cows consumed the grass from 3.7 acres, while the soiled cows ate the forage from 1.5 acres. The yield of forage was as follows:

	Pounds
Green clover, 3 cuttings	18,792
Green fodder corn	23,658
Green oats	2,385
Total green forage produced	44,835
Waste from the above	1,655
Total green forage eaten from 1.5 acres	43,180

The products obtained were as follows:

Blue-grass pasture compared with soiling crops.

	From 3.7 acres pasture	From 1.5 acres soiling crops	Returns per acre	
			Pasture	Soilage
	Lbs.	Lbs.	Lbs.	Lbs.
Milk	6,583	7,173	1,780	4,782
Butter	303	294	82	196

This shows that in Wisconsin 1 acre of soilage crops equals about 2.5 acres of good blue-grass pasture for feeding dairy cows. (**223**)

328. Labor involved.—Many who concede the advantages of soilage are deterred from practicing it because of the large amount of labor required in growing, gathering, and feeding the green forage. Wilson[2] shows that green forage gathered twice each week and spread thinly on the barn floor will keep in good condition until required for feeding. Most soilage crops can be cut with a mower, gathered by a horse rake, and loaded with a hay loader. Even if pitched by hand, a large quantity of forage can be gathered in a short time. A cow or steer will require from 60 to 100 lbs. of green forage daily.

329. Partial soilage.—So revolutionary is complete soilage that few farmers are prepared to adopt it. On the other hand, partial soilage

[1] Rpt. 1885. [2] Iowa Bul. 15.

is not only practical but is absolutely essential to reasonable success on most stock farms. The usual midsummer shrinkage in milk flow with cows and in flesh with beef cattle can best be avoided by housing them in darkened stables during the heated portion of the day, and by feeding liberally with fresh-cut green forage, turning the cattle to pasture at night for exercise and grazing. Under this system young animals continue growing, steers increase in fatness, and cows yield a normal flow of milk during a period of the year when, because of heat, flies, and scant pastures, there is usually no profit, but often serious loss. It is also advantageous to supply extra green forage during the fall months, even tho the pastures have then in part recovered their ability to supply nutriment.

330. A soiling chart.—Below is given a soiling chart by Voorhees[1] of the New Jersey Station:

Forage crops grown at the New Jersey Station for the support of a herd equal to 50 dairy cows for 6 months.

Crops grown	Total seed used	Date of seeding	Period of cutting and feeding	Total yield
	Bushels			Tons
Rye, 2 acres	4.0	Sept. 27	May 1–7	9.4
Rye, 2 acres	4.0	Oct. 3	May 7–19	19.2
Alfalfa, 1 acre, 1st cutting	0.6	May 14	May 19–25	11.1
Wheat, 2 acres	4.0	Sept. 26	May 25–June 1	10.4
Crimson clover, 6 acres	1.2	July 16	June 1–21	42.8
Mixed grasses, 1 acre			June 21–26	8.3
Oats-and-peas, 2 acres	4.0 / 3.0	April 2	June 26–July 4	12.4
Oats-and-peas, 2 acres	4.0 / 3.0	April 11	July 4–9	8.2
Alfalfa, 2d cutting			July 9–11	2.1
Oats-and-peas, 5 acres	10.0 / 7.5	April 19	July 11–22	16.4
Southern white corn, 2 acres	0.5	May 2	July 22–Aug. 3	17.7
Barnyard millet, 2 acres	1.4	June 19	Aug. 3–19	23.2
Soybeans, 1 acre	2.0	June 1	Aug. 19–25	8.8
Cowpeas, 1 acre	2.0	June 10	Aug. 25–Sept. 1	10.5
Cowpeas-and-kafir corn, 2 acres	2.0 / 1.0	July 10	Sept. 1–16	24.4
Pearl millet, 2 acres	0.25	July 11	Sept. 16–Oct. 1	20.2
Cowpeas, 1 acre	1.5	July 24	Oct. 1–5	8.0
Mixed grasses, 5 acres (partly dried)			Oct. 5–27	20.0
Barley, 2 acres	3.5	Sept. 2	Oct. 27–Nov. 1	5.2
Total				278.3

This chart is especially helpful as an example of a practical system of soilage, since it records the actual attainment of one who has suc-

[1] Forage Crops, p. 35.

cessfully specialized in this system for many years. The results here reported were obtained upon lands once regarded as of low agricultural value, brought to high productiveness by systematic soilage and fertilization. The table shows that 24 acres of land, producing 2 and sometimes 3 crops during the season, yielded 278.3 tons of green forage, supplying an average of 60.4 lbs. of green forage daily per head to an equivalent of 50 dairy cows from May 1 to November 1, a period of 6 months.

Wherever soilage is practiced there must be a high degree of order and system, so that suitable green forage is available from early spring until late fall, without excess or shortage. Only experience and close study will make it possible for one to successfully carry out the details. This experience in time finds expression in such a soiling chart as the foregoing, which each operator will formulate to meet his own particular conditions.

Otis of the Kansas Station[1] found that it required 0.71 acre of soiling crops, one-half alfalfa, to furnish a cow roughage for 144 days, while, when the cow was grazed, during the same period it required 3.6 acres of pasture composed of prairie and mixed grasses. After allowing for the grain consumed, soilage returned $18.08 and pasturage $4.23 per acre. Land intelligently devoted to soilage will produce from 2 to 3 times the feed yielded by the same land in pasture. Voorhees[2] found that to produce a ton of dry matter in soiling crops yielding from 3 to 4.5 tons of dry matter per acre, annually, cost on an average $6.50, and that the total cost per ton of dry matter, including the cost of cutting and hauling to the barn, would be about $9.[3] The feeding value of this dry matter was nearly equal to that in purchased concentrates costing over $20 per ton.

Soiling crops should not be fed until reasonably mature. Green, immature plants are composed largely of water, and often cattle cannot consume enough of them to secure the required nourishment. (**16**, **249**) For this reason, where quite green crops are fed, some dry forage should also be supplied. The use of silage in summer is practically soilage. The dairyman should use either silage or soilage during summer to secure the best returns from his herd. The New Jersey Station[4] found that when concentrates were fed, soilage and silage were of equal value in milk production. (**662**)

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[1] Press Bul. 71.
[2] Forage Crops.
[3] Rpt. New Jersey Sta., 1907.
[4] Rpts. 1906, 1907.

II. The Preparation of Feeds.

In the nomadic stage of husbandry the animals gathered their own food, the care of the owner ending when grazing, water, and protection from marauders were provided. With the change from primitive times the growing of plants and their conservation for animal use becomes an ever-increasing burden on the stockman. After growing the feed the next step is to harvest, store, and prepare it economically.

331. Grinding corn for steers.—In a comprehensive study of the practices of the cattlemen of Missouri, Iowa, and Illinois, Waters of the Missouri Station,[1] summarizing reports from 852 feeders, found that:

74 per cent fed ear corn during all or part of the feeding period,
50 per cent fed ear corn exclusively,
25 per cent fed shelled corn during some part of the feeding period,
6.2 per cent fed crushed corn exclusively,
3.2 per cent fed ground corn regularly.

The ear corn was given either husked or unhusked, whole or broken, and pigs followed the cattle to work over the droppings. These feeders fed ear corn not thru ignorance or inability to grind, but because long experience and close observation had taught the economy of so feeding it.

In trials with fattening steers getting clover hay for roughage, Mumford of the Illinois Station[2] reached the conclusion that whole corn was more efficient than shelled corn, and that, including the gains made by pigs running with the steers, shelled corn was as economical as corn meal, closing his report with the statement, "The cheapest gains were made where the labor element in preparing the feed was reduced to the minimum."

Whoever studies the subject impartially will agree with Georgeson of the Kansas Station,[3] who, on reviewing his own feeding trials bearing on this problem, writes: "This is not a very favorable showing for corn meal, and I confess the result is contrary to my expectations. A considerable percentage of the whole corn passes thru the animal undigested, and it would seem that the digestive juices could act to better advantage on the fine corn meal than on the partially-masticated corn and extract more nourishment from it, but apparently this is not the case." Where pigs do not run with cattle it is usually best to grind or crush the corn before feeding. (**523**)

[1] Bul. 76. [2] Bul. 103. [3] Buls. 34, 60.

332. Grinding grain for cows.—Shaw and Norton of the Michigan Station[1] saved the droppings of animals fed whole grain with the following results:

Average per ct. of grain left whole when fed to cows, heifers, and calves.

Grain fed	Cows	Heifers	Calves
	Per cent	Per cent	Per cent
Corn	22.8	10.8	6.3
Oats	12.1	5.5	3.0
Corn and oats	26.5	17.5	5.8

This shows that as much as 26.5 per ct., or over one-quarter, of the grain eaten by cows may pass undigested. Four per ct. of the corn and 11 per ct. of the oats in the droppings germinated, and analyses showed that it had lost but little of its nutriment. Unfortunately there have been no extensive trials where whole and ground grains for cows were directly compared. In a trial by Lane of the New Jersey Station[2] in which corn-and-cob meal and whole corn were fed in opposition one to the other in rations otherwise the same, the yield of milk was 9.3 per ct. greater from the meal ration. (**621**, **703**)

333. Grinding corn for pigs.—Each fall for 10 years at the Wisconsin Station (**821**) one lot of fattening pigs was fed old shelled corn while the other received ground corn. The average saving by grinding was 6 per ct., an amount too small to pay for grinding in most cases. It was observed that the pigs getting meal gained faster than those fed whole corn, but they also ate more feed in a given time. This explains in part the quite common opinion of farmers that it pays to grind corn for fattening pigs.

The question of grinding corn for pigs may be considered as now settled negatively by the exhaustive studies conducted at the Iowa Experiment Station. (**822**, **845**)

334. Cooking feed.—In 1854 Professor Mapes voiced the sentiment of the times when he wrote:[3] "Raw food is not in condition to be approximated to the tissues of animal life. The experiment often tried has proved that 18 or 19 lbs. of cooked corn are equal to 30 lbs. of raw corn for hog feed." A book could be filled with similar statements made in the earlier times. (**60**)

335. Artificial digestion trials.—At the New York (Geneva) Station[4] Ladd determined artificially the digestibility of the crude pro-

[1] Bul. 242. [2] Rpt. 1898. [3] Trans. Am. Inst., 1854, p. 373. [4] Rpt. 1885.

tein in several common feeds, before and after cooking, with the results shown below:

	Uncooked	Cooked
Fresh corn meal	68.6 per cent	60.5 per cent
Old corn meal	72.6 per cent	63.2 per cent
Clover hay	67.7 per cent	53.3 per cent
Cotton-seed meal	87.7 per cent	73.8 per cent

In each case cooking lowered the digestibility of the crude protein.

336. Steaming roughage for cattle.—As late as 30 years ago there could be found in this country establishments more or less elaborate, used for steaming or boiling straw, corn stalks, hay, etc., for cattle feeding. It is doubtful if there is today a single establishment for this purpose. Feeding steamed hay to oxen at Poppelsdorf, Germany,[1] showed that steaming rendered the components of hay, especially the crude protein, less digestible. When dry hay was fed, 46 per ct. of the crude protein was digested, while in steamed hay only 30 per ct. was digested. The advice given years ago by the editor of an agricultural journal is as sound today as when given:[2] "The advantages are very slight and not worth the trouble of either building the fire, cutting the wood, or erecting the apparatus, to say nothing of all these combined, with danger and insurance added."

337. Cooking feed for swine.—While cooking feed for cattle was abandoned years ago, it is still practiced to some extent for swine. Fortunately the matter has been carefully studied by several experiment stations and definite conclusions reached. The most extended trial was one running nine years at the Maine Agricultural College,[3] in which cooked and uncooked corn meal were fed. In each case there was a loss by cooking. It is not going too far to say that the investigators of this subject usually began their studies in the full belief that the common feeding stuffs would be improved by cooking. The following are fair samples of the comments which commonly accompanied the reports of feeding trials with cooked and uncooked feed for swine.

Shelton[4] closes an account of his own findings with these words: "The figures given above need but little comment. They show as conclusively as figures can show anything, that the cooked corn was less useful than the raw grain. . . . Such entire unanimity of re-

[1] Hornberger, Landw. Jahrb., 8, p. 933; Armsby, Manual of Cattle Feeding, p. 266.
[2] Country Gentleman, 1861, p. 112.
[3] Ann. Rpt. of Trustees of the Maine State Col. of Agr., 1878.
[4] Rpt. Prof. Agr., Kan. Agr. Col., 1885.

sults can only be explained on the theory that the cooking was an injurious process so far as its use for food for fattening animals is concerned.''

Brown of the Ontario Agricultural College,[1] reviewing several trials with cooked and uncooked peas and corn, wrote: ''I am not at present prepared to say definitely what other kinds of food may do, raw or cooked, with pigs or other domestic animals, or how the other animals will thrive with peas or corn, raw or boiled, but I now assert on the strongest possible grounds . . . that for fast and cheap production of pork, raw peas are 50 per ct. better than cooked peas or Indian corn in any shape.''

At the Wisconsin Station[2] the author, starting with the belief that cooking must increase the value of the common feeds for swine, after some 15 trials with cooked and uncooked whole corn, corn meal, ground barley, and wheat middlings, was forced to the conclusion that the Maine findings were correct. (**823**)

338. Concerning cooked feed.—No one can review the large accumulation of data from the experiment stations without being convinced that generally it does not pay to cook feed for stock. However, some feeds, the potato and field bean of the North, for example, can be successfully fed to swine only after being cooked. Unless first thoroughly softened by cooking or soaking, such small hard grains as rice, wheat, and rye cannot be advantageously fed except to sheep. Musty hay and corn fodder are rendered more palatable and safe by steaming.

An occasional allowance of steamed or cooked barley, bran, etc., is especially helpful to horses because of its favorable action on the bowels, and is doubtless true in lesser degree with fattening cattle. In winter, breeding swine and stock hogs are benefited by a daily feed of steamed roots, tubers, clover or alfalfa chaff, etc., with meal added. It is safe to say that it does not generally pay to cook feed for farm stock when such feed will be satisfactorily consumed without cooking. It is often advantageous to administer warm feed in winter, especially to swine, but warming should not be confused with cooking feed. (**823**)

339. Soaking feed.—Corn becomes hard and flinty a few months after husking, and sometimes causes sore mouths, so little being then eaten that gains may cease or the animals lose in weight. Grain which is difficult of mastication should be either ground or softened by soaking, so that the animals may at all times consume full rations.

[1] Rpt. 1876.

[2] Rpt. 1893.

Studying the results of 12 feeding trials with pigs at 8 stations, Rommel[1] finds a difference of slightly over 2 per ct. in favor of soaked over dry feed for fattening pigs. Grisdale of the Ottawa Experimental Farms[2] found a loss from soaking ground grain, while whole grain returned better gains when soaked. (**522, 822, 824**)

340. Chaffing hay and straw.—The use of cut or "chaffed" hay and straw is common in establishments where large numbers of horses are kept. A little water lays the dust of chaffed hay, and the feeder can rapidly and accurately apportion the allowance for each animal. If meal is mingled with a limited portion of moistened chaffed hay, the mixture is in condition to be quickly masticated and swallowed so that it can remain longer in the stomach undergoing digestion—an item of importance with hard-worked horses which are in the stable only at night. (**447**) In feeding trials with short- and long-fed steers, Cummings of the Ontario Agricultural College[3] found little difference between cut and uncut hay of good quality. Jordan of the Maine Station[4] fed cows long hay and meal for 30 days, and then for 51 days following they were fed cut hay and meal which had been moistened with water and allowed to stand for several hours before it was fed. At the close of this period, long hay and dry meal were once more supplied for 30 days. The returns from the 5 cows were:

	Milk	Butter
Average daily yield when meal and long hay were fed dry	115.3 lbs.	4.6 lbs.
Average daily yield when meal and cut hay were fed wet	113.2 lbs.	4.2 lbs.

It is shown that long hay and dry meal gave somewhat better returns than wet cut hay and meal. These findings are confirmed by Speer of the Iowa Station,[5] who fed calves dry meal and long hay in opposition to a wet mixture of cut hay and meal.

341. Shredding corn forage.—At the Wisconsin Station[6] the author conducted 3 trials in which cows were fed either shredded or unshredded corn stover or fodder corn, with the same allowance of grain and hay for all. The results follow:

Feeding shredded corn stover or fodder to cows.

	Forage fed	Forage eaten	Forage refused	Yield of milk
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, fed shredded stover or fodder	3,538	All	None	3,794
Lot II, fed long stover or fodder	4,667	3,788	879	3,730

[1] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.
[2] Bul. 33.
[3] Rpt. 1903.
[4] Rpt. 1890.
[5] Bul. 12.
[6] Rpt. 1886.

It is seen that 3,538 lbs. of shredded corn stover or fodder corn gave as good returns as 4,667 lbs. of long forage—a saving of 24 per ct. by shredding. At the Kansas Station[1] Shelton, conducting experiments covering 3 seasons, fed stover cut into lengths varying from 0.25 to 2 inches to cows, and found an average waste of 31 per ct. of the cut stover, with no greater milk returns than from the uncut stover. It was observed that the finer the stover was cut the larger was the waste, and the conclusion was that the only advantage from cutting stover lay in the greater convenience in handling it in the stable. The findings of Shelton for Kansas conditions are confirmed by those of Waters at the Missouri Station.[2] In accounting for the difference between these results and those from Wisconsin it may be said that the stalks of corn grown in the middle and lower portions of the corn belt are larger, coarser, more woody, and doubtless less nutritious than the smaller, softer stalks of the northern states. It is also possible that in the Kansas trial the sharp edges of the cut stalks made the mouths of the cattle sore. This can be avoided by changing the length of the cut or by shredding. Cutting or shredding corn forage makes it easier to handle. The only other possible advantage comes in getting the animals to eat more, or to eat those parts that would otherwise be wasted, rather than that the finer material is more digestible. (**500**)

342. General conclusions.—It has generally been assumed that by cutting, grinding, and cooking feed much labor was saved the animal, to the advantage of the feeder. This idea is based on the general theory that the less work the animal does in mastication and digestion the larger the net production of work, flesh, or milk. On the contrary, we know that the muscles of the body do not grow strong thru idleness, and that work and activity are conducive to bodily health, growth, and strength. We must therefore conclude that the organs of mastication and digestion would best be kept at work to their reasonable capacity. Feeding liberally and in an orderly manner, with ample variety and in wise combination, is more important and helpful than making feeds fine and soft so that they can be quickly swallowed with little chewing.

When cutting, grinding, cooking, or pulping brings more satisfaction to fattening animals soon to be slaughtered, and causes them to consume heavier rations, such preparation may pay, (**275**) as it may also with exceptionally hard-worked animals that have but limited

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[1] Rpt. 1889.

[2] Bul. 75.

time for taking their rations. For horses which are extremely hard worked and spend much of their time away from the stable, most of the grain should be ground and mixed with a small allowance of moistened chaffed hay. Ordinarily horses can grind their own oats and corn, and idle horses should always do so. Steers with pigs following usually give the most economical returns from ear corn, husked or unhusked as best suits them. (**523**) When no pigs follow and where a high finish is required, necessitating a long period of feeding, the use of meal, especially during the latter stages of fattening, will usually prove economical. A cow yielding a large flow of milk should be regarded as a hard-worked animal, and her feed should usually be prepared by grinding. Sheep worth feeding can always grind their own grain.

III. Condimental or Stock Foods.

Proprietary articles styled "stock foods," "seed meals," "condition powders," etc., costing from 10 to 30 cents or more per lb., are extensively advertised and sold to American farmers. Woll of the Wisconsin Station,[1] after ascertaining the amount of stock foods sold in three counties in Wisconsin, estimates that the farmers of the state pay annually about $300,000 for 1,500 tons of such material. Michel and Buckman of the Iowa Station[2] estimate that Iowa farmers paid $190,000 for stock foods in 1904. (**445, 893**)

343. Composition of stock foods.—The better class of stock foods have for their basis such substances as linseed meal or wheat middlings, while the cheaper ones contain ground screenings, low-grade milling offal, the ground bark of trees, etc. To this "filling" is added a small per cent of such materials as common salt, charcoal, copperas, fenugreek, gentian, pepper, epsom salts, etc., with or without turmeric, iron oxide, etc., for coloring. The stockman is told that a tablespoonful of the compound with each feed will cause his stock to grow faster, fatten quicker, give richer milk, etc., etc. Tests of many of these stock foods by the experiment stations support the view of Sir John Lawes, the world's greatest investigator in scientific and practical agriculture, who, after carefully testing the stock foods then being sold in England, wrote:[3] "In conclusion, I feel bound to say that I require much clearer evidence than any that has hitherto been adduced, to satisfy me that the balance-sheet of my farm would present a more satisfactory result at the end of the year,

[1] Bul. 151. [2] Bul. 87. [3] Rothamsted Memoirs, Vol. II.

were I to give to each horse, ox, sheep, and pig, a daily allowance of one of these costly foods."

Farm animals managed with reasonable care have appetites which do not need stimulating. Sick animals or those out of condition should receive specific treatment rather than be given some cure-all. A good manager of live stock has no use for high-priced stock foods or condition powders, and a poor manager will never have fine stock by employing them. In rare cases the available feeding stuffs may be of such poor quality that some condiment may cause the animal to eat more heartily, and where animals are in low condition and without appetite some spice may prove helpful. To cover such rare cases the formulæ for three "stock foods" or "spices" are presented.

First formula	Lbs.	Second formula	Lbs.	Third formula	Lbs.
Fenugreek	2	Powdered gentian	8	Ground gentian	4
Allspice	2	Ginger	8	Powdered saltpeter	1
Gentian	4	Fenugreek	8	Ground ginger	1
Salt	5	Powdered sulfur	8	Powdered copperas	1
Saltpeter	5	Potassium nitrate	8		
Epsom salts	10	Resin	8		
Linseed meal	100	Cayenne pepper	4		
		Linseed meal	44		
		Powdered charcoal	20		
		Common salt	20		
		Wheat bran	100		

The above materials are easily obtainable and there is no trouble in compounding them. Oil meal or middlings is not necessary if one will thoroly mix together the other ingredients and give the proper amount along with some rich concentrate like oil meal, wheat middlings, or ground oats. At ordinary prices for the materials, either formula can be made up for about 5 cents per lb., or about one-fourth what is usually charged for something no better. A tablespoonful in each feed will supply more drugs of possible value than the same measure of most of the advertised stock foods.

IV. Commercial Feeding Stuffs Control.

A large part of all the by-products of the grain elevators, flouring mills, sugar, glucose and oil factories, breweries, distilleries, etc., form legitimate feeding stuffs, usually of high quality. There is next a middle class, such as the light grains of wheat, barley, and oats, certain weed seeds, oat hulls, oat dust, etc., which range from low to fair in feeding value, and should not be wasted. Finally there is the trash of elevators and mills—rice hulls, corn cobs, peanut hulls, cocoa waste, certain weed seeds, etc., ranging from worthless to dangerous. As most of the mill and factory by-products are legitimate and useful, so most of them are properly handled and sold. On the other hand, all over the country individuals and firms are practicing all degrees of adulteration of feeding stuffs.

344. Examples of feed adulteration.—In Tennessee the United States Department of Agriculture[1] seized a shipment labeled "Mixed Wheat Middlings, from Pure Wheat Bran and Ground Corn," which consisted of bran and ground corn cobs. Woll and Olson of the Wisconsin Station,[2] examining a carload of so-called wheat bran shipped into Wisconsin, found that each pound of the whole carload contained on an average 28,000 pigeon grass seeds, 16,000 wild buckwheat seeds, 5,000 pigweed seeds, and many seeds of other kinds. Beach of the Vermont Station,[3] examining 18 brands of molasses and flax feeds offered for sale in his state, found from 1,150 to 131,000 weed seeds in each pound of such feeds. In one case it was estimated that there were 129 million weed seeds, weighing 400 lbs., in a ton of one of these feeds. Beach found that 2 to 13 per ct. of these seeds would grow after having passed thru the cow. The New York (Geneva) Station[4] found that 7 out of 12 gluten feeds examined contained free mineral acid and a coloring matter used to give the feed a yellow color. (**158**)

345. State and national regulation.—To protect honest dealers as well as the users of commercial feeding stuffs, laws have been passed by the general government and by many of the states which in general direct that each package or car of concentrated feed must have a label, tag, or statement attached giving the weight of the contents and stating the percentage of crude protein and fat the feed contains. From time to time the experiment stations or boards of agriculture, intrusted with feed supervision, issue bulletins setting forth the results of examinations, analyses, etc. Those interested should consult the bulletins issued, and aid and support the officers in the administration of the laws.

Users of purchased feeds in large quantity are generally experienced and buy only the better grades of standard feeding stuffs at close prices. The small buyer, often feeling the pinch of poverty, too frequently is looking for something that sells for less than is demanded for standard goods, and so is the more easily caught by the low-grade trashy articles often bearing catchy, high-sounding names. Low-grade feeding stuffs, no matter what their names, are almost sure to bring hardship to the animals that are fed on them, and to

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[1] Notices of Judgment, 66, 67—Food and Drugs Act.
[2] Bul. 97.
[3] Buls. 131, 133, 138.
[4] Bul. 303.

the owners of such animals as well. Whenever one is in doubt he should purchase only the pure unmixed grains, standard mill or factory by-products, or proprietary feeds of the highest grade that have won a good reputation, always remembering that, as a rule, the highest priced concentrates are usually the cheapest.

346. Standards.—Lindsey of the Massachusetts Station[1] gives the following standards of quality for first-class commercial feeding stuffs bearing the different names:

Standards for commercial feeding stuffs.

Feeding stuffs	Crude protein	Fat	Fiber
Feeds rich in crude protein	Per cent	Per cent	Per cent
Blood meal	85	0.2	0
Cotton-seed meal (high grade)	41–46	8–10	7
Cotton-seed meal (medium grade)	36–41	7–9	8
Cotton-seed meal (low grade)	24	5–6	18
Linseed meal (n. p.)	38	2	9
Linseed meal (o. p.)	32	6	9
Gluten meal	35	1	2
Gluten feed	25	3	7.5
Germ meal	22	10	9.5
Dried distillers' grains	32	10	12
Malt sprouts	25	1	12.5
Dried brewers' grains	22	5	12
Wheat middlings (flour)	18–20	5	3.5
Wheat middlings (standard)	17–19	5	7
Wheat mixed feed	16–18	4–5	8.5
Wheat bran	15–17	4–5	10
Oat middlings	17	7	2.5
Rye feed	15	3	4
Starchy (carbohydrate) feeds			
Ground oats	11	4	10
Ground wheat	11	2	3
Barley meal	11	1–5	6
Rye meal	10	1–5	2
Corn meal	9	3	2
Hominy meal	10	7.5	4.5
Provender	10	3.5	6
Corn and oat feed	8–10	3–5	....
Fortified oat feed	12–14	3–5	....
Oat feed	5–8	2	20–26
Corn bran	9	5	10
Dried beet pulp	8	0.3	18

The crude protein and fat set forth in the table represent valuable parts of the feeds, while the fiber indicates the woody and more or less inert, useless matter. Accordingly, the higher a feed is in crude protein and fat above the standard and the more it falls below it in fiber the better is that feed.

[1] Bul. 120.

CHAPTER XV.

THE ENSILAGE OF FODDER.

I. Concerning Silage.

The preservation of beet leaves, beet waste, and other green forage by gathering into heaps or into earthen pits and covering with earth has long been practiced in Europe. In 1877 the French farmer, Goffart, published his "Manual of the Culture and Siloing of Maize and Other Green Crops," the first book of its kind, covering 25 years of practical experience. To Goffart belongs the credit of describing the first modern silo and of observing and recommending the peculiar merits and advantages of the maize (corn) plant for silage. In 1876 Francis Morris, Oakland Manor, Howard county, Maryland, built the first silo in America. In 1879 Mr. J. B. Brown of New York gave American readers a translation of Goffart's book, and in 1880 Dr. J. M. Bailey issued "The Book of Ensilage, the New Dispensation for Farmers." In 1881 Professor I. P. Roberts[1] of Cornell University, and the author[2] at the University of Wisconsin, built and filled the first silos used for experimental purposes in America. By these means silos and silage were brought prominently before the farmers of this country, and the interest which was awakened has steadily increased until the ensilage of fodders has become a factor of vast importance in American agriculture.

347. Indian corn for silage.—Indian corn is preëminently suited for silage. The solid, succulent stems, when cut into short lengths, pack closely and form a solid mass which not only keeps well but furnishes a product that is greatly relished by stock—especially cattle. It is reasonable to estimate that there are over 100,000 silos now in use in America. Probably 95 per ct. of all the forage stored in them is from the corn plant and 95 per ct. of the silage made is fed to dairy cows. (**220**)

348. Losses by ensiling and field curing.—After studying the losses of forage preserved in wooden silos during 4 seasons at the Wisconsin Station,[3] King concludes that, omitting the top and bottom waste, which is the same for deep or shallow silos, the losses of

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[1] From information to the author.
[2] Rpt. on Amber Cane and the Ensilage of Fodders, 1881, pp. 60–69.
[3] Bul. 59.

dry matter need not exceed 10 per ct. for corn silage and 18 per ct. for red clover silage. The chemist's conclusions are that considerable of the protein in ensiled fodder is changed to amids, (5) and some of the starch and sugar is destroyed, while the fiber is not diminished; thus the losses fall on the best portions of the ensiled material. Numerous trials at the stations show practically no difference between the digestibility of corn silage and dry corn fodder, while both are somewhat less digestible than the green forage.

The following table summarizes the comparative losses in preserving corn forage by ensiling and field-curing as reported by 4 stations:

Relative losses of field-curing and ensiling the corn crop.

Station and reference	Corn silage		Corn fodder in shocks	
	Dry matter	Crude protein	Dry matter	Crude protein
	Per cent	Per cent	Per cent	Per cent
Vermont, av. 4 yrs., Rpts. 1889-94	18.2	12.0*	17.7	12.7*
New Jersey, Bul. 19	18.0	--------	17.3	--------
Pennsylvania, Rpt. 1889	10.8	4.4	21.0	11.6
Wisconsin, av. 4 yrs., Rpt. 1891	15.6	16.8	23.8	24.3
Average at 4 stations	15.7	11.1	20.0	16.2

*Average of 3 years.

The table shows that in 10 trials at 4 stations more dry matter and crude protein were lost by drying corn forage in shocks than by ensiling.

349. Milk per 100 lbs. of dry matter.—From feeding trials with dairy cows at several stations, the following data are taken, showing the yield of milk from 100 lbs. of dry matter fed in silage and in corn fodder:

Milk produced from 100 lbs. of dry matter in silage and dry fodder corn.

Station and reference	No. of trials	Based upon dry matter in—	Silage	Fodder corn
			Lbs.	Lbs.
Wisconsin, 7th Report	2	Whole ration	76.9	86.0
Wisconsin, 8th Report	1	Whole ration	70.4	78.7
Vermont, Report 1892	1	Whole ration	82.0	76.5
Vermont, Report 1892	1	Whole ration	73.5	73.4
Pennsylvania, Report 1890	2	Whole ration	111.9	106.3
Wisconsin, 6th Report	3	Exptl. forage only	155.0	146.1
Wisconsin, 5th Report	3	Exptl. forage only	166.2	149.6
Vermont, Report 1891	1	Exptl. forage only	240.0	218.0
Average	-------	-------------------	122.0	116.8

We observe that in all but the first Wisconsin trials the dry matter in corn silage gave larger returns than that in field-cured fodder corn, the average difference in 14 trials being about 5 per ct. in favor of silage.

350. Corn silage v. fodder corn.—Tests of corn silage and field-cured fodder corn at the Vermont[1] and Wisconsin[2] Stations were conducted in the following manner: Two rows of maturing corn extending across the field were placed in shocks, while the next 2 rows were run thru the feed cutter and placed in the silo. By thus alternating until the silo was filled, substantially equal quantities of material having the same composition were obtained. The field-cured fodder, after being run thru the cutter, was fed in opposition to the silage to dairy cows along with equal quantities of hay and grain.

The results at the Vermont Station were:

24,858 lbs. green fodder corn when dried and fed with a uniform daily allowance of hay and grain produced 7,688 lbs. of milk.

24,858 lbs. of green fodder corn when converted into silage and fed with the same daily ration of hay and grain produced 8,525 lbs. of milk.

At the Wisconsin Station the results were:

From 29,800 lbs. of green fodder were obtained 24,440 lbs. of silage, which, fed with 1,648 lbs. of hay and 2,884 lbs. of grain, produced 7,496 lbs. of milk, containing 340.4 lbs. of fat.

From 29,800 lbs. of green fodder were obtained 7,330 lbs. of field-cured fodder corn, which, fed with 1,567 lbs. of hay and 2,743 lbs. of grain, produced 7,119 lbs. of milk, containing 318.2 lbs. of fat.

At the Vermont Station the silage ration produced 837 lbs., or 11 per ct., more milk than the dry-fodder ration. At the Wisconsin Station the silage ration produced 377 lbs., or 5 per ct., more milk and 22 lbs., or nearly 7 per ct., more fat than did the dry-fodder ration.

We have seen that the losses of nutrients by ensiling and drying corn forage are not materially different, tho somewhat favoring silage, and that silage and dry forage are about equally digestible. On the other hand, actual feeding trials with dairy cows, as here reported, show that silage gives better results than a corresponding amount of dry fodder. The difference in favor of silage is doubtless due in part to the fact that cattle usually reject the dry butts of the corn stalks even when cut fine, while in silage they are eaten without waste. Again, silage-fed animals will, if permitted, consume a larger ration

[1] Rpt. 1891. [2] Rpt. 1891.

and thereby have more nutriment available for milk or flesh production after supplying the wants of the body. (**654**)

351. Yield of silage corn and roots.—Since corn silage and roots are both succulent and equally relished by stock, the choice between them will, in many cases, finally turn upon the cost of production and the amount of nutriment yielded by each crop on a given area of land. The following table from Woll[1] and the Pennsylvania Station[2] shows the green substance and dry matter yielded by an acre of fodder corn and roots, grown under the same conditions at 4 stations:

Yield of fresh and dry matter per acre of roots and fodder corn.

Crops compared	Maine Station		Pennsylvania Station		Ohio Station		Ontario College	
	Green substance	Dry matter	Green substance	Dry matter	Green substance	Dry matter	Green substance	Dry matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Rutabagas	31,695	3,415					42,780	4,877
Mangels	15,375	1,613	38,273	4,554	31,500	3,000	55,320	5,034
Sugar beets	17,645	2,590	25,591	4,683			32,663	4,737
Fodder corn	39,645	5,580	18,332	6,763		6,000	41,172	8,135

It is shown that crops of corn yield about twice as much dry matter as do crops of roots grown on similar land.

352. Dry matter in roots and silage.—The value of the dry matter in roots and silage for milk production has been studied at the Ohio,[3] Pennsylvania,[4] and Vermont[5] Stations with the following results:

Milk from 100 lbs. of dry matter in corn silage and beet rations.

Station	Beet ration	Silage ration
	Lbs.	Lbs.
Ohio Station, 1889	59	62
Ohio Station, 1890	59	60
Ohio Station, 1891	62	66
Ohio Station, 1892	69	76
Pennsylvania Station	87	82
Vermont Station	113	119

It will be seen that, altho practically all of the dry matter in beets is digestible and only a part of that in corn silage, dairy cows gave somewhat better returns on the dry matter of silage than on that in the beet ration.

[1] Book on Silage.
[2] Rpt. 1898.
[3] Rpt. 1893.
[4] Rpt. 1890.
[5] Rpt. 1895.

At the Massachusetts (Hatch) Station[1] in a feeding trial with dairy cows fed equal amounts of hay and grain, those getting 30 lbs. of corn silage daily gave 4 per ct. more milk than those getting 40 lbs. of mangels daily. (**563, 656, 757-8**)

353. Relative cost of beets and silage.—At the Pennsylvania Station[2] Waters and Hess estimated the cost of 1 acre of corn placed in the silo at $16.17, while to grow and house an acre of beets cost $57.54. In this case it cost 5 times as much to produce 100 lbs. of dry matter in roots as in corn silage. At the Ohio Station[3] Thorne found that to grow and harvest an acre of beets yielding 15.75 tons and containing 3,000 lbs. of dry matter cost more than an acre of corn yielding 57 bushels of grain and containing 6,000 lbs., or twice as much, dry matter. Grisdale of the Ottawa Experimental Farms[4] found turnips more expensive and not much more effective than corn silage for milk production. Sugar beets proved the best of the root crops, but were more expensive than corn silage. After experimenting with steers fed roots and corn silage with hay and grain, Day of the Ontario Agricultural College[5] concludes that when a ton of roots is worth $2, corn silage is worth $2.44 per ton for beef production.

354. Southern v. northern seed for silage corn.—At the North corn plants from southern seed grow much larger than those from northern seed. The merits of the two classes of seed corn have been tested at several stations, as the data given below will show.

Yield of corn forage at the North from northern and southern seed.

Station reporting	Green weight	Dry matter	Digestible substance
	Lbs.	Lbs.	Lbs.
Maine—7 trials, 5 years*			
Southern corn	34,761	5,036	3,251
Field corn	22,269	4,224	3,076
*Pennsylvania**—3 years*			
Southern corn	32,321	7,993	5,042
Dent corn	18,606	6,177	4,149
Cornell §			
White Southern corn	34,060	7,320	4,758
Pride of the North corn	16,980	4,102	2,953
Wisconsin †			
B. & W. silage corn	47,040	8,329	5,414
Dent corn	24,890	7,263	5,229
Minnesota ‡			
Southern corn	43,000	7,985	3,887
Dent corn	19,500	4,518	2,911

*Rpt. 1893. **Rpt. 1892. §Bul. 16. †Rpt. 1888. ‡Bul. 40.

[1] Rpt. 1893.
[2] Rpt. 1898.
[3] Rpt. 1893.
[4] Rpt. 1904.
[5] Rpt. 1902.

The table shows larger yields of green forage in every instance from southern corn, which likewise leads in dry matter and digestible substance. Southern corn is, however, percentagely lower in digestibility, as shown by Jordan of the Maine Station,[1] who found as a result of studies covering 5 seasons 65 per ct. of the dry matter of silage from southern and 73 per ct. of that from northern corn was digestible.

355. When to use southern corn for silage.—The table shows that larger returns of total dry matter and digestible matter are assured at the North by growing the large southern varieties of corn. However, such corn should not be used for either silage or dry forage unless the climatic conditions permit the ears to develop kernels which reach the glazing stage at time of harvest. This southern corn will prove a favorite for both silage and dry forage where there is an urgent demand for the largest possible amount of palatable roughage from a given acreage. By its use northern farmers can provide an enormous quantity of forage from a given area. On the other hand, the stockman who has hay, straw, or stover at command will aim to fill his silo with a richer feeding stuff than southern corn yields, and for this purpose will use northern dent or flint varieties, planting in such manner as to secure a relatively large proportion of grain to roughage. The smaller varieties of northern corn, planted not too thickly and carrying a goodly weight of ears, will provide a rich silage that will materially reduce the amount of concentrates that are required when feeding southern corn silage.

356. Removing the ears before ensiling.—It has been recommended that, instead of ensiling the entire corn plant, the ears be removed and cured elsewhere, and only the stalks and leaves converted into silage. This grain-free silage would then be fed along with more or less of the grain separately saved. This matter has been tested by Woll of the Wisconsin Station[2] and Hills of the Vermont Station[3] with adverse results. Hills found that 1 acre of green corn fodder, including ears, reduced to silage was equal in feeding value to 1.26 acres of silage from stalks stripped of their ears fed with the meal made by grinding the dry ear corn which was produced by the crop.

357. Frozen corn silage.—Hills of the Vermont Station[4] found that frozen-corn silage is not necessarily poorer in quality because of having been frosted. It is not dangerous to cows and does not injuriously affect the milk. He concludes that it is often advisable to

[1] Rpt. 1893. [2] Rpts. 1891–2. [3] Rpt. 1892. [4] Rpt. 1906.

allow a crop of immature, watery corn to stand one or two weeks longer than usual, thereby gaining from 6 to 15 per ct. in dry matter should no frost come. When frosted, corn forage should be quickly ensiled, for the storm which usually follows the first fall frosts will wash out much nutriment from the frosted forage, and the winds will soon whip off the dried, brittle leaves.

358. Cured fodder-corn silage.—Neale of the Delaware Station[1] placed field-cured fodder corn, cut fine, in a silo and poured over it from one-third to two-thirds its weight of water. A rise in temperature followed, and an aromatic odor was developed as with silage from green forage. Stock ate this moistened dry-fodder silage without waste in preference to dried shredded fodder. Such treatment of dried corn forage seems practical only in special cases.

359. Steaming silage.—At the Oregon Station[2] Withycombe and Bradley found in digestion trials with cows that steaming corn silage immediately after placing it in the silo reduced the digestibility of the dry matter 16 per ct., the crude protein 91 per ct., the ash 79 per ct., and the fiber, nitrogen-free extract, and fat to a slight extent. Hence, tho the steamed silage was admirably preserved and contained only half as much acid as ordinary silage, its feeding value was greatly reduced. (**60**)

360. Crops for the silo.—Indian corn is the one great silage plant. By seeding a little thicker than for grain the proper proportion of ears and stalks develops to form a rich silage. Corn should be cut for silage while most of the leaves are yet green and succulent, but not until the kernels are dented and hardened. Immature corn makes sour silage of low feeding value. (**214**)

Sorghum is possibly next to corn for the silo, yet because of the high content of sugar it usually makes a sour silage. Soule, as the result of 5 years' experience at the Tennessee Station,[3] reports that well matured sorghum, properly ensiled, makes sweet silage. The bagasse, or waste of the sorghum syrup factories, which has considerable feeding value, should not be wasted but may be satisfactorily ensiled. (**222**) In England meadow grasses have been converted into stack silage, in which case the decaying outside protects the interior of the mass—a practice which, however, is not gaining favor. Potts of Australia[4] reports that 3 tons of grass silage is estimated to be worth 1 ton of oat hay. A stack containing 200 tons of grass silage, opened after 10 years, furnished good feed. Georgeson

[1] Rpt. 1903.
[2] Bul. 102.
[3] Bul. Vol. XVII, No. 1.
[4] N. S. Wales Gaz., Vol. 15, p. 82.

of the Alaska Experiment Station[1] reports that fresh native grasses kept well when stored in a log silo made smooth inside, and that such silage satisfactorily maintained oxen during 3 winters. Green rye is fairly satisfactory for silage, providing it is ensiled by the time the heads have shot and before the stems have become woody. Since the hollow stems contain air, rye forage must be closely compacted in the silo.

As a class the legumes have proved disappointing for silage. (**247**) Red clover silage usually has a rank, tenacious odor and is not particularly relished by stock. At the Agassiz (British Columbia) Station[2] 3 cuttings of red clover, yielding 32 tons of green forage per acre, made a cheaper silage than that from the corn plant. Dean of the Ontario (Canada) Agricultural College[3] reports that an acre of clover silage did not yield one-half the returns of an equal area of corn silage. The Colorado Station[4] reports fair results from ensiling alfalfa, and that the silage was relished by cows and calves. The cowpea, so valuable in southern agriculture, fortunately shows favorably as a silage plant. Doane of the Maryland Station[5] found cowpea silage slightly superior to corn silage for dairy cows. Crenshaw of Georgia[6] recommends that cowpeas carrying a heavy crop of grain be ensiled when well matured, since immature vines make watery, sour silage. While the reports on the soybean plant for silage are not in accord, it is probable that further experience will rank it with the cowpea for this purpose.

Such substances as beet pulp, beet leaves, apple pomace, and sorghum bagasse may be successfully ensiled in silos, or placed in heaps and covered with earth, or, if no better provision can be made, massed in large heaps without covering, in which case the outside portion on decaying forms a preserving crust. (**310**) Cooke of the Vermont Station[7] found that ensiled apple pomace was preferred by cows to either hay or corn fodder, and concludes that it has equal value with corn silage for cows. (**657**) Boyce of Australia[8] reports prickly pears making silage relished by cattle, the thorns softening and becoming harmless. Weeds and other waste vegetation may sometimes be advantageously ensiled. Featherstonhaugh of Australia[9] reports a case where 800 tons of ensiled thistles made satisfactory silage. Attempts to ensile cabbage, rape, and turnips have failed, the product being ill-smelling and watery.

[1] Bul. 1.
[2] Canada Expt. Farms Rpt. 1905.
[3] Rpt. Ontario Dairyman's Ass'n, 1901.
[4] Bul. 57.
[5] Bul. 98.
[6] Country Gentleman, Feb. 16, 1899.
[7] Rpt. 1903.
[8] N. S. Wales Gaz., Vol. 8, p. 505.
[9] N. S. Wales Gaz., Vol. 9, p. 71.

361. Pea-vine silage.—Especially in Wisconsin, great quantities of the pea-vine silage, a waste product of the canning factories, are employed in fattening lambs and cattle. According to The Breeder's Gazette,[1] western lambs fed 60 to 90 days on pea-vine silage frequently top the Chicago market. Cases are cited where fattening steers made an average gain of nearly 100 lbs. during 8 weeks' feeding on pea-vine silage alone. A bunch of range cows gained 77 lbs. in 6 weeks.

362. Effects of silage on milk.—The largest milk condensing company in this country prohibits the use of silage by its patrons. On the other hand, three companies, one of which has two factories in Michigan and two in New York, permit or favor the feeding of silage by patrons. The Michigan Condensed Milk Company not only accepts milk from silage-fed cows, but some years since prepared and distributed to its patrons a pamphlet containing directions for constructing silos and making and feeding silage. Mr. C. B. McCanna,[2] President of the Wisconsin Condensed Milk Company, in order to thoroly test the matter, constructed a silo on his own farm, and from it fed silage to cows furnishing milk to his condensary with satisfactory results.

Fraser of the Illinois Station[3] fed a ration of 40 lbs. of corn silage, with a small allowance of clover hay and grain, to one lot of cows, while a second received clover hay and grain. The milk from the two lots was sampled by 372 persons, 60 per ct. of whom, without knowledge of the feeds used, expressed a preference for the silage-made milk. Experts, as a rule, can detect a silage odor or flavor in the milk of silage-fed cows, but such flavor is rarely as marked as that of cows freshly turned to grass in springtime. With over 100,000 silos in use by the dairymen of this country, thousands of whom are furnishing the choicest of dairy products—milk, cream, and butter—to critical customers, the time is surely at hand when objections to silage should cease, just as have the early charges that it would burn the farm buildings, destroy the cows' teeth, eat up their stomachs, induce tuberculosis, etc. Like any other feed, silage may be abused. Only that which is well made should be used, and this should be fed after milking and be eaten up clean at each feed, none being left scattered on the floor of the stable, the air of which should be kept pure and wholesome by proper ventilation. If such conditions prevail, no one need fear ill effects from feeding silage to dairy cows. (**620**)

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[1] Vol. 55, 1909, p. 450. [2] Communication to the author. [3] Bul. 101.

363. Silage as a feeding stuff.—Silage is preëminently a feed for the dairy cow. (**654-9**) In almost equal degree it is a necessity with breeding cattle, growing stock, and young animals, which would otherwise be wintered exclusively on dry forage. Given to breeding and growing stock, silage tends to keep the bowels normal, the body tissues sappy, the skin pliant, and the coat glossy, all of which mark the animals as in condition to make the most from their feed. This is also true of fattening cattle. At the Utah Station[1] Sanborn found that the flesh of steers fed silage contained 6 per ct. and that of sheep 2 per ct. more water than the flesh of others fed dry forage. If cattle are at their best on summer pastures, then winter conditions which most nearly approach those of summer are to be desired. Those interested in pure-bred beef cattle and in beef production who do not use roots for their stock in winter should take lessons from dairymen who feed silage. (**559-564**) Silage can be advantageously fed in moderation to breeding ewes, especially after they have yeaned, and to fattening sheep and lambs. (**757-8**) It may also be used in a limited way with idle horses and those not hard worked in winter, especially brood mares and growing animals. (**443**) The high fiber content of corn silage plainly indicates that it cannot be successfully used to any extent in swine feeding. (**904**)

364. The position of silage on the stock farm.—The silo and its products are now fixed factors of vast importance in American agriculture. Old-style farming, where corn is planted for the grain only, the forage being wasted, and where straw stacks slowly rotting in the barnyard show that grain production dominates, has no place for the silo. There should be no thought of the silo on such farms until the present wastage is properly conserved and more mouths are waiting for feed than the system of farming in vogue will support. On too many farms stock cattle barely hold their own during winter. This means that for half of each year all the feed consumed goes for body maintenance, returning nothing to the owner, and serving only to carry the animals over winter and to pasture time, when they once more begin to gain in weight and thereby really increase in value. By the use of corn silage, combined with other cheap roughages, young cattle can be made to gain steadily all winter at small cost, so that with the coming of spring they will not only have increased in weight but are in condition to go on pasture and make the largest possible gains.

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[1] Bul. 8.

On farms heavily stocked with cattle, where everything already raised finds mouths waiting and demanding still more, the owner will find Indian corn and the legumes his best crop allies. Heavily manured land will yield enormous crops of corn forage carrying much grain, and this, utilized in part as dry forage but mostly as silage, will materially extend the feeding powers of the farm in roughage rich in carbohydrates. Then let red clover, alfalfa, cowpeas, vetch, or other legumes be grown to furnish a protein-rich dry roughage. With an abundance of corn silage, corn stover, and legume hay, the stockman has then to supply his cattle with only the minimum of rich concentrates which he must either grow or purchase, and so the cost of producing meat and milk is cut to the minimum, while the number of animals the farm will carry is greatly increased. By growing corn for silage and the legumes for hay, the number of cattle which a farm can carry may often be doubled, to the great advantage of both land and owner.

365. Cost of silage.—The following data show the entire cost of silage per ton, including the rent of land, cost of fertilizers, and the labor involved in growing and ensiling the crop, as reported from widely different sources:

The ton-cost of silage.

Source of information	Crop ensiled	Production cost per ton
		Dollars
Soiling Crops and Ensilage, Peer	Corn	1.20
Country Gentleman, 1904, p. 831	Corn	1.62
Canada Expt. Farm, Rpt. 1903	Corn	1.64
Kansas Expt. Station, Bul. 123	Kafir	1.65
Kansas Expt. Station, Bul. 123	Corn and cowpeas	1.95
Tennessee Expt. Station, Vol. XVII, No. 1	Corn	2.00
New Jersey Expt. Station, Rpt. 1906	Corn	2.55*

*Not including rent of land.

Carrier of the United States Department of Agriculture,[1] collecting data from 31 Wisconsin and Michigan farms, found the amount of corn forage placed in the silo daily varied from 3.3 to 7.4 tons for each man employed, and that the expense for fuel, binding twine, teams, engine hire, and labor ranged from 46 cts. to 86 cts. for each ton ensiled.

366. Space occupied by silage and dry fodder.—A cubic foot of hay in the mow weighs about 5 lbs. According to King,[2] an average

[1] Farmers' Bul. 292. [2] Wis. Bul. 59.

cubic foot of corn silage in a 30-ft. silo weighs 39.6 lbs. Estimating that hay contains 86.8 per ct. and corn silage 26.4 per ct. of dry matter, we have the following:

1 cubic foot of hay in the mow contains 4.34 lbs. of dry matter.
1 cubic foot of silage in a 30-ft. silo contains 10.45 lbs. dry matter.

We learn that a given volume of silage contains nearly 2.5 times as much dry matter as the same volume of hay stored in the mow.

367. Silage waste.—At the Wisconsin Station[1] King placed about 65 tons of green corn forage in 8 layers in a silo lined with galvanized iron, which entirely prevented the passage of air thru its walls. The forage was so placed that the loss incurred in each of the 8 layers after standing from September to March was determined, with the following results:

Surface layer,	8,934	lbs., lost	32.5	per cent dry matter
Seventh layer,	8,722	lbs., lost	23.4	per cent dry matter
Sixth layer,	14,661	lbs., lost	10.3	per cent dry matter
Fifth layer,	48,801	lbs., lost	2.1	per cent dry matter
Fourth layer,	13,347	lbs., lost	7.0	per cent dry matter
Third layer,	7,723	lbs., lost	2.8	per cent dry matter
Second layer,	12,689	lbs., lost	3.5	per cent dry matter
Bottom layer,	12,619	lbs., lost	9.5	per cent dry matter

It is seen that the surface layer of silage lost over 32 per ct. of its original dry matter, while the third layer from the bottom lost less than 3 per ct., showing the importance of air-tight walls and deep silos.

368. Summer silage.—In many dairy districts summer droughts frequently injure the pastures, greatly reducing the milk flow, and again, many dairymen desire to keep more cows than their pastures will support. These conditions can often best be met by feeding silage in summer. Silage left over from winter may be advantageously used in summer, tho it is better to employ a special silo for the purpose. Grisdale of the Ottawa Experimental Farms[2] writes concerning summer silage: "It was always at hand, no matter what the weather nor how busy the teams and men in the field; it was always in good shape to feed, that is, did not vary in character to such a degree as to affect the digestive organs, as not infrequently happens when soiling crops are fed. It was always palatable and eaten with apparent relish, no matter how much other feed was available. It required a smaller area to furnish a given amount of feed than would have been required had soiling crops been used." The

[1] Bul. 83.
[2] Rpt. 1906, p. 50.

only disadvantage of summer silage is the tendency to decay more rapidly than in winter. This can be minimized by so limiting the diameter of the silo that somewhat more than 2 inches of silage is fed off daily from the surface of the mass.

369. Filling the silo.—Provided the material is closely packed, it is not essential that green forage be cut into bits to preserve it in the silo. The legumes, such as alfalfa, clover, cowpea vines, etc., are often ensiled uncut, and some farmers prefer to ensile whole corn forage, tied in bundles. Because of the greater ease in filling and especially in removing the material, corn forage is usually cut into lengths varying from 0.5 to 2 inches. When filling the silo the inpouring material should be thoroly mixed, evenly spread, and well tramped next the walls, as the friction there tends to unevenness in settling. The filling should be by daily additions, tho experience shows that intermissions of 1 or 2 days work little or no harm. If possible the operation should extend over 1 or 2 weeks, as this permits close packing and insures better silage than is made by hurrying the operation. Time is required for the forage to soften, settle, and thereby expel the entangled air thru heat and the generation of carbonic acid gas. If feeding is not to begin immediately, there should be a covering of about a foot of any cheap or waste material such as straw, corn stalks, weeds, etc. This should be spread evenly and wet with water so as to quickly decay and seal the ensiled mass beneath. Oats scattered over the cover will germinate and help increase the density of the cover.

370. Danger from carbon dioxid.—In silo filling there is possible danger to those who go into the pit after an intermission, due to the generation of carbonic acid gas, which sometimes accumulates in sufficient quantity to prove fatal to life. The possibility of danger may be ascertained by lowering a lighted candle into the pit. If the candle continues to burn at the bottom human beings can live in the same atmosphere, but if the light goes out it means death to one entering the pit. The opening of a door low down in the silo will allow the poisonous gas to pour out, or pouring a lot of cut forage into the pit soon creates a circulation which removes the danger.

II. The Silo.

This work can present only the primary principles relating to silo construction, advising those interested to secure from the experiment stations or the United States Department of Agriculture instructions concerning the form, materials, manner of construction, etc., as detailed in bulletins which are available for the asking.

371. The cylindrical silo.—With the devising of the cylindrical silo by King of the Wisconsin Station,[1] its form and construction emerged from uncertainty and imperfection to definiteness and stability, thereby greatly advancing and strengthening the practice of ensiling forage plants. The cylindrical form of silo should usually be adopted because it is the most economical of building material, its sides are unyielding, and it has no corners, which are specially to be avoided.

372. Weight of silage.—King[2] reports the weight of silage 2 days after filling the silo to be as follows:

Weight of a cubic foot of corn silage in silos of different depths.

Depth	Weight at given depth	Mean weight for whole depth
Feet	Lbs.	Lbs.
1	18.7	18.7
10	33.1	26.1
20	46.2	33.3
30	56.4	39.6
36	61.0	42.8

The second column shows that 10 ft. from the top corn silage weighs about 33 lbs. per cubic ft., while 36 ft. down it weighs 61 lbs., or nearly twice as much. The last column shows that the whole mass down to 10 ft. has a mean weight of about 26.1 lbs., while the whole mass in a 36-ft. silo has a mean weight of 42.8 lbs. per cu. ft.

373. Proper size of the silo.—The diameter of the silo should be gauged by the number and kind of animals to be fed from it, and its height by the length of the feeding period. About 2 inches of silage should be removed daily from the exposed silage surface to minimize the loss from molding. Two inches in depth of ordinary corn silage weighs about 3 lbs. per surface square foot near the top of the silo and 10 lbs. near the bottom, averaging about 7.5 lbs. On this basis the proper feeding area may be placed at about 5 sq. ft. per cow daily. Gurler[3] allows 6 sq. ft., with 8 as the limit. King[4] gives the following table, showing the proper inside diameter of a silo where silage is to be fed off at the rate of 2 inches per day, allow-

[1] Bul. 28, issued July, 1891.
[2] Wis. Bul. 59.
[3] The Farm Dairy.
[4] Physics of Agriculture.

ing 40 lbs. of silage daily per cow, the silo being 30 ft. deep and holding sufficient silage for 6 months:

Number of cows to be fed	30	40	50	60	70	80	90	100
Diameter in feet	15.2	17.5	19.6	21.4	23.2	24.8	26.3	27.7
Tons of silage held	108.0	144.0	180.0	216.0	252.0	288.0	324.0	360.0

It is shown that, where 30 cows are to be fed a daily allowance of 40 lbs. of silage each for 6 months, a silo 30 feet deep should have an inside diameter of 15.2 ft., while one of the same depth holding 6 months' feed for 100 cows should have an inside diameter of 27.7 ft.

374. Silo economy.—King[1] states that a silo 36 ft. in depth will store 5 times as much feed as one 12 ft. deep, due to the greater compactness of the stored mass. A silo 20 ft. in diameter will hold 4 times as much as one having half that diameter, while it costs but twice as much to build. Gurler[2] advises against silos over 25 ft. in diameter on account of the increased labor involved in removing the silage. He found no objections to silos 38 ft. in depth.

375. Capacity of the silo.—The next table, likewise by King,[3] gives the capacity of cylindrical silos of different depths and varying inside diameters.

Approximate capacity of cylindrical silos stated in tons of corn silage.

Depth	Inside diameter in feet											
	15	16	17	18	19	20	21	22	23	24	25	26
Feet	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons
20	59	67	76	85	94	105	115	127	138	151	163	177
21	63	72	81	91	101	112	123	135	148	161	175	189
22	67	77	86	97	108	120	132	145	158	172	187	202
23	72	82	92	103	115	128	141	154	169	184	199	216
24	76	87	98	110	122	135	149	164	179	195	212	229
25	81	90	104	116	129	143	158	173	190	206	224	242
26	85	97	110	123	137	152	168	184	201	219	237	257
27	90	103	116	130	145	160	177	194	212	231	250	271
28	95	108	122	137	152	169	186	204	223	243	264	285
29	100	114	128	144	160	178	196	215	235	256	278	300
30	105	119	135	151	168	187	206	226	247	269	292	315
31	110	125	141	158	176	195	215	236	258	282	305	330
32	115	136	148	166	185	205	226	248	270	295	320	346

The table shows that a silo 20 ft. deep and 15 ft. in diameter will hold about 59 tons of cut corn silage, while one 32 ft. deep and 26 ft. in diameter will hold about 346 tons.

[1] Physics of Agriculture.
[2] The Farm Dairy.
[3] Loc. cit.

The following from "Modern Silage Methods"[1] gives approximately the capacity of silos of different sizes, the area of land required to furnish a corn crop, when averaging 15 tons per acre, which will fill such silos, and also the number of cows provided for, allowing 40 lbs. of silage per cow daily for 6 months:

Area of corn crop required to fill silos of different sizes.

Diameter	Depth	Capacity	Area of crop required	Cows it will keep
Feet	Feet	Tons	Acres	Number
10	20	26	2.0	8
12	20	38	3.0	11
12	24	49	3.4	13
12	28	60	4.0	15
14	22	61	4.5	17
14	24	67	4.7	19
14	28	83	5.7	22
14	30	93	6.0	23
16	26	97	7.0	26
16	30	119	8.0	29
18	30	151	10.2	37
18	36	189	12.3	45

The above shows that a silo 10 ft. in diameter and 20 ft. deep has a capacity of 26 tons. To fill a silo of this size will require about 2 acres of corn, and it will furnish 8 cows 40 lbs. of silage daily for 6 months.

[1] Silver Manufacturing Co., publishers.

CHAPTER XVI.

MANURIAL VALUE OF FEEDING STUFFS.

In many parts of the United States the soil is now so depleted of fertility that those who till it are forced to use commercial fertilizers in order to secure remunerative crops. The commercial fertilizers sold in this country during the year 1907 amounted to 4,451,523 tons.[1] At $20 per ton, a reasonable valuation, we have a total of nearly $90,000,000 paid in a single year by farmers, planters, and gardeners, principally in the Atlantic and Gulf States, for commercial fertilizers. In the year 1907 there were purchased in Massachusetts 85,000, in Ohio 140,000, and in California 21,000 tons of commercial fertilizers, while Georgia led all the states, using nearly 800,000 tons.

376. Composition and value of fertilizers.—Of the constituents which plants remove from the soil, only three need ordinarily be replaced, viz. nitrogen, phosphoric acid, and potash. Phosphoric acid and potash, when naturally lacking, or when they have been carried off in crops or animals sold, must be replaced by buying fertilizer or by applying the manure made from feeds. The nitrogen may, however, be indirectly obtained from the air by raising legumes. In practice much nitrogen is purchased along with phosphoric acid and potash.

Barnyard manures benefit the soil because the vegetable matter they contain forms humus, helps retain moisture, improves its physical condition, etc.; but for directly feeding the plant their worth is in the nitrogen, phosphoric acid, and potash they contain. The selling price of a commercial fertilizer is based on its content of nitrogen, phosphoric acid, and potash, and because of the enormous quantity used thruout the civilized world each of these constituents has a recognized price, which fluctuates no more than that of any other standard article of worldwide commerce. In this country the average price of these ingredients to those who buy in large quantities is about as follows: Nitrogen 18, phosphoric acid 5, and potash 5 cents per lb.

The officials of the Ohio Station,[2] after much practical work, give to the elements of fertility in farm manures the same value they

[1] American Fertilizer, Jan. 1909. [2] Bul. 183.

have in tankage, bone meal, and muriate of potash, all of which are standards in their class among commercial fertilizers. Animal manures not only supply plant food, but also benefit the soil by furnishing humus, increasing its moisture-holding power, improving the mechanical condition, and favoring bacterial and chemical action. Such being true, it is usually safe to value animal manures on equal terms with commercial fertilizers, based on the content of nitrogen, phosphoric acid, and potash at the market price of these constituents.

377. Fertilizing constituents of plant and animal products.—Table III of the Appendix shows the amount of nitrogen, phosphoric acid, and potash contained in the various feeding stuffs. From this table and Table V the following examples are taken showing the fertilizing constituents in various plant and animal products:

Fertilizing constituents in 1,000 lbs. of various plant and animal products.

Feeding stuffs	Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.
Wheat straw	5.0	2.2	6.3
Timothy hay	9.4	3.3	14.2
Clover hay	19.7	5.5	18.7
Corn	16.5	7.1	5.7
Wheat	19.0	5.5	8.7
Wheat bran	24.6	26.9	15.2
Oil meal, o. p.	54.2	16.6	13.7
Fat ox	23.3	15.5	1.8
Fat pig	17.7	6.5	1.4
Milk	5.8	1.9	1.7
Butter	1.2	0.4	0.4

From the table we learn that 1,000 lbs. of wheat straw contains 5.0 lbs. of nitrogen, while the same weight of timothy hay carries nearly twice as much, or 9.4 lbs. Clover hay is much richer than timothy hay in nitrogen and especially in potash, tho poorer in phosphoric acid. Wheat bran contains much more nitrogen, phosphoric acid, and potash than does the wheat grain. This is because the starchy part of the grain, which constitutes most of the flour, holds but little fertility, while the outside portion of the grain, which goes into the bran, contains much of the nitrogen and ash.

The value of farm manures depends primarily and principally on the character of the food from which they originate, for the animal merely works over the food given to it, appropriating for the formation of flesh or milk more or less of the fertilizing constituents the food furnishes, and voiding the rest in the excrements. The fattening animal takes little or no fertility from the feed it receives. The farmer should know that the animal creates nothing in the way of fertilizing value, so that if it is fed wheat straw, for example, it will void manure low in fertilizing elements, while if fed oil meal, wheat bran, or clover hay it will furnish a rich manure.

378. Selling fertility.—The table in the preceding article shows that those who sell such crops as hay, corn, and wheat dispose of far more fertility for the money returned than do those who sell animals or their products, produced from the crops they raise. The farmer who sells 1,000 lbs. of clover hay, worth perhaps $5, parts with about as much fertility as if he had sold 1,000 lbs. of fat ox or fat pig, worth $50 or more. Based on the selling price milk carries off much fertility from the farm, and butter practically none. Farm crops may be regarded as raw products, while farm animals, milk, wool, butter, etc., represent manufactured products. A large amount of raw material in the form of grass, hay, corn, etc., is put into animals, and the heavy waste or by-product resulting, in the form of manure, when carried back to the fields conserves most of the fertility. The stock farmer who feeds his crops to live stock is a manufacturer as well as a producer, with two possible profits instead of one, while his farm loses but little of its fertility. On the other hand, the farmer who grows and sells grain, hay, and straw is selling a large amount of fertility, the need of which will surely be apparent as time goes on and his fields give smaller and smaller returns. Such a farmer is slowly but surely mining out phosphorus and potash from his soil, which can be replaced only by some purchased material. The successful cropping of land rests primarily on its fertility. Crops remove this fertility, and manure restores it. As one does not expect returns from his animals without giving them feed, so he should not crop his fields without feeding them also.

379. Fertilizing value of feeds.—If for study purposes we place the same money values on the nitrogen, phosphoric acid, and potash in feeding stuffs that these constituents cost in commercial fertilizers, we are in position to compare the several feeding stuffs on the basis of the fertility they contain. On this basis wheat bran and corn are compared in the table on the next page.

We there learn that the fertilizing constituents in 1,000 lbs. of bran, which is rich in nitrogen, phosphoric acid, and potash, are worth $6.54, and those in the same weight of corn, which is relatively poor in mineral matter, only $3.62, or about one-half as much.

Value of the fertilizing constituents in 1,000 lbs. of wheat bran and corn.

Fertilizing constituents	Wheat bran			Corn		
	Lbs.	Price per lb.	Total	Lbs.	Price per lb.	Total
		Cents	Dollars		Cents	Dollars
Nitrogen	24.6	18	4.43	16.5	18	2.97
Phosphoric acid	26.9	5	1.35	7.1	5	0.36
Potash	15.2	5	0.76	5.7	5	0.29
			6.54			3.62

Doubling the figures we have the following:

Value of the fertilizing constituents in 1 ton of wheat bran ... $13.08
Value of the fertilizing constituents in 1 ton of corn ... 7.24

These figures mean that the amount of nitrogen, phosphoric acid, and potash found in a ton of bran or corn, if bought in commercial fertilizers, will cost not less than the sums named. It means that the farmer who harvests a ton of corn and seeks to return to the field from which it came the same amount of fertility that was taken out of the soil by this ton of corn must pay not less than $6.90 for the requisite fertilizers if bought in the market.

In rare cases feeding stuffs are directly used as fertilizers to enrich the soil. For example, the tobacco planters of Connecticut[1] in 1907 bought and spread directly upon their tobacco fields 5,000 tons or 200 carloads of cotton-seed meal, one of the richest and best of feeds for dairy cows and fattening cattle, costing over $30 per ton. Millions of dollars worth of cotton-seed meal are annually used by the planters of the South to fertilize their cotton fields in order to make another crop of cotton.

Virgin soils as a rule contain great quantities of available fertility, and the pioneer farmers in America, drawing upon Nature's store, have given little consideration to the subject of how their crops are fed and have rarely realized that they are steadily and often wastefully drawing on the store of fertility which represents their principal capital. The western farmer, when marketing corn, considers that in so doing he is selling labor and rent of land. Rarely does he realize that he is also selling fertility, to replace which would cost a considerable part of all the crop brings. Eastern farmers and southern planters are in many cases cultivating soils so

[1] Rpt. Conn. Expt. Sta., 1907.

depleted of available food that the matter of fertilizers is of deepest concern.

380. British practice.—In Great Britain, where many of the farmers are long-period tenants, the manurial value of feeding stuffs is recognized by law in a manner that tends greatly to the betterment and permanence of her agriculture. The Agricultural Holdings Act, which is the law governing the relations between landlord and tenant, directs that when a tenant is vacating his leasehold he shall be reasonably compensated for the improvements he has made. Among these, credit must be given for the fertilizing value of feeding stuffs which the tenant may have purchased and fed out, and also, under certain conditions, for the fertilizing value of grains produced on the farm and fed to stock. In order to furnish data to guide the valuers, who serve in settlement between landlord and tenant, Dr. Voelcker, chemist of the Royal Agricultural Society of England, and Dr. Hall, director of the Rothamsted Experiment Station, working jointly, recommended,[1] after full and extended study, that in such cases the outgoing tenant should be credited, and the incoming tenant charged, substantially as follows:

For all unused manure resulting from feeding purchased feeds to stock on the leasehold, the tenant shall be credited with the value of one-half the nitrogen, three-fourths of the phosphoric acid, and all of the potash the feeds originally contained. The money value of such manure shall be ascertained by multiplying the pounds of the three fertilizing elements, as calculated, by the current value of each per pound in commercial fertilizers. Where the manure has been on the land one year and thereby fed a crop, only one-half of its original value shall be credited. If two crops have been grown on the manure, one-fourth of its value shall be allowed, and so on for four years, after which the manure is considered exhausted.

A committee appointed by the Council of the Central and Associated Chambers of Agriculture[2] recommend in substance that the Voelcker-Hall table of valuations be adopted practically without change, but that compensation be allowed for but three years instead of four.

The principles of the English law should be drafted into every lease drawn between landlord and tenant in this country.

381. Fertilizers retained and voided.—In the case of mature animals neither gaining nor losing in weight, substantially as much

[1] Jour. Royal Agr. Soc. Eng., 1902.

[2] Central Chamber of Agriculture, Rpt. Com. Scale of Compensation for Unexhausted Improvements, 2d ed., July, 1908.

nitrogen and ash, the latter containing the phosphoric acid and potash, will be found in the excrements as is supplied in the food. With fattening animals whose bodies are nearly or quite mature, but little nitrogen and ash are retained by the body, while young, growing animals and those giving milk take large quantities of nitrogen and ash from their food. These points are helpfully brought out in the following table by Warington:[1]

Nitrogen and ash voided or secured as animal produce from food consumed.

	Nitrogen				Ash, containing phosphoric acid and potash	
Kind of animal	Obtained in carcass or milk	Voided in solid excrement	Voided in urine	In total excrement	Obtained in carcass or milk	Voided in excrement and perspired
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Horse at work	None	29.4	70.6	100.0	None	100.0
Fattening ox	3.9	22.6	73.5	96.1	2.3	97.7
Fattening sheep	4.3	16.7	79.0	95.7	3.8	96.2
Fattening pig	14.7	21.0	64.3	85.3	4.0	96.0
Milch cow	24.5	18.1	57.4	75.5	10.3	89.7
Calf, fed milk	69.3	5.1	25.6	30.7	54.3	45.7

The horse at work renews its tissues as fast as they are worn out, and so the intake and outgo of nitrogen and mineral matter are equal. Having already built up its lean-meat tissues, the fattening ox retains but 3.9 per ct. of the nitrogen supplied in the food, while the dairy cow takes out of her feed 24.5 per ct., or about one-quarter of the nitrogen it contains, using it in the production of the casein and albumin of the milk. The young calf, which is growing rapidly in bone, muscle, and body organs, puts into its body over two-thirds of all the nitrogen and over one-half of the mineral matter supplied in the food. Columns 3 and 4 of the table show that about three-fourths of the nitrogen which is voided by farm animals passes out in the urine.

382. Amount of excrement voided.—Information on this subject is limited and incomplete, but the following table arranged from all available data may be held as representing averages:

Voiding of farm animals per day of 24 hours.

Animal	Solid excrement	Urine	Total
	Lbs.	Lbs.	Lbs.
Horse	33	8	41
Cow	49	19	68
Sheep	2	2	4
Pig	4	3	7

[1] Chemistry of the Farm, p. 214.

The great variation in quantity and composition of animal excrements, owing to difference in the feeds consumed, is shown by Warington.[1] In one feeding trial each cow of one lot was fed 154 lbs. of mangels daily, while each cow of another lot received 26 lbs. of alfalfa hay and 66 lbs. of water daily. The results are shown below:

Amount and composition of excrement voided daily by cows fed mangels or alfalfa hay.

	Cow fed mangels		Cow fed alfalfa hay	
	Solid excrement	Urine	Solid excrement	Urine
	Lbs.	Lbs.	Lbs.	Lbs.
Voidings per day	42	88	48	14
Content of voidings	Per cent	Per cent	Per cent	Per cent
Water	83.00	95.94	79.70	88.23
Nitrogen	0.33	0.12	0.34	1.54
Phosphoric acid	0.24	0.01	0.16	0.01
Potash	0.14	0.60	0.23	1.69

The cows fed watery mangels voided 6 times as much urine as those fed alfalfa, but the urine of the latter was 13 times richer in nitrogen and 3 times richer in potash than the urine from those eating mangels. This plainly illustrates that the quality of manure depends primarily upon the nature of the feed.

383. Composition of fresh excrements.—The quantity of nitrogen, phosphoric acid, and potash in the voidings of farm animals depends primarily upon the amount of each supplied in the feed, and secondarily upon the animal to which the feed is given. While it is impossible to formulate anything like an exact table showing the composition of the excrements of the different classes of farm animals, the following, originally from Wolff,[2] is helpful:

Fertilizing constituents in 1,000 lbs. of fresh excrements of farm animals.

Animal	In solid voidings				In urine			
	Water	Nitrogen	Phosphoric acid	Alkalies*	Water	Nitrogen	Phosphoric acid	Alkalies*
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Horse	760	5.0	3.5	3.0	890	12.0	0.0	15.0
Cow	840	3.0	2.5	1.0	920	8.0	0.0	14.0
Swine	800	6.0	4.5	5.0	975	3.0	1.25	2.0
Sheep	580	7.5	6.0	3.0	865	14.0	0.5	20.0

*The alkalies include potash, lime, etc.

[1] Chemistry of the Farm, p. 218.

[2] Bailey, Cyc. Amer. Agr., Vol. I, p. 491.

The source of the fertility in manures is well illustrated by the following table from Hebert:[1]

Location of nitrogen, phosphoric acid, and potash in excrement.

	Nitrogen	Phosphoric acid	Potash
	Per cent	Per cent	Per cent
Horse urine	1.52	Trace	0.92
Horse, solid excrement	0.55	0.35	0.10
Cow, urine	1.05	Trace	0.36
Cow, solid excrement	0.43	0.12	0.04

We learn that the urine of the horse contains 1.52 per ct. of nitrogen and the solid excrement 0.55 per ct., or only one-third as much. The reverse holds true for the phosphoric acid, for only a trace of this appears in the urine and nearly all in the solid excrement. Of the potash, 0.9 per ct. is found in the urine and only 0.1 per ct. in the solid excrement.

The fertilizing constituents which pass off with the solid excrement are largely insoluble and to this extent not directly available to plants when applied in manures. On the other hand, the constituents in urine are in soluble form and directly available to the plant.

384. Fertilizing matter produced yearly.—According to Roberts,[2] the quantity and value of manure from farm animals maintained under good conditions is substantially as follows:

Amount and value of fertilizing constituents voided yearly by farm animals.

Animal	Nitrogen	Phosphoric acid	Potash	Value per year
	Lbs.	Lbs.	Lbs.	Dollars
Horse (Hebert)	125	48	43	27.05
Cow	171	26	108	37.48
Sheep (Muntz and Girard)	8	6	14	2.44
Pig (Boussingault)	12	11	12	3.31

The last column of the table, showing the commercial value of the manure of farm animals, is obtained by giving to the several fertilizing constituents the price per pound they at present command in commercial fertilizers, viz. nitrogen 18 cents, phosphoric acid 5 cents, and potash 5 cents per lb.

[1] Expt. Sta. Record, Vol. 5; also Fertility of the Land, Roberts, p. 180.
[2] The Fertility of the Land.

385. Formula for manure production.—Heiden[1] worked out a formula for calculating the amount of manure, both solid and liquid excrements, produced by farm animals from a given quantity of feed. He found that on the average for each 100 lbs. of dry matter supplied in the feed of the horse, 47.33 lbs. reappears in the manure. As fresh horse manure contains about 22.5 per ct. of dry matter, 100 lbs. of dry matter in horse manure would yield:

$$47.33 \text{ lbs.} \times \frac{100}{22.5} = 210 \text{ lbs. fresh manure.}$$

By similar calculations it is found that exclusive of bedding:

For each 100 lbs. of dry matter in the feed:

The horse voids 210 lbs. of fresh manure.
The cow voids 384 lbs. of fresh manure.
The sheep voids 183 lbs. of fresh manure.

386. Value of manure.—The figures given below[2] show the quantity of the several fertilizing constituents in a ton of manure from farm animals, and the value of the same based on the commercial prices for the nitrogen, phosphoric acid, and potash contained:

Value of manure per ton.

Source of manure	Amount in 1 ton			Value
	Nitrogen	Phosphoric acid	Potash	
	Lbs.	Lbs.	Lbs.	Dollars
Horse	9.8	5.2	9.6	2.50
Cow	8.5	5.8	8.8	2.26
Sheep	15.4	7.8	11.8	3.75
Hog	16.8	7.8	6.4	3.73
Calf	10.0	3.4	10.6	2.50

[1] Storer, Agriculture, 1899, Vol. II, p. 289.
[2] Adapted from Bul. 56, New York (Cornell) Expt. Sta.

Part III.

FEEDING FARM ANIMALS.

CHAPTER XVII.

INVESTIGATIONS CONCERNING THE HORSE.

I. Mare and Foal.

387. Period of gestation.—According to Youatt,[1] the average period of gestation for the mare is 11 months, but it may be diminished by 5 weeks or extended 6 weeks. Of 582 mares reported by M. Tessier,[2] the shortest period was 287, the longest 419, and the average 330 days. William Russell Allen of Allen Farm,[3] Pittsfield, Massachusetts, from records of 1,071 foals produced by trotting mares during 15 years, found the maximum gestation period 373, the minimum 319, and the average 340 days.

388. Weight and growth of foals.—Boussingault[4] found that:

"1. Foals, the issue of mares weighing from 960 to 1,100 lbs., weigh at birth about 112 lbs.

"2. During suckling, for 3 months the weight increases in the relation of 278:100, and the increase corresponds very nearly to 2.2 lbs. per head per day.

"3. The increase in weight per day of foals from the end of the first to the end of the second year is about 1.3 lbs., and towards the third year the increase per day falls to something under 1 lb.

"4. After 3 full years, the period at which the horse has very nearly attained his growth and development, any increase becomes less and less perceptible."

Allen found[5] the birth-weight of 1,071 trotting-bred foals to be:

	Maximum Lbs.	Minimum Lbs.	Average Lbs.
Weight of colts at birth	152	66	111
Weight of fillies at birth	144	74	109

[1] The Horse, p. 222.
[2] Farmers' Cyc., Johnson, p. 562.
[3] Catalog, 1905.
[4] Rural Economy, Am. ed.
[5] Allen Farm Catalog, 1905.

The average yearly gain in weight of these foals was:

	Lbs.
Average weight at birth	110
Average gain during first year	534
Average gain during second year	264
Average gain during third year	118
Average gain during fourth year	76
Average weight at end of the fourth full year	1,102

389. Mare's milk.—Below is given the average composition of mare's milk with cow's milk for comparison:[1]

Mare's milk compared with cow's milk.

	Number of analyses	Water	Casein and albumen	Fat	Sugar	Ash	Specific gravity
		Per cent	Per cent	Per cent	Per cent	Per cent	
Mare's milk	72	90.58	2.05	1.14	5.87	0.36	1.0347
Cow's milk	705	87.27	3.39	3.68	4.94	0.72	1.0313

It is shown that mare's milk contains more water and only about one-half as much casein, albumen, and ash as cow's milk, while the sugar is nearly 1 per ct. higher. (**595**) It is white or bluish in color and has an aromatic, sweetish, slightly bitter taste. According to Fleishmann,[2] Tartarian mares sometimes remain in milk for 2 years, producing 440 to 490 lbs. of milk annually in addition to that required by their foals. Vieth[3] reports that good Russian milking mares, when milked 5 times a day as is the practice, yield 4 to 5 quarts of milk daily.

When it becomes necessary to rear foals on cow's milk, it should be diluted with water, and sugar added, tho Peterson and Höfker[4] question the advisability of adding sugar.

II. The Relation of Feed to the Work of the Horse.

The most complete and extensive investigations with the horse bearing on the relations of feed to work are those of Wolff, Grandeau, and Leclerc, and the more recent studies of Zuntz and his associates. Wolff's experiments were with a sweep-power constructed to act as a dynamometer so that the amount of work performed could be measured. Zuntz, in conjunction with Lehmann

[1] König, Chem. d. mensch. Nahr. u. Genuss-mittel, 1904, Vol. II, pp. 602, 663.
[2] Lehrb. d. Milchwirtschaft, 1901, p. 65.
[3] Landw. Vers. Stat., 31, 1885, p. 354.
[4] Milch. Ztg., 26, 1897, p. 647.

and Hagemann, conducted hundreds of tests with horses working on a tread-power so constructed that the distance traveled and the work performed were accurately measured. The animals breather thru a tube inserted in the windpipe, by which means the oxygen inhaled and the carbon dioxid exhaled were accurately determined. (**107**) To such gaseous intake and outgo was added that which passed thru the skin and vent, as determined by placing the animal in a Pettenkofer respiration apparatus. (**61**)

390. Work.—The "foot-pound" and "foot-ton" are terms which denote the work done in lifting a weight of 1 lb. or 1 ton 1 ft. against the force of gravity. When the rate at which the work is done is taken into consideration the unit used is the horse power. A horse power (H. P.) is a power which can lift a weight of 1 lb. at the rate of 33,000 ft. per minute. If by means of rope and pulleys a horse raises a bucket of water weighing 100 lbs. from a well 330 ft. deep in 1 minute, it exerts a force equal to 1 H. P. The pull or draft exerted by the horse may be measured by a dynamometer, a crude form of which is a spring balance placed between the singletree or evener and the vehicle or object on which the pull is exerted. According to King,[1] the maximum pulling power of a horse when walking on a good road is about one-half its weight, but for steady and continuous work for 10 hours per day and at the rate of 2.5 miles per hour the pull should not be more than one-eighth or one-tenth the weight of the animal. The work performed by horses of different weights would accordingly be as follows:

Work performed per day by horses of various weights.

	Power produced	Work done per day
	Horse-power	Foot-tons
800-lb. horse	0.53–0.67	5,247– 6,633
1000-lb. horse	0.67–0.83	6,633– 8,217
1200-lb. horse	0.80–1.00	7,920– 9,900
1400-lb. horse	0.93–1.17	9,207–11,583
1600-lb. horse	1.06–1.33	10,494–13,167

The table shows that a 1000-lb. horse will develop 0.67–0.83 H. P., and will do from 6,633 to 8,217 ft.-tons of work when working 10 hours per day, heavier horses performing proportionately more work.

[1] Physics of Agriculture, p. 490. [2] Loc. cit., p. 436.

According to King,[2] the draft required to haul a 4-wheel wagon on various types of road is approximately as follows:

Character of road	Lbs. draft required per ton
Common earth	75 to 224
Gravel	75 to 140
Macadam	55 to 67
Wood block	28 to 44
Plank	25 to 44

This shows that it requires a draft of 75 to 224 lbs., or a pull of this amount as measured on a spring balance placed between horse and load, to draw a load of a ton, including wagon, on a country earth road, while on a plank road the draft is but 25 to 44 lbs.

The ox draws a load equal to the horse, but ordinarily at only two-thirds the speed. A man's work is usually from one-sixth to one-tenth of a horse power, or about one-fifth that of an average horse. For a minute or two he can do a full horse power or more.

391. Digestion trials.—Since there have been relatively few digestion trials with the horse, we are often obliged to use for this animal the coefficients of digestibility obtained with the ox or sheep. (**58**) While the horse digests the easily digestible feeds about as completely as do the ruminants, it falls below them in ability to digest the more difficultly digestible feeding stuffs, as is shown in the following table from Wolff:[1]

Digestion coefficients of common feeds for the horse and sheep compared.

	Dry matter	Crude protein	Carbohydrates		Fat
			Fiber	N-free extract	
	Per cent	Per cent	Per cent	Per cent	Per cent
Corn					
Horse	89	77	70	94	61
Sheep	89	79	62	91	85
Oats					
Horse	67	79	20	74	70
Sheep	71	80	30	76	83
Alfalfa hay (excellent quality)					
Horse	58	73	40	70	14
Sheep	59	71	45	66	41
Clover hay					
Horse	51	56	37	64	29
Sheep	56	56	50	61	56
Meadow hay (good quality)					
Horse	51	62	42	57	20
Sheep	64	65	63	65	54
Wheat straw					
Horse	23	19	27	18	-------
Sheep	48	----------	59	37	44

[1] Land. Vers. Stat., 20, 1877; 21, 1878; Landw. Jahrb., 8, Sup. I, 1879; 10, 1881; 12, 1884.

It is shown that the horse digests corn, which is low in fiber, equally well as does the sheep. On the other hand, it digests oats and hay, which contain considerable fiber, less completely. Of the dry matter of wheat straw the horse digests only 23 per ct., while the sheep digests 48 per ct. Both animals digest crude protein about equally well, but the digestive powers of the horse are markedly lower for fiber and fat. (**60**)

392. Influence of work on digestibility.—Grandeau and Leclerc,[1] on feeding three 950- to 1000-lb. horses of the Paris Cab Company rations composed of about three-fourths grain and one-fourth hay and straw, obtained the following digestion coefficients:

Digestion coefficients for the horse at rest and at work.

State of the horse	No. of trials	Organic matter	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
		Per cent	Per cent	Per cent	Per cent	Per cent
At rest	21	72	74	46	77	58
Walking, no work	3	72	74	44	77	59
Work at a walk	3	70	72	39	75	62
Trot, no work	3	69	69	40	76	53
Work at a trot	6	67	67	33	73	55

The table shows that the horse digests his ration as well when walking 12 miles per day as when at rest. When the horse worked at a walking pace, there was a slight depression in the digestibility of the ration, and when it worked hard at a trot the depression amounted to as much as 5 per ct. of the organic matter, 7 per ct. of the protein, and 13 per ct. of the fiber. Exercise and work affect the digestion of the fiber of feeding stuffs more than that of the other constituents, doubtless because the fiber, which is digested principally in the colon or large intestine, is hurried thru this organ by the motion of the horse in action. (**60, 609**)

393. True maintenance requirement.—It cannot be assumed that the true maintenance ration of the horse has been found when the intake of the body equals the outgo, as with the ox and sheep. (**96**) Kellner[2] points out that any excess of nutrients supplied the idle horse above maintenance will not usually be wholly stored as flesh or fat, for confined horses, even of quiet temperament, dissipate more or less energy thru restlessness and activities, so that a ration which may barely maintain them is really somewhat in excess of the theoretical requirement.

[1] Ann. Sci. Agron., 1884, Vol. II, p. 235. [2] Ernähr. landw. Nutztiere, 1907, p. 447.

Either of two methods may be employed in determining the true maintenance ration for the horse:

(1) Gradually increasing amounts of a given feed are supplied during successive periods, in each of which the maximum amount of work the horse can perform on the allowance and still maintain his weight is ascertained. Thereby the nutrients required for the performance of a given amount of work are found. By substracting the nutrients expended in the work done during any period from the total nutrients supplied in that period, the net maintenance requirement is determined.

(2) The horse at rest is first insufficiently fed as shown by a decreasing body weight. Then after a time the supply of nutrients is gradually increased until bare body equilibrium is established.

Using the latter method, Grandeau and Leclerc[1] were able to maintain the weight of 3 horses getting walking exercise for half an hour daily on a ration of 17.6 lbs. of meadow hay, which supplied 6.1 lbs. of digestible nutrients, or 7 lbs. per 1000 lbs. live weight.

Using the first method, Zuntz[2] and his colleagues found the average maintenance requirements of the 1100-lb. horse to be as follows:

	Lbs.	Therms*
Digestible nutrients required to warm the body	7.06	12.7
Nutrients required for the upkeep of the body, finally changed into heat	2.43	4.4
Digestible nutrients needed to furnish the remainder of heat necessary to warm the body, by difference	4.63	8.3

* In this table 1 lb. digestible nutrients, including fat multiplied by 2.4, equals 1.8 therms. Scientists have disagreed as to the relative fuel value of fats and carbohydrates. Zuntz in his work assigns to fat 2.4 times the fuel value of the carbohydrates. It is now generally held that the factor should be 2.25, which factor is used elsewhere in this book.

By this method it is shown that to maintain the weight of the 1100-lb. horse when doing no work required a ration containing 7.06 lbs. of digestible nutrients. This is the amount of food fuel required to properly warm the body. Of this amount 2.43 lbs. was used in the internal work of the body and in repairing the body tissues, exclusive of the energy expended in masticating and digesting the ration, and hence was required in the form of net nutrients. (**70**) Nutrients so consumed are ultimately converted into heat and thus help to warm the body. Subtracting 2.43 lbs.

[1] Warington, London Live Stock Journal, 1894, p. 9.

[2] Land. Jahrb., 27, 1898, Sup. III, pp. 422–426.

from 7.06 lbs., there remains 4.63 lbs., the amount of digestible nutrients which were required to furnish the remainder of the heat needed to warm the body. Since the energy used in masticating and digesting the ration is also finally changed into heat in the body, the nutrients used for this purpose are not wasted but help in warming the body. Hence the heat generated in the body as a result of the internal work and the work of masticating and digesting the ration may be enough to properly warm the body, and no nutrients need then be burned up in the body simply as fuel.

Feeds such as poor hay, corn stover, and straw, which contain relatively little net energy, are lower in price than concentrates which supply much net energy. It is therefore usually most economical to formulate a ration for maintenance made up so far as possible of such roughages. So long as 2.43 lbs. of net nutrients are furnished for the upkeep of the body, the other digestible nutrients in the maintenance ration for the 1000-lb. horse may be used up in the work of digesting, masticating, and assimilating the feed. The net nutrients expended in external work and the nutrients used up in the work of digestion, mastication, and assimilation will then furnish sufficient heat to warm the body.

394. Minimum protein requirement.—In experiments by Grandeau and Leclerc,[1] 3 horses maintained their weight for 4 or 5 months on a ration of meadow hay furnishing an average of 0.54 lb. of digestible protein daily per 1000 lbs. live weight, the hay of course containing some amids beside the true protein. One of the horses gained 5 lbs. in 2 months on a daily allowance of only 0.45 lb. of digestible protein per 1000 lbs. live weight. In another case an allowance of 0.37 lb. of digestible protein daily per 1000 lbs. of live weight proved insufficient to maintain the nitrogen equilibrium. Evidently the minimum protein requirement for the horse ranges from 0.4 to 0.6 lb. per 1000 lbs. live weight, which is the same as that of the resting ox as determined by Armsby. We may therefore hold that about 0.45 lb. of digestible protein constitutes the minimum daily maintenance allowance of that nutrient for the 1000-lb. resting horse. (**97**)

395. The nutritive ratio.—We have seen that under normal conditions the non-nitrogenous nutrients—carbohydrates and fats—furnish the energy necessary for the production of muscular work. and that no more protein tissue is usually broken down during

[1] Warington, London Live Stock Journal, 1884, p. 9.

work than during rest. (**109**) Hence, as Kellner[1] points out, there is a great similarity between the nutrient requirement of mature working and mature fattening animals. After growth is completed and the protein tissues and organs of the body have reached full size, both working and fattening animals need only so much crude protein in their food in excess of maintenance requirements as is necessary to insure complete digestion of the ration. The remainder of the nutrient requirements, whether for producing fat with the ox or performing work with the horse, may be met thru a sufficient supply of carbohydrates and fat. (**97**) Accordingly a narrow nutritive ratio is not essential with the work horse. (**131**) Grandeau and Alekan[2] found that when horses working at a trot were fed rations of corn, sugar, and oat straw, furnishing but little crude protein and having extremely wide ratios, varying from 1:21 to 1:28, the ration still contained sufficient digestible crude protein to keep them in excellent condition. Kellner[3] found that horses were able to perform hard labor without deterioration on a ration having a nutritive ratio of 1:9. Grandeau fed 3 horses during a whole year, sometimes on a ration of horse beans and straw having a nutritive ratio of 1:3, and again on one of Indian corn and straw having a ratio of 1:10. While on these rations the horses were either resting in the stall, exercising at a walk or trot, working on a sweep at a walk or trot, or finally working before the carriage. The effect of the rations was about the same in all cases, and any difference was in favor of the corn-and-straw ration having the wider ratio. These and other experiments, as well as practical experience, show that the nutritive ratio for work horses may vary widely without injury so long as the minimum requirement of crude protein is satisfied. Kellner[4] states that the only exception to this rule are animals which have not finished their growth and those undergoing severe exertion at a rapid pace. Such exertion necessitates an unusually abundant supply of oxygen to the muscles. Hence the blood, which is the carrier of oxygen, should be increased in quantity to a certain extent, and this can be brought about only thru a liberal supply of crude protein. Experience has shown that a nutritive ratio as narrow as 1:7 is sufficient for this purpose. Horses which are in low condition and must gain in weight and muscle before they are fit for hard work must of course receive a liberal supply of crude protein.

[1] Ernähr. landw. Nutztiere, 1907, p. 443.
[2] Ann. Sci. Agron., 1901, II, p. 38.
[3] Landw. Jahrb., 9, p. 665.
[4] Ernähr. landw. Nutztiere, 1907, p. 430.

396. The work of the horse.—That work which the horse performs may be resolved into:

(1) Locomotion, or advancing the body along a level course.

(2) Lifting the body, with or without a load, against the force of gravity in ascending a grade.

(3) Carrying a load.

(4) Draft, or hauling a load.

Zuntz[1] determined the amount of energy expended in these various forms of work at different speeds and under varying conditions. His more important findings are presented in articles which follow.

397. Locomotion.—The horse weighing 1100 lbs. including harness expends the following amounts of energy in moving his body 1 mile along a level road at various speeds:

Walking at a speed of 2.9 miles per hour	0.26 therm
Walking at a speed of 3.4 miles per hour	0.29 therm
Walking at a speed of 3.7 miles per hour	0.32 therm
Trotting at a speed of 7.3 miles per hour	0.44 therm

It is shown that increasing the walking speed causes a considerable increase in the amount of energy expended in moving a mile. Trotting at a speed of 7.3 miles per hour causes the expenditure of 69 per ct. more energy than walking at a speed of 2.9 miles per hour.

Since in locomotion the body of the horse is alternately raised and lowered, it is difficult to measure the actual amount of mechanical work performed in order to compare it with the energy expended. Computations by Zuntz indicate that about 35 per ct. of the total energy expended by the horse moving on the level is actually transformed into the external work of advancing his body, the remainder of the energy producing no external work, but taking the form of heat. (**112**)

398. Influence of grade.—When the tread power was set so that the walking horse ascended a grade of 10.7 ft. in 100 at a speed of 3.1 miles per hour, Zuntz found that more than 3 times as much energy was expended as when walking the same distance on the level at a slightly faster pace. When the still steeper grade of 18.1 ft. in 100 was ascended on the tread power at a speed of only 2.8 miles per hour, nearly 5 times as much energy was expended as when moving on a level course.

In going down a gentle incline, owing to the pull of gravity, less energy was expended than in moving on a level road, resulting in a

[1] Landw. Jahrb., 27, Sup. III; Kellner, Ernähr. landw. Nutztiere.

saving of nutrients, such saving being greatest when the down grade was about 5 ft. in 100. If the grade was steeper than this, the horse expended energy in bracing himself to check too rapid progress. When the downward grade reached 10 ft. in 100, as much energy was expended as when traveling on a level, and on a still steeper down grade the amount of energy expended was greater than that expended on the level.

399. Lifting the body.—Zuntz found that a horse walking at a speed of 3.1 miles per hour on a tread power having a grade of 10.7 feet in 100 expended 1.89 Cal., or 0.00189 therm, of energy per ft.-ton in raising the body against the force of gravity This sum is in excess of the energy which would have been expended if the horse had been moving on a level course. It means that in ascending a hill having a grade of 10.7 ft. per 100, the 1000-lb. horse does 1 ft.-ton of work in raising his body 2 ft., expending 1.89 Cal. in performing such work. On this grade 34 per ct. of the energy expended appeared in the external work done in raising the body. The rest of the energy used up produced no external work but was changed into heat. When moving at a speed of 2.8 miles per hour on the steeper grade of 18.1 ft. in 100, 2 per ct. more energy was expended per ft.-ton than upon the gentler grade.

400. Carrying a load.—When carrying a load the horse expends energy in addition to that required for merely moving his body, as the following by Zuntz shows. Upon loading the saddle with about 275 lbs. of lead plates, 8 per ct. more energy was expended when walking at a speed of 3.4 miles an hour than when no load was carried. Trotting at a speed of 6.9 miles per hour with the load caused an expenditure of about 10 per ct. more energy than trotting at the same speed with no load.

401. Draft.—Zuntz found that after deducting the energy necessary for moving the body along a level course, 2.1 Cal., or 0.0021 therm, was required per ft.-ton of draft performed by the horse. Of the total energy used up in the body for performing a given amount of draft, only 31 per ct. resulted in draft, as shown by the dynamometer, the remainder taking the form of heat. We thus see that in performing draft the horse is not able to turn as large a part of the energy used up in his body into mechanical work as he does in moving his body along a level course or in raising it against the force of gravity. In other words, he is able to perform mechanical work less economically in hauling a load than in moving his own body. In drawing a load up a grade of 8.5 ft. in 100 but 23 per ct.

of the energy expended for draft was utilized in the work performed. When performing draft up that grade more work was done per minute, and this led to an increase in the rapidity of breathing and the over-exertion of certain groups of muscles, with the result that more energy was wasted as heat and less was utilized in moving the load.

402. Net nutrients needed in work.—Zuntz, studying the 1100-lb. horse carrying a 44-lb. harness, found the net nutrients (**70**) required for the performance of various kinds of work, in addition to those required for maintenance, to be as follows:

	Net nutrients required Lbs.
Traveling 1 mile on the level	
At a walking speed of 2.5 miles per hour	0.134
At a walking speed of 3.5 miles per hour	0.169
At a trotting speed of 6.6 to 7.6 miles per hour	0.254
Traveling 1 mile when carrying a load of 220 lbs. at	
Walking speed of 3.4 miles per hour	0.210
Trotting speed of 6.9 miles per hour	0.323
Raising his body 100 feet	
In climbing incline of 10.7 per cent	0.060
In climbing incline of 18.1 per cent	0.062
Lowering body 100 ft. on a road with a 5 per cent dip, compared with traveling on the level, saves	0.025
Work of ascent per 1000 ft.-tons	
On an incline of 10.7 per cent	1.050
On an incline of 18.1 per cent	1.072
Draft on level per 1000 ft.-tons, not including locomotion of body	1.157

By means of the above table a given amount of work done by the horse may be resolved into its factors, so that the nutrients required for its production may be estimated and a suitable ration formed. The table is of theoretical rather than practical interest, however, because the work of most horses varies greatly from day to day; consequently it is impossible to more than roughly set forth the nutrients required.

Kellner[1] expresses in starch values the net nutrient requirement of the 1100-lb. working horse as follows:

	Starch values
Light work	10.1 pounds
Medium work	12.8 pounds
Hard work	16.5 pounds

403. True value of feeds.—The true value of different feeds for the horse is not based merely on their content of digestible nutrients, since, as we have seen, a varying percentage of their total energy is

[1] Ernähr. landw. Nutztiere, 1907, p. 453.

used up in the work of mastication and digestion. By subtracting the energy thus expended from the total energy furnished by the digestible portion of any feed its net nutritive value may be found. With the resting animal the energy of the food expended in mastication and digestion serves, within certain limits, to maintain the temperature of the body after its conversion into heat; but for producing external work, only that net portion of the digestible nutrients which remain after the work of mastication and digestion has been performed is of value. (**71**)

According to Zuntz,[1] the 1100-lb. horse when moving on a practically level road will produce about 864.4 ft.-tons of work in draft for each pound of net nutrients consumed in addition to the maintenance requirement. In accordance with such conclusion the following table shows the possible work various feeding stuffs will yield when fed to the horse in excess of the amount required for its maintenance:

Possible work from 1 lb. of various feeds when fed to the horse.

Feeding stuffs	Contained in the feed			Nutrients required for mastication and digestion	Net nutrients remaining	Possible work from 1 lb. of feed
	Dry matter	Digestible nutrients	Fiber			
	Per cent	Per cent	Per cent	Lbs.	Lbs.	Ft.-tons
Corn	87	78.5	1.7	0.082	0.703	607.7
Horse bean	86	72.0	6.9	0.111	0.609	526.4
Peas	86	68.7	5.9	0.102	0.586	506.5
Linseed cake	88	69.0	9.4	0.125	0.565	488.4
Oats	87	61.5	10.3	0.124	0.491	424.4
Alfalfa hay	84	45.3	26.6	0.219	0.234	202.3
Potatoes	25	22.6	1.0	0.027	0.199	172.0
Meadow hay	85	39.1	26.0	0.209	0.182	157.3
Clover hay	84	40.7	30.2	0.239	0.168	145.2
Carrots	15	11.3	1.6	0.021	0.092	79.5
Wheat straw	86	18.1	42.0	0.297	—0.116	—100.3

The table shows that after supplying the horse with sufficient feed to maintain the body when at rest, each additional pound of corn supplied, up to the capacity of the animal, will furnish energy sufficient to produce 607.7 ft.-tons of external work, or enough to lift a weight of one ton 607.7 ft. against the pull of gravity. Because of its high per cent of digestible nutrients and its low content of fiber, Indian corn is the most potential of all the given feeds for the production of work.

[1] Landw. Jahrb. 27, 1898, Sup. III, p. 431.

Feeds containing much fiber, such as hay and straw, furnish correspondingly less net food for the production of external work. The table shows that masticating and digesting wheat straw requires more energy than the straw supplies. Hence the table shows a negative value of —100.3 ft.-tons for 1 lb. of wheat straw. However, so long as the work of masticating and digesting a ration containing straw does not altogether consume more energy than is necessary to furnish sufficient heat to warm the body, the straw in such a ration has a positive value corresponding to its content of digestible nutrients. On the other hand, when the energy used in masticating and digesting a ration containing straw furnishes more heat than the body needs, then the energy of the straw is wasted and its presence in the ration may be deleterious. This helps to explain why straw is useful in the ration of horses doing light or slow work and is of no value or even detrimental in the ration of horses at rapid or hard work.

404. Computing rations.—Two examples are here presented showing the manner in which rations may be computed from the preceding data:

(*1*) *A maintenance ration.*—The amount of meadow hay required to maintain the 1100-lb. horse when at rest is thus calculated:

$$\frac{\text{7.06 lbs. diges. nutr. required for maintenance } \mathbf{(393)}}{\text{0.391 lb. diges. nutr. in 1 lb. meadow hay } \mathbf{(403)}} = \text{18.1 lbs., amount of hay required.}$$

It has been shown that the maintenance ration must contain at least 2.43 lbs. of net nutrients. (**393**) Since 1 lb. of the hay furnishes 0.182 lb. of net nutrients, (**403**) 18.1 lbs. of hay will furnish 0.182 times 18.1 lbs., or 3.3 lbs. The ration of 18.1 lbs. of hay will thus furnish net nutrients somewhat in excess of the minimum requirement. As shown before, this amount of hay is necessary, however, to warm the body.

(*2*) *A work ration.*—If an 1100-lb. farm horse is required to haul a load of 1 ton 20 miles per day on a level road at a speed of 2.9 miles per hour, the average draft being 100 lbs., the work performed will be:

100 (lbs. draft) x 5,280 (ft. per mile) x 10 (miles) = 10,560,000 ft.-lbs. = 5,280 ft.-tons.

During each day the horse will thus perform 5,280 ft.-tons of draft in hauling 1 ton 20 miles. Accordingly, for locomotion, draft, and maintenance the following net nutrients must be supplied in the daily ration:

	Net nutrients
For 20 miles locomotion (0.134 x 20) (**402**)	2.68 lbs.
For 5,280 ft.-tons draft (1.157 x 5,280) (**402**)	6.11 lbs.
For maintenance (exclusive of work of mastication and digestion) (**393**)	2.43 lbs.
Total	11.22 lbs.

If 10 lbs. of meadow hay and 10 lbs. of oats be chosen for the basal ration, the computations would be as follows: (**403**)

		Net nutrients
Total requirement		11.22 lbs.
In 10 lbs. meadow hay (0.182 lb. x 10)	1.82 lbs.	
In 10 lbs. oats (0.491 lb. x 10)	4.91 lbs.	
Total basal ration		6.73 lbs.
Remainder to be supplied		4.49 lbs.

We may supply the lacking 4.49 lbs. of net nutrients by adding 6.4 lbs. corn (4.49 lbs. ÷ 0.703 lb., net nutrients in 1 lb., = 6.4 lbs.). Hence 10 lbs. of meadow hay, 10 lbs. of oats, and 6.4 lbs. of corn will furnish a satisfactory ration for an 1100-lb. horse when drawing a load of a ton 20 miles on a level road at the rate of 2.9 miles per hour.

405. Relation of speed to work.—According to Fourier,[1] a good horse, with the best load for each speed, will perform the maximum amount of work at the speed of about 2 miles per hour. Taking this maximum as unity, he gives the following as the probable value of work performed at other speeds:

Miles per hr.	Daily work	Miles per hr.	Daily work
1.25	0.69	6.25	0.68
2.00	1.00	7.50	0.51
2.50	0.99	8.75	0.33
3.75	0.94	10.00	0.18
5.00	0.83	11.25	0.07

The data show that the horse is at its best for drawing loads when moving at the rate of from 2 to 2.5 miles per hour. As the rate of speed increases beyond this, the amount of energy which the horse can devote to drawing the load grows rapidly less, until when 11.25 miles per hour is reached less than 0.1 of the maximum work can be performed.

[1] Thurston, The Animal as a Machine and a Prime Motor, p. 52.

Where the horse must develop the maximum power continuously at any considerable speed, the number of horses required for a specific work will always be greatly increased. Thus the proprietors of mail-coaches, even on the admirable highways of Great Britain, maintain 1 horse per mile of route for each coach, each horse traveling only 8 miles and working only an hour or less per day on the average, 4 horses drawing the loaded coach which weighs 2 tons. Draft horses moving 2.5 miles an hour are expected to do 7 times the work of coach horses moving 10 miles per hour.

In racing, the requirement of speed reduces the work performed (carrying the rider) to the smallest amount possible. Low writes:[1] "When it is considered that an ounce of additional loading to the same horse may make the difference of a yard or more in half a mile of running, it will be seen how greatly the weight borne may affect the issue in the case of horses of equal powers." (**111**)

406. Relation of speed to feed.—Grandeau[2] found that a horse walking 12.5 miles per day was kept in condition on a daily allowance of 19.4 lbs. of hay, while a ration of 24 lbs. was insufficient when the same distance was covered at a trot. A horse hauling a load 12.5 miles daily, the draft performed being equivalent to 1,943 ft.-tons, was sufficiently nourished by a ration of 24.6 lbs. of hay, while one of 36.2 lbs.—all the horse would eat—was not enough to maintain its weight when the same amount of work was done at a trot.

There are several reasons why rapid labor is less economically performed than slow labor. When a horse is walking at a rapid speed the work of the heart is greatly increased. In trotting or galloping the rise and fall of the body is much greater than in walking, and therefore a smaller part of the energy expended is available for propelling the body. The temperature of the body also rises, and much heat is lost by the evaporation of water thru the skin and lungs. The proportion of food producing heat is thus increased, while that appearing as work is diminished. There are still other reasons why rapid mechanical motion generally consumes more power than slow motion, even when the distance traveled and the weight moved are the same.

407. Severe work.—The horse at severe labor must receive a large supply of net nutrients, and, since its digestive organs are of relatively small capacity, the ration must not have undue bulk. This

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[1] The Breeds of the Domestic Animals of the British Isles.
[2] After Warington, London Live Stock Journal, 1894, p. 49.

necessitates a ration composed largely of rich concentrates, furnishing a high percentage of net nutrients. Roughages, furnishing relatively little net energy, are of low value for producing work, place an increased burden on the already hard-worked animal, and hinder breathing. The more severe the labor, the smaller must be the allowance of coarse feeds. On the other hand, some roughage must be supplied even during severe labor. Kellner[1] states that roughage cannot be long withheld without injury. Horses fed no roughage, but given an abundance of oats, which are rather high in fiber, soon show loss of appetite and impairment of digestive organs. (**428**)

Wolff cites the intense work of the mail-coach horses on the route from Plieningen to Stuttgart, Germany. Two strongly-built, spirited horses, in good flesh, draw a heavy mail coach, often carrying 8 passengers, up and down the mountain road 35 miles daily, trotting at the speed of 5.4 miles per hour. They are fed daily 22 to 24 lbs. of oats mixed with cut straw, and hay without limit, of which they eat very little—often none at all. Under these severe conditions these horses receive sufficient fiber in the oats and cut straw, and hence instinctively refuse hay.

The German army horse often travels over 40 miles in a day, one-third of the distance being at a walk, trot, and gallop respectively. This means the performance of about 11,900 ft.-tons of work. They are fed only 5.5 lbs. of hay, 11 lbs. of oats, and some cut straw, the ration containing only about 8.8 lbs. of digestible nutrients, an amount far below the nutritive requirement. It is therefore not hard to understand why these horses lose heavily in weight during the maneuvers, and that when these are over large numbers have to be disposed of as not suitable for military service.

408. Variations in body weight.—Grandeau and Leclerc[2] found that during exercise and work 2 horses lost in weight as follows:

	Average length of period	Loss in weight
	Min.	Lbs.
Walking, no work	148	2.3
Work at a walk	148	4.3
Trotting, no work	79	4.0
Work at a trot	79	9.3

The loss in body weight by the horse during exercise and work is due to the slight wear of the muscles, the heavier oxidation of the nutritive fluids of the body during work, and the largely increased evaporation of water.

[1] Ernähr. landw. Nutztiere, 1907, p. 455.
[2] Ann. Sci. Agron., 1888, II, p. 276.

The water evaporated daily by the horse with varying exercise and diet was found to be as follows:

Condition of horse	Water evaporated per day
At rest	6.4 pounds
Walking exercise	8.6 pounds
Work at a walk	12.7 pounds
Trotting	13.4 pounds
Work at a trot	20.6 pounds

In this study the distance traveled and the work done was the same in each case. It is shown that the horse when trotting gave off three times as much water vapor as when at rest. Such losses diminish the amount of energy available for the production of work.

Rueff,[1] studying the losses in weight, after making corrections for food and voidings, found that farm horses doing medium work lost 7.7 lbs. each on the average during 11 hours. Army horses ridden for 25 minutes at walk, trot, and gallop lost 4 lbs. each on the average. An 8-yr.-old gelding carrying a 176-lb. load lost 11 lbs. in 25 minutes. Another horse lost the same amount and after 24 hours had regained only 1 lb. A 14-yr.-old blind stallion ridden 90 minutes by a rider weighing 166 lbs. lost 33 lbs., regaining 22 lbs. during the following 24 hours. A 23-yr.-old, 770-lb. mare ridden 6 miles at a walk or trot lost 22 lbs.

Boussingault[2] found the maximum variation in the weight of 2 horses on the same keep and care during 15 days to be 25 and 28 lbs. respectively. A horse put in the scales each morning at 4 o'clock after fasting weighed 1,051 lbs. one morning, 1,060 lbs. the next morning, and 1,038 lbs. the third morning. Boussingault calls attention to the necessity of carrying on feeding experiments for considerable periods and with several animals in order to escape, or rather lessen, the errors which are introduced into the calculations thru accidental variations in the weights of the animals studied.

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[1] Landw. Wchenbl. d. k. k. Ackerbaum., 1870, 109; v. Gohren, Fütterungeslehre, 1872, p. 370.

[2] Ann. Sci. Agron., 1884, II, p. 330; Rural Economy, p. 397.

CHAPTER XVIII.

FEEDS FOR THE HORSE.

I. Concentrated Feeding Stuffs.

409. Oats.—No other grain is so keenly relished by the horse and so prized by horsemen as the oat, which serves as the standard of excellence for nourishing this animal. Not only are oats palatable, but the nutrients they contain are in such proportion that this grain alone forms almost a balanced ration. Tho the oat hull has little nutritive value, it lightens up the feed, giving bulk and lessening possible errors in administering the ration too liberally. The digestive tract cannot hold such a quantity of oats as will ordinarily produce serious troubles from gorging. Because of their universal favor and the wide demand for them, oats are rarely an economical grain, but where expense is not a prime factor they easily hold first place. Only hard-worked horses and those with poor teeth need have their oats ground. New and musty oats should be avoided. A safe rule is 1 quart or pound of oats for each 100 lbs. of horse—more for the hard-worked and less for the idle. (**168**)

410. Substitutes for oats.—While oats are easily the best single concentrate, there are many other grains and by-products from the grains which can be successfully and economically employed in nurturing the horse. On this point Lavalard,[1] the great French authority on the alimentation of the horse, writes: "Not only may single grains and other single foods be substituted for oats, but more or less complex mixtures may be used as well. We believe that both from a hygienic and an economical standpoint our experiments have settled this matter which has provoked so much discussion. An examination of the statistics we have gathered in the last 35 years shows that altho a great saving has been effected, it has not been at the expense of the productive power of the horses." With this view in mind, the several articles which follow will present many grains and by-products that may be successfully fed to the horse.

411. Indian corn.—Next to oats, Indian corn (maize) is the common grain for horses in America, being most largely used in the middle and southern portions of the corn belt and southward in the

[1] Expt. Sta. Rec., 12, p. 4.

cotton states. Millions of horses and mules on American farms and plantations get their strength from corn, not even knowing the taste of oats. While corn does not have all of the superlative qualities of oats, nevertheless because of lower cost and higher feeding value it will always be extensively used in this country wherever large numbers of horses must be economically maintained.

In all cases changes from oats or other feeds to corn should be brought about very gradually. New corn may produce indigestion. The dent varieties, having more floury starch, are softer and more easily masticated, tho no more nutritious than the flint varieties. Ear corn is safer to feed than shelled corn, as the grain keeps best on the cob, and the horse eats corn on the cob more slowly and chews the grain more completely. The Paris Omnibus Company[1] found it advantageous to feed corn-and-cob meal, holding that the fiber of the cobs made the ground material more like ground oats in fiber content Burkett of the North Carolina Station[2] found no gain in corn-and-cob meal over ear corn. When there is ample hay or other roughage in the ration, it is probably best to omit the cob, especially with hard-worked horses. (**157**)

412. Corn v. oats.—At the Ohio Station[3] Carmichael fed mixed clover and timothy hay for roughage to 3 farm teams. One horse in each team was given oats and the other shelled corn in a trial beginning May 16th and lasting 48 weeks, with the results shown below:

Feed consumed and work done by corn-fed and oat-fed horses.

	Av. initial weight	Av. gain or loss	Average ration			Cost of feed	Av. daily gain	Cost of feed per hour of work
			Corn	Oats	Mixed hay			
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dols.	Hrs.	Cents
3 corn-fed horses	1,525	−3	14.9	......	16.0	50.89	5.4	3.3
3 oat-fed horses	1,424	+9	......	14.8	17.3	69.82	5.3	4.5

It is shown that the corn-fed horses ate slightly more grain and less hay than those getting oats. At 40 cents per bu. for corn, 30 cents for oats, and $8 per ton for hay, the corn-fed horses cost $50.89 for 48 weeks keep, while the oat-fed horses cost $69.82. The feed cost 3.3 cents per hour of work done by the corn-fed horses and 4.5 cents, or about 33 per ct. more, for the oat-fed horses. Carmichael reports that during hot weather the corn-fed horses endured hard

[1] Rec. Med. Vet., Feb. 1880; Centbl. Agr. Chem., 1881, p. 767.
[2] Bul. 189.
[3] Bul. 195.

work as well as those fed oats, and that corn was not detrimental to health nor did it induce laziness or lack of endurance. He holds that for mature horses at general farm work ear corn is as efficient as the same weight of oats. It should be remembered that the horses used were mature geldings employed at farm work, and that the roughage fed was mixed clover and timothy hay.

At the North Dakota Station[1] Shepperd found that mules fed 7.7 lbs. of mixed corn and oats gained 0.7 lb. daily, while on 8.8 lbs. of oats they lost 0.6 lb., the work being the same for all. Shepperd concluded that 100 lbs. of corn mixed with 125 lbs. of oats had a greater feeding value than 225 lbs. of clear oats.

Beginning in 1874 the Paris Omnibus Company, employing nearly 10,000 horses averaging about 1200 lbs. each, conducted extensive feeding trials with Indian corn. Feeding corn exclusively was found to depress the spirits of the horses, and accordingly a mixture of 6.6 lbs. of corn and 12.1 lbs. of oats was adopted, varying somewhat with different horses. Lavalard[2] states that thru this combination the company effects a saving of from $200,000 to $300,000 yearly. The Paris Cab Company, also beginning at about the same time to feed corn in place of oats, had such satisfactory results that it has almost entirely ceased feeding oats. Concerning his studies with military horses Lavalard writes: "The horses fed the corn ration were used the same number of hours in military drill, and in the maneuvers were ridden at the same gait as those fed oats, and it was practically impossible to perceive the least difference in the two classes. The army officers, prejudiced as they naturally were, were forced to admit that all the horses showed the same energy and vigor. Careful records kept show that sickness and mortality were the same for the horses on the two rations."

After years of study, covering the feeding of some 16,000 horses in Paris and some 17,000 French army horses, Lavalard[3] writes: "Experiments have demonstrated that corn can replace oats in the ration of both army and cavalry horses, and if substituted weight for weight, it increases the nutritive value of the ration. This is the same deduction which . . . was made for the two great cab companies of Paris."

Many persons object to corn, affirming that horses fed thereon lack nerve and action, sweat easily, and wear out earlier, all of which may be true in certain rather rare cases. The high position of corn

[1] Bul. 45. [2] Expt. Sta. Rec., 12. [3] Loc. cit.

as a horse feed is now so well established that instead of ignoring it we should know its place and possibilities and use it accordingly.

413. Barley.—This grain is extensively employed for horse feeding in Europe, especially in Italy, Spain, and Algiers. In this country it is used on the Pacific Coast, especially in California, where it is in general use. At the North Dakota Station[1] Shepperd fed about 12 lbs. of oats or whole barley to each farm horse daily with timothy hay. The oat-fed horses gained somewhat in weight, while those getting barley lost. The conclusion was that hard-worked horses cannot be quite so well supported on barley as on oats. Lavalard[2] concludes after 20 years' experience that to replace oats a slightly greater quantity of barley must be fed, and this is especially true when rations are calculated as closely as they are with army horses. Where the horses' teeth are good and their labor not severe, barley may be fed whole, but it is usually best to grind or, better, roll it. Barley meal forms a pasty, unpleasant mass when mixed with the saliva in the mouth. This can be largely avoided by crushing the grain to flattened discs between iron rollers, instead of grinding it. (**171**)

414. Wheat.—Shepperd of the North Dakota Station[3] found that whole wheat fed alone proved unsatisfactory, while two parts of ground wheat mixed with one part of wheat bran, by weight, gave good results. Lavalard[4] states that wheat may cause irritation of the skin so that horses suffer greatly. He also speaks of accidents following the feeding of wheat. (**161**)

415. Rye.—Lavalard[5] reports that the Paris Cab Companies feed rye, especially when cheap, using one part of rye to four parts of oats. Like wheat this grain should be ground or, better, rolled. (**177**)

416. Kafir, milo.—In the regions where they flourish, the seeds of the various sorghums are extensively employed for horse feeding, tho somewhat less valuable than corn. Being small and hard, they should be ground or "chopped," and if possible mixed with bran or middlings, as they tend somewhat to constipation. These grains may also be fed unthreshed in the heads along with the forage. Morrow of the Oklahoma Station[6] reports the successful feeding of kafir to farm mules. (**183-4**)

417. Northern field pea.—In the northern portion of the corn belt and farther north the field pea flourishes and furnishes a valuable concentrate for the nourishment of the horse. It should always

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[1] Bul. 45.
[2] Expt. Sta. Rec., 12.
[3] Bul. 45.
[4] Expt. Sta. Rec., 12.
[5] Loc. cit.
[6] Rpt. 1898.

be ground and mixed with corn meal, ground oats, middlings, etc. At the Maine Station[1] Jordan found that draft-type colts fed on ground field peas and wheat middlings made slightly better gains than those fed oats. (**205**)

418. Cowpea.—At the North Carolina Station[2] Burkett found cowpea meal an economical and satisfactory substitute for one-half the usual grain allowance given farm horses and mules. (**206**)

419. Wheat bran, middlings, shorts.—Bran is one of the most useful of feeds for the horse. Because of its phosphorus-holding phytin it is a mild laxative. If not more freely used, it should be given at least once weekly, dry, wet, or steamed, for its beneficial effect on the alimentary tract. Middlings and shorts are hardly so desirable as bran, tho probably furnishing as much nutriment. It is not always safe to feed them alone, as they tend to produce colic with some horses. All these valuable milling by-products are best fed in combination with other concentrates—corn, oats, barley, dried brewers' grains, etc. (**165-6**)

420. Wheat bran v. oats.—At the New Hampshire Station[3] Burkett fed 4 farm work horses 12 lbs. each of timothy hay daily during the summer season. All were fed 7 lbs. of corn each daily, and either 7 lbs. of oats or 7 lbs. of bran additional, with the results shown in the table.

Wheat bran and corn compared with oats and corn.

Average ration	Av. weight at beginning	Average gain	Average work done
	Lbs.	Lbs.	Hours
Lot I			
Timothy hay, 12 lbs.			
Corn, 7 lbs.			
Oats, 7 lbs.	1,270	28	1404
Lot II			
Timothy hay, 12 lbs.			
Corn, 7 lbs.			
Wheat bran, 7 lbs.	1,220	113	1266

It is shown that the horses getting wheat bran in place of oats did somewhat less work but gained more in weight. Burkett repeated the trial during the winter with substantially the same results. The conclusion was that for work horses bran could replace an equal weight of oats when combined with corn and timothy hay.

From years of practical experience Shepperd of the North Dakota Station[4] concludes that a mixture of equal parts by weight of bran

[1] Rpt. 1891. [2] Bul. 189. [3] Bul. 82. [4] Bul. 45.

and shorts is equal to the same weight of oats for feeding farm work horses, tho not quite so palatable. Merrill of the Utah Station[1] found bran and shorts satisfactory with horses getting alfalfa hay.

421. Dried brewers' grains.—At the New Jersey Station[2] dried brewers' grains were substituted for oats with street-car horses averaging 1000 lbs. in weight and traveling not less than 24 miles per day. The rations were:

Dried-brewers'-grains ration	Lbs.
Hay	6
Wheat bran	2
Shelled corn	4
Dried brewers' grains	8

Oats ration	Lbs.
Hay	6
Wheat bran	2
Shelled corn	4
Oats	8

The veterinarian in charge of the horses wrote: "I have watched the horses closely from the beginning to the end of the experiment and have failed to discover any ill effects from dried brewers' grains. The horses fed the grains have been as healthy as I have ever known them to be." The station authorities reported that on the whole a pound of dried brewers' grains was as useful as a pound of oats when forming part of the concentrates in the ration of work horses. Lindsey of the Massachusetts Station[3] found dried brewers' grains of good quality fully equal to oats for horses and more economical. Not being particularly palatable they should be mixed with other concentrates such as bran and corn. **(175)**

422. Linseed oil meal.—At the Iowa Agricultural College[4] Kennedy, Robbins, and Kildee, during a 100-day trial beginning in June, fed 1 horse in each of 3 teams on corn, oats, and an allowance of 0.1 lb. linseed oil meal daily. With the others the corn allowance was materially increased, the oats reduced, and the oil meal increased by 1 lb. The results are shown in the table.

Feeding linseed oil meal and corn in place of oats.

Average ration	Av. weight at beginning	Av. loss in weight	Av. daily work done	Cost of feed per day per horse
	Lbs.	Lbs.	Hours	Cents
Lot I				
Corn, 7.3 lbs.				
Oats, 10.0 lbs.				
Oil meal, 0.1 lb.				
Hay, 13.7 lbs.	1,522	12	6.4	24.6
Lot II				
Corn, 14.1 lbs.				
Oats, 2.6 lbs.				
Oil meal, 1.1 lb.				
Hay, 13.5 lbs.	1,385	1	6.4	23.0

[1] Bul. 77. [2] Rpt. 1892. [3] Bul. 99. [4] Bul. 109.

It is shown that the horses getting corn and linseed meal in place of most of the oats in the ration did as much work and lost slightly less in weight than those getting more oats and less corn and oil meal. The change saved 1.6 cents daily in cost of feed. It was found that the oil meal has a laxative tendency which prevents its too free use with horses, especially in summer. Otherwise it was entirely satisfactory in maintaining their weight, spirits, and willingness for work. (**200**)

423. Cotton-seed meal.—In a test lasting 154 days with 3 work teams at the Iowa Station[1] it was found that in combination with corn and oats 1.1 lbs. of cotton-seed meal was as effective in maintaining the weight of the horses and in enabling them to do work as 1.4 lbs. of linseed oil meal. The cotton-seed meal was less laxative than the oil meal, and for that reason better adapted to the needs of hard-worked horses in summer.

At the North Carolina Station[2] Burkett found that a daily allowance of 2 lbs. of cotton-seed meal could be safely fed to farm horses and mules. Corn stover, corn, and cotton-seed meal made a satisfactory winter ration for horses and mules doing moderate work. Judge Henry C. Hammond of Augusta, Georgia,[3] reports that for 5 years he fed 1 lb. of cotton-seed meal daily to each of 10 pleasure and work horses, and during that time there was not a sick horse or one not ready for work. Since horses do not relish cotton-seed meal, Hammond advises that it be thoroly incorporated with ground feed rather than fed with whole grain. (**189**)

424. Mixed concentrates.—At the New Jersey Station[4] Voorhees fed 2 lots, each of 2 horses averaging about 1,160 lbs. in weight, the following rations during a 6 months' trial:

Lot I	*Lot II*
Timothy hay, 8 lbs.	Timothy hay, 8 lbs.
Corn meal, 6 lbs.	Corn meal, 6 lbs.
Dried brewers' grains, 6 lbs.	Wheat bran, 6 lbs.
	Oil meal, n. p., 1.5 lbs.

The horses in both lots maintained their weight and were in satisfactory condition thruout the whole period. At the ton-prices allowed—timothy hay, $18; wheat bran, $17.50; corn meal, $22; dried brewers' grains, $17; and linseed meal, $29—the dried-brewers'-grains

[1] Bul. 109.
[2] Bul. 189.
[3] Pamphlet "Cotton-seed Meal for Horses and Mules"; private correspondence.
[4] Rpt. 1893.

ration cost 19.4 cents and the wheat-bran and oil-meal ration 21.6 cents. A gardener living near the station, guided by its teachings, successfully fed a ration similar to No. 1 to 8 animals with a saving in his yearly feed bills of about $150 over previous cost.

425. Cane molasses.—Walton[1] reports the successful feeding of over 1,000 horses on a sugar plantation in the Fiji Islands on a ration of 15 lbs. cane molasses, 3 lbs. wheat bran, and 4 lbs. corn (maize), with green cane tops for roughage. The health of the horses was greatly improved by the molasses. Constipation caused by the molasses was counteracted by the bran. There was no undue fatness or softness of flesh and no injury to the wind. Dalrymple of the Louisiana Station,[2] collecting data from 47 Louisiana sugar plantations, found that an average of 10 lbs. of cane molasses was fed daily to each horse, effecting a saving of from 10 to 50 per ct. in the cost of the ration and reducing the number of digestive ailments. Lindsey of the Massachusetts Station[3] considers cane molasses at 14 cents per gallon of 12 lbs. a cheap carbohydrate for horses. In reasonable amount, cane molasses should prove particularly helpful with horses at hard work, such as draft teams in cities. (**314**)

426. Beet molasses.—Because of its alkaline purging properties beet molasses must be fed with caution and in limited quantity. Many of the molasses feeds now on the market are of low quality. Only those known to be of good quality should be fed. Goldsmith[4] reports that in Denmark 2.2 lbs. of a mixture of beet molasses and dried swamp peat could advantageously replace an equal weight of corn for street-car horses. (**312**)

Lindsey of the Massachusetts Station[5] holds that dried molasses beet pulp should prove a valuable feed for horses. (**311**) Goldsmith[6] found that blood-molasses feed can economically replace one-fourth of the grain in rations for horses. (**312**)

427. Miscellaneous.—At the Indiana Station[7] Plumb found dried distillers' grains, when forming about one-third of the grain allowance, fairly satisfactory with some horses, while unpalatable to others. Lindsey of the Massachusetts Station[8] reports that dried distillers' grains gave excellent results with horses when forming one-fourth of the concentrates in the ration. (**317**)

[1] Agr. Gaz. New South Wales, 9, 1898, p. 169.
[2] Bul. 86.
[3] Bul. 99.
[4] Expt. Sta. Rec., 10, p. 778; Ugeskr. Landm., 43, 1898, pp. 306–309.
[5] Bul. 99.
[6] Landmandsblade, 32, 1899, p. 349; Exp. Sta. Rec. XI, p. 880.
[7] Bul. 97.
[8] Bul. 99.

At the North Carolina Station[1] Burkett found tankage and dried blood useful for run-down and thin horses. Lindsey[2] states that from 0.5 to 1 lb. of blood meal daily will prove a helpful addition to the ration of hard-worked horses. (**306**)

Clark of the Utah Station[3] found that farm horses will eat as much as 20 lbs. of wet beet pulp daily without injury, and that when combined with oats and alfalfa 9 lbs. of well-fermented wet beet pulp is equal to 1.5 lbs. of oats. (**309**)

Rusche[4] states that peanut meal and malt sprouts may be used in place of oats for feeding foals. (**176, 202**)

The French War Department[5] found that cocoanut meal was equal to the same weight of oats for maintaining army horses. (**204**)

Nordendahl[6] reports the successful feeding of Swedish army horses on bread made of ground oats and skim milk, 1 lb. of bread equaling 2 lbs. of oats.

II. Roughages for the Horse.

428. Necessity for roughage.—Patterson of the Maryland Station[7] attempted to feed 2 horses on oats alone, offering from 13 to 15 lbs. to each daily. By the end of the fourth day one of the horses refused the oats entirely and drank but little water. On the seventh day the other horse would eat only a part of the grain, and by the tenth day none whatever. Evidently the horse cannot live upon concentrates alone, even oats with their straw-like hulls. (**118**)

429. Timothy hay.—Altho not particularly rich in digestible nutrients, timothy hay is the standard roughage for the horse thruout almost the whole of the northeastern United States. The freedom from dust of good timothy hay commends it as a horse feed, and it is an excellent roughage for those horses whose sustenance comes mostly from concentrates. A reasonable allowance of this hay is 1 lb. daily per 100 lbs. of animal, given mostly at night. So far as possible the other roughages here considered will be compared with timothy hay as the standard. (**224**)

430. Cereal hay.—On the Pacific Coast, especially in California, the cereal hays—barley, the wild oat, wheat, etc.—are extensively employed as roughages for horses. The excellence of the speed horse and the endurance of the work horse of the Coast region attest the

[1] Bul. 189.
[2] Mass. Bul. 99.
[3] Bul. 101.
[4] Jahrsb. Agr. Chem., 1889, p. 621.
[5] Milch. Zeit., 1883, p. 517.
[6] Expt. Sta. Rec., 8, p. 152.
[7] Bul. 51.

merits of these feeds. In some cases where speed horses were sent to the East for racing, cereal hay was forwarded with them for their nourishment. Cereal hay may often be advantageously employed for horse feeding in the eastern United States. At the North Carolina Station[1] Burkett found that hay from oats cut in the milk stage compared favorably with clover and cowpea hay for horses. (**231**)

431. Brome hay.—At the North Dakota Station[2] Shepperd gave oats and brome hay to one horse in each of two work teams during spring plowing, while the other received oats and timothy hay, with the results shown in the table:

Brome hay compared with timothy for farm horses.

Hay fed	Ration		Average daily gain in weight	Average daily work
	Oats	Hay		
	Lbs.	Lbs.	Lbs.	Hours
Brome hay	14.5	22.2	0.77	5.2
Timothy hay	14.5	21.9	0.42	5.2

The horses getting brome hay gained more in weight than those getting timothy, showing that for Dakota conditions brome hay is fully equal to timothy hay for farm work horses when oats are fed as the concentrates. (**228**)

432. Bermuda hay.—At the Mississippi Station[3] in a trial with mules getting corn for concentrates, Lloyd found Bermuda hay equal to timothy hay in feeding value. (**232**)

433. Millet hay.—Hay from Hungarian grass, Japanese millet, etc., may often be advantageously fed to horses, provided the allowance is limited. Hinebauch of the North Dakota Station[4] found that, fed exclusively to horses for long periods, millet hay caused increased action of the kidneys, lameness and swelling of the joints, infusion of the blood into the joints and finally destruction of the texture of the bones, which were rendered soft and less tenacious so that movements of the animal would sometimes cause the ligaments and muscles to be torn from them. Since the millets are among the oldest and most widely grown of all agricultural plants, it is but fair to hold that good millet hay, fed in moderation, or with some other roughage and always with some concentrate, should prove satisfactory and produce no unfavorable effects. (**229**)

[1] Bul. 189. [2] Bul. 45. [3] Bul. 15. [4] Bul. 26.

434. Sorghum hay.—Forage from the sweet sorghums, when properly cured, is superior to corn forage for horses. It usually deteriorates rapidly in value after midwinter unless well cured and kept in a dry place. Moldy, decaying sorghum forage is especially dangerous to horses. Kafir, tho not quite so palatable as the sweet sorghums, is extensively and profitably used for horse feeding over a large region in the southwestern United States. The Oklahoma Station[1] found kafir stover equal in feeding value to corn stover. (**222**)

435. Corn forage.—Thickly grown fodder corn and corn stover, when properly cured and cared for, are among the best of roughages for the horse. Corn leaves are usually quite free from dust, palatable, and full of nutriment. For stallions, brood mares, idle horses, and growing colts good corn forage is usually a most economical and helpful substitute for timothy hay. When the yield of fodder corn and its feeding value are compared with that of the timothy hay from a like area, the usefulness and economy of this much neglected forage is apparent. The cured corn plant should be much more generally used in America for horse feeding than it now is. (**217**)

436. Corn stover v. timothy hay.—At the New Hampshire Station[2] Burkett fed 4 farm horses in winter on oats, bran, and corn for concentrates, giving 2 horses 12 lbs. each of timothy hay daily for roughage, while 2 others received the same weight of fine-cut corn stover. The table shows the average results for the period covering January to April:

Cut corn stover compared with timothy hay.

Average ration	Average weight	Average gain	Average work done
	Lbs.	Lbs.	Hours
Lot I Corn stover, 12 lbs. Oats or bran, 7 lbs. Corn, 7 lbs.	1,215	3	247
Lot II Timothy hay, 12 lbs. Oats or bran, 7 lbs. Corn, 7 lbs.	1,235	18	241

Since the stover-fed horses did a little more work than the others and gained but slightly less, cut corn stover may be regarded as equal to timothy hay in this trial. Since timothy hay sells for from 2 to 4 times as much as stover, the great economy in using stover is apparent.

[1] Rpt. 1899. [2] Bul. 82.

437. Straw.—Straw contains much fiber, and its mastication and digestion by the horse calls for a large amount of energy, which appears as heat, thereby warming the body, tho not producing useful work. Because of this, horses doing little or no work in winter and having ample time for chewing and digesting their feed can often be profitably wintered largely on good bright straw. Many horses are fed costly hay in winter when straw, corn fodder, or corn stover would prove equally satisfactory and much cheaper. In Europe nearly all rations for horses contain some straw, those hardest worked receiving the least. In feeding value the straws rank in the following order: oat, barley, wheat, rye, the last named having but slight value. (**242**)

438. Corn stover and straw.—At the Michigan Station[1] Norton fed 2 lots, each of 6 farm work horses doing moderate work, for 10 weeks during winter on feeding stuffs costing as follows per ton:

			Dollars
Shredded corn stover (husked shock-corn forage)			4.00
Oat straw			5.00
Carrots			3.00
Timothy hay			12.00
Ear corn			20.00
Oats			31.00
Wheat bran			24.00
Dried beet pulp			18.00
Old process linseed-oil cake			30.00
Dried beet pulp	4 lbs.	Feed mixture	21.00
Bran	1 lb.		
Linseed-oil cake	1 lb.		

The following table gives the average amount of feed consumed daily per horse and the cost of the same:

Feed consumed and daily cost per horse.

Lot	Av. wt. at beginning	Timothy hay	Corn stover	Oat straw	Carrots	Oats	Ear corn	Feed mixture	Cost of feed per day
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Cents
I	1,254	20.4	--------	--------	--------	11.0	--------	--------	29.6
II	1,291	4.2	8.6	4.3	5.4	3.1	4.2	2.6	17.7

In addition to hay and oats the horses of Lot I were given a light feed of bran once a week. During the trial the horses in Lot I lost 11 lbs., and those in Lot II gained 14 lbs.

It is shown that when fed timothy hay and oats, farm horses doing ordinary work in winter cost about 30 cents per head daily for

[1] Bul. 254.

keep, while the keep of those fed corn stover, oat straw, and carrots in place of most of the hay, and ear corn and mixed feed in place of most of the oats, cost about 18 cents per head daily—a saving of 40 per ct. In this trial corn stover and oat straw proved both an economical and a satisfactory substitute for timothy hay as a winter feed for horses at moderate work.

439. Clover hay.—Because clover hay is ordinarily carelessly made and loaded with dust, it is almost universally disliked by horsemen, yet it is successfully used by some liverymen. Roberts[1] writes: "The chief reasons for not feeding clover hay to driving horses are two: It is always more or less dusty, and it is too proteinaceous, and hence tends to loosen the bowels when the animal is put at hard, fast work. However, if clover hay be mixed with bright straw, and the mass dampened, a satisfactory roughage ration will be secured for all but fast drivers." Terry,[2] the conservative, reliable farmer-writer, kept a medium-weight farm work team for a number of years in prime condition solely on well-made clover hay. In clover hay and bran, which when combined furnish much crude protein, phosphorus, and lime for muscle and bone building, the horseman has a most valuable combination, especially for brood mares, foals, and growing horses. Johnstone[3] writes: "Bright clover hay that is gotten into the barn without rain and is entirely free from dust and mold is, used in moderation, the best possible ration for brood mares and young horses." (**254, 446**)

440. Alfalfa hay.—As with clover, there is a prejudice among liverymen against alfalfa hay; yet some use it, and it furnishes the sole roughage for horses upon tens of thousands of farms and ranches in the West. At the Utah Station[4] alfalfa formed the sole roughage for all the work and driving horses at the station for 12 years, except during brief periods while they were on other experimental fodders. During all that time not a horse was lost either directly or indirectly from alfalfa feeding. It was found that horses fed timothy hay voided an average of 16 lbs. each of urine daily, and those on alfalfa 27 lbs., early-cut alfalfa hay causing a greater excretion than late-cut. Emery of the Wyoming Station[5] found that 13.8 lbs. of alfalfa hay and 2.25 lbs. of oat straw would maintain the weight of a 1000-lb. idle horse. (**245**)

441. Alfalfa v. timothy hay.—At the Utah Station,[6] during experiments covering 310 days, Merrill fed 25 lbs. of alfalfa hay daily

[1] The Horse, p. 282.
[2] Our Farming, p. 137.
[3] The Horse Book, p. 74.
[4] Bul. 77.
[5] Twelfth Rpt.
[6] Bul. 77.

to each of 2 horses, while 2 others received 25 lbs. each of timothy hay, all doing farm work. For concentrates each horse received 10 lbs. of mixed bran and shorts daily, except during unusually hard work when 15 lbs. was given. The alfalfa-fed horses held their weight or gained, while those fed timothy hay sometimes lost. In all cases the alfalfa-fed horses appeared in better condition than those getting timothy hay. Merrill writes: "The teamsters did not notice any particular effect of the feed on the willingness of the horses to do work, tho they were agreed that if they could have their choice they would much prefer those fed alfalfa."

442. Cowpea hay.—In a feeding trial at the North Carolina Station[1] Burkett found that cowpea hay combined with corn-and-cob meal made a satisfactory work ration, and that cowpea hay with a reasonable quantity of corn could be substituted for bran and oats. (**261**)

443. Corn silage.—This feed has been successfully used in a limited way by a few individuals. Nourse of the Virginia Station[2] fed 6 mules and 2 horses during winter on hay, corn, and from 50 to 200 lbs. of corn silage per head weekly. The conclusion was that corn silage is a good roughage for horses when combined with hay, corn stover, and grain. Nourse holds that most of the troubles caused by feeding silage to horses come from not gradually accustoming the animals to this feed, from feeding too heavily, and from not realizing that silage often contains much corn. Pearson[3] of the University of Pennsylvania, investigating an outbreak where 5 horses suddenly died, found that moldy silage had been fed. On feeding half a bushel of the moldy silage paralysis of the throat occurred, followed by death. When water which had percolated thru this moldy silage was given to a horse it likewise proved fatal. Wing[4] reports the death of 8 horses from eating waste silage thrown into yards from racks where lambs were being fed. In view of such remotely possible troubles, silage should be fed to horses only where intelligent supervision insures the use of good material given in moderation to animals gradually accustomed thereto. (**363**)

444. Roots.—The use of roots and tubers for nourishing horses will hardly assume importance in this country because Indian corn, kafir, etc., furnish nutriment at lower cost. Roots, especially carrots, are greatly relished by horses, and because of their succulence may serve a most useful purpose in the stable, where they are great favor-

[1] Bul. 189.
[2] Bul. 80.
[3] Expt. Sta. Rec., 12, p. 886.
[4] Breeder's Gaz., 45, 1904, p. 568.

ites when cost of keep is not a prime requisite. In 1844 the great French chemist and farmer, Boussingault, conducted the most extensive studies of roots for horse feeding ever carried on. His findings[1] may be summarized as follows:

That 280 lbs. of cooked potatoes mixed with cut straw are equal to 100 lbs. of meadow hay.

That 350 lbs. of carrots cannot quite replace 100 lbs. of good meadow hay.

That artichokes were greedily eaten by horses, which thrived on them, 30 lbs. of sliced tubers taking the place of 11 lbs. of meadow hay.

That 400 lbs. of rutabaga turnips (swedes) are about equal to 100 lbs. of meadow hay.

445. Stock food.—Grisdale of the Ottawa Experimental Farms[2] gave 1 horse in each of 5 work teams the amount of International Stock Food indicated in the directions accompanying the package, the other horse in each team receiving no condimental food. All received 14 lbs. a day of an oats-and-bran mixture for concentrates. The horses getting the stock food made an average total gain of 12 lbs. each in 42 days, while those getting no stock food made an average gain of 13 lbs. each. Grisdale reports that in appearance and spirit the horses getting no stock food were the equal of their mates fed stock food. (**343**)

446. Fleshing horses for market.—With three expert horse dealers for counsel, Obrecht of the Illinois Station[3] studied the cost of fleshing horses for the market. Thirteen Eastern chunks were divided into 3 groups and fed the rations given below for 84 days:

Fleshing horses for market.

Average ration	Av. daily gain	Av. total gain	Av. cost of 1 lb. gain	Av. value of 1 lb. gain	Av. total increased value
	Lbs.	Lbs.	Cents	Cents	Dollars
Lot I, 5 horses					
Corn, 17.7 lbs.					
Wheat bran, 2.4 lbs.					
Oil meal, 0.4 lb.					
Clover hay, 13.9 lbs.	2.3	192	13.9	26.6	51.00
Lot II, 4 horses					
Corn, 8.6 lbs.					
Oats, 8.6 lbs.					
Wheat bran, 2.4 lbs.					
Oil meal, 0.4 lb.					
Clover hay, 13.7 lbs.	3.0	250	12.4	19.5	48.75
Lot III, 4 horses					
Corn, 8.4 lbs.					
Oats, 8.3 lbs.					
Wheat bran, 2.6 lbs.					
Oil meal, 0.4 lb.					
Timothy hay, 14.7 lbs.	1.9	158	20.0	22.2	35.00

[1] Rural Economy, p. 400. [2] Rpt. 1906. [3] Bul. 141.

In this trial clover hay proved far superior to timothy hay, putting on 1.1 more lbs. of gain daily for 84 days, a difference of 58 per ct. in favor of clover hay. A ration of half corn and half oats fed in conjunction with clover hay put on 0.5 lb. more gain daily than one containing corn and no oats. In a second trial with clover hay for roughage, 3 parts corn and 1 part oats proved more economical than half corn and half oats, and a ration of 4 parts corn and 1 part wheat bran proved superior to a corn ration. When much bran was fed with clover hay the combination proved too laxative. It was found that horses getting no exercise gained 24 per ct. more than those walking 2.8 miles daily. Those in single stalls gained 8 per ct. more than others in box stalls, because in the latter the horses took some exercise by moving about the stalls.

Valuing corn at 65 cents and oats at 55 cents per bu., and bran at $26, oil meal at $32, clover hay at $11, and timothy hay at $12 per ton, the gain of Lot I, receiving corn and clover hay, cost 13.9 cents per lb., and of Lot II, on corn, oats, and clover hay, 12.4 cents, while the gain of Lot III, fed timothy hay and the same concentrates, cost 20 cents per lb. The great superiority of clover over timothy hay for fleshing horses is plainly shown. It is evident that fattening horses require about the same amount of feed as fattening cattle for a given gain in weight.

III. Preparation of Feeding Stuffs for the Horse.

447. Chaffed hay.—In large establishments chaffing or cutting the hay given to horses is usually advisable, because the cut roughage can then be accurately administered according to the needs of each animal, dust can be allayed, and the feeding operations more systemized and expedited. Horses that have been on the street all day and have worked to the limit may be given meal mixed with a small portion of the moistened chaffed hay, some of the nourishment thus being passed to the stomach more quickly than is possible when feeding long hay. On this point Lavalard,[1] summarizing extensive experience with omnibus and cab horses in Paris, writes: "For the past 4 or 5 years we have chopped coarse fodder, using a ration of equal parts of hay and straw, and have found this practice the most economical for several reasons: Straw may thus be made to form an integral part of the ration, and the proportion of hay and straw may be accurately regulated. Furthermore, horses waste much less of

[1] Expt. Sta. Rec., 12, p. 12.

such fodder. . . . The feeding of chopped fodder has brought about a considerable saving and permitted greater uniformity than was previously the case in our experiments.'' On the other hand, having in mind farm horses, Lindsey of the Massachusetts Station[1] holds that there is no particular advantage in cutting hay. (**340**)

448. Cooked feed.—The custom of cooking even a small portion of the feed given to horses is gradually falling into disuse. Johnstone,[2] who had the practice thoroly ingrained into his nature by his early Scotch experience, out of his later studies and observations writes: ''Time was when I considered the feeding of sloppy stuff a necessity in properly wintering brood mares, but experience has shown me that dry food is best. Therefore I prefer uncooked food. . . . Time was when I believed that for stallions during the season it was an excellent plan to give a mash of boiled barley every Wednesday and Saturday night. . . . The experiments have, however, shown that the addition of this material to a horse's grain ration makes no appreciable difference in the manner in which the grain is digested.'' (**334-8**)

449. Soaked grain.—Wolff[3] found that healthy horses with good teeth utilized beans and corn equally well whether fed whole and dry or after having been soaked in water for 24 hours, care being taken in the latter case to guard against loss of nutrients. Ear corn that is so dry and flinty as to injure the horse's mouth should be soaked or ground. Whole wheat and barley should always be soaked if they cannot be ground or, better, rolled. (**339**)

450. Ground grain.—From his extensive studies with thousands of cab, omnibus, and army horses in France, Lavalard[4] gives the following helpful counsel: ''Contrary to the opinion of some experts, the writer believes it is not necessary to grind grain for horses. This is especially true in the case of oats. It does not appear that the advantages gained by grinding are sufficient to cover the cost of the operation. In some of our earlier experiments, where ground grain was fed, it was noticed after a few months that the horses preferred to crush it themselves. Of course this does not refer to old horses. They can be fed ground grain to advantage.''

At the North Carolina Station[5] when ear corn was compared with corn-and-cob meal the difference was in favor of the corn-and-cob meal when corn stover was used as a roughage. When clover hay was fed the difference was inconsiderable.

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[1] Bul. 99.
[2] The Horse, p. 77.
[3] Landw. Jahrb., 16, 1887, Sup. III, p. 21.
[4] Expt. Sta. Rec., 12, p. 12.
[5] Bul. 189.

Grisdale of the Ottawa Experimental Farms[1] concludes that where a mixture of cut hay and bran is fed to horses having good teeth, there is no advantage in grinding oats. When horses are hard worked and have but little time in the stable, or when their teeth are poor, it is well to grind their grain. All small, hard grains, such as wheat, barley, rye, and kafir, should always be ground or, better, rolled. (**331-3**)

IV. Water Drank; Cost of Keep.

451. Water drank.—Wolff[2] found that as much as 47 per ct. of the water consumed by the horse reappeared in the feces or solid excrement, and 39 per ct. in the urine, the remainder being exhaled from the lungs and skin. Grandeau and Leclerc,[3] experimenting with Paris cab horses, found the daily consumption of water to be as follows:

Water drank daily by cab horses.

Work done	Horse No. 1	Horse No. 2
	Lbs.	Lbs.
Walking, with no load	24.9	30.7
Walking, drawing load	28.9	35.4
Trotting, with no load	31.3	27.6
Trotting, drawing load	52.0	50.7

The table shows that the horse drinks much more water during labor than when idle.

Merrill of the Utah Station[4] found that horses fed timothy hay drank 79 lbs. of water each daily, while on alfalfa hay they drank 10 lbs. more. One of 2 horses getting alfalfa hay drank 21 lbs. of water more per day than the other. Morrow of the Oklahoma Station[5] reports that during hot weather in August a pair of farm mules drank 350 lbs. of water in 1 day—an extremely large amount. It is evident that the amount of water which horses will drink depends upon many factors, the most important of which are the individuality of the animals, the temperature of their surroundings, the nature of their food, and the amount of work performed. (**87**)

452. Time of watering.—The following conclusions were reached by Tangl[6] of Budapest, whose investigations concerning the time of watering horses are the most complete of any recorded: Horses

[1] Rpt. 1905.
[2] Landw. Jahrb., 16, 1887, Sup. III, p. 109.
[3] Ann. Sci. Agron., 1888, 2, p. 276.
[4] Bul. 77.
[5] Rpt. 1898.
[6] Landw. Vers. Stat., 57, 1902, p. 329.

may be watered before, after, or during meals without interfering with the digestion or the absorption of the food they eat. All methods are equally good, tho circumstances may favor one over the other. A horse long deprived of water, or having undergone severe exertion, should be watered before getting his feed. An animal accustomed to a certain order of watering should not be changed to another order, for such change diminishes the appetite. Horses drink the greatest amount of water when it is given after they have been fed, and the least when it is supplied before they are fed. The excretion of urine is directly proportional to the amount of water consumed, while the composition of the feces is not so affected. The weight of the horse varies with the amount of water drank. Tangl shows that the only important point in this whole matter, about which there has been so much discussion and dogmatic assertion, is to adopt a reasonable, convenient system of watering and then rigidly adhere to it.

In making provisions for water from 10 to 12 gallons, or about 100 lbs., should be allowed for each horse.

453. Feed consumed yearly.—Only a limited amount of data are available relating to the total annual feed consumption of horses. At the New Hampshire Station[1] Burkett recorded all feed eaten, water drank, and hours of work performed by five farm horses during two years, with the results shown in the following table:

Feed and water consumed and work done by five farm horses during two years.

Feed and price of feed	Feed eaten		Value of feed	Water drank	Work done
	Concentrates	Roughage			
	Lbs.	Lbs.	Dollars	Lbs.	Hours
Oats, 36 cts. per bu	10,044		113.00		
Corn, $16 per ton	25,570		204.56		
Gluten feed, $18 per ton	1,530		13.77		
Linseed meal, $28 per ton	1,440		20.16		
Cotton-seed meal, $26 per ton	225		9.93		
Wheat bran, $17 per ton	10,711		91.04		
Timothy hay, $16 per ton		36,540	292.32		
Corn stover, $5 per ton		2,190	5.48	279,918	21,460
Average for 1 horse 1 year	4,952	3,873	74.33	27,992	2,146

It is shown that each horse consumed about 13.6 lbs. of grain daily, while the average daily consumption of roughage was 10 lbs.—

[1] Bul. 82.

a small amount. Each horse drank nearly 80 lbs. of water daily. At the prices named for feed, the keep of each horse cost $74.33 per year. During the year each horse performed an average of 2,146 hours of work, or about 7 hours for each working day—a large aggregate for farm horses. The feed cost 3.4 cents for each hour of work done.

Grisdale of the Ottawa Experimental Farms[1] reports that each of the 19 station horses consumed during a year an average of 6,225 lbs. of meal or grain and 5,500 lbs. of hay. The average cost of feed per horse was $99.80 per year, or 27.3 cents per day. It may therefore be held that a 1,200 to 1,400-lb. work horse will consume from 2.5 to 3 tons of concentrates—grain, meal, etc.—and from 2 to 3 tons of roughage—hay, straw, etc.—annually.

[1] Rpt. 1902.

CHAPTER XIX.

FEED AND CARE OF THE HORSE—RATIONS.

I. Feed and Care.

At any point of observation we usually find the ration for the horse restricted to one or two kinds of grain and the same limited number of roughages. In the northern Mississippi-Valley states the almost universal feeds for the horse are timothy hay and oats. In the South, Indian corn serves mainly for the concentrates, with dried corn leaves for roughage. On the Pacific Coast crushed barley is the common grain, while the hay comes from the wild oat, barley, or wheat plant. Passing to other countries we find an interesting array of articles in the dietary of the horse, tho still no large number in any one locality. In Loudon[1] we read: "In some sterile countries, horses are forced to subsist on dried fish, and even vegetable mould; in Arabia, on milk, flesh balls, eggs, broth, etc. In Persia, barley is a common food for good horses. In some parts of India, salt, pepper, and other spices are made up into balls, as big as billiard balls, with flour and butter, and thrust down the animal's throat. . . . Meat broth (especially sheep's head) is also given to horses. . . . In Bengal, a vetch, something like the tare, is used. On the western side of India, a sort of pigeon pea, called gram, is the usual food; with grass in the season, and hay all the year. . . . In the West Indies they are fed on maize, Guinea corn, and sugar-cane tops; and in some instances, on the sugar itself in the form of molasses. In France, Spain, and Italy, besides the grasses, the leaves of limes, vines, the tops of acacia, the seeds of the carob tree, etc., are used."

454. Successful horse feeding a skilled art.—With the brief bill of fare usually adopted, the administration of feed to the horse would seem a simple matter. It is, however, far from such. Given two grooms with similar conditions as to horses to be cared for, work performed, and feed bins to draw from. In one case the team emerges from the stable with an action and style which at once announces it in the best of condition. In the other case the lagging step, dull eye, and rough coat tell better than words the lack of judgment in feeding and management. The unsatisfactory condition

[1] Encyclopedia of Agr., 1866: Art., Feeding of Horses.

has not necessarily been brought about by any saving at the feed bin and hay mow. Indeed, the poorer groom usually makes the more frequent requests for supplies. The indescribable qualities which, rightly commingled, mark the good feeder cannot be acquired from lectures or books, but must, in a large measure, be born in the horseman. Study and observation will add to the ability of the alert feeder, but all that may be written will not make one an adept if he does not take to the work naturally.

No one can study the practices of successful horsemen without being strongly impressed with the fact that there are several ways of reaching the desired end of high finish and fine action with the horse. With the pig and steer we can estimate about how much increase is returned from a lb. of corn. The horse is on a higher plane, nerve and action counting for more than mere weight. The skill of the "artist" horse feeder enters, along with the food he supplies, into the very life of the creature he manages. If the reader finds the counsel here given on feed and management not entirely to his satisfaction, let him remember that we have chosen a rational and generally applicable course, conceding that good results may also be obtained by following other systems.

455. The foal.—It is of the highest importance in horse rearing that the foal start life in full health and vigor, and to this end it should, immediately after birth, take a good draught of the colostrum or first milk of the dam, which possesses alterative properties that tend to relieve the alimentary tract of fecal matters collected therein during fetal life. If this result is not accomplished naturally, a gentle purgative of castor oil should be administered. Some dams, more frequently those with their first foal and those too hard-worked, fail to supply the proper amount of nourishment, and the young languish. In such cases the mare should be provided with food which will stimulate the milk flow. Good pasture grass is of course the best, but in its absence concentrates should be given in the shape of oats, rolled barley, wheat bran, etc., with an equal weight of corn. Sometimes the foal suffers from an over-supply of nourishment or because the milk is too rich, and the indigestion resulting may terminate in diarrhea. In such cases the dam's ration should be reduced and some of her milk drawn, remembering always that the last portion carries the most fat, which is usually the disturbing element.

After foaling the mare should be confined for a few days, her feed being simple and not too abundant. With favorable conditions at the end of a week she should be turned to pasture where the dam and foal will largely shift for themselves. Watchfulness should always detect the first appearance of ailment. Diarrhea brought on by overfeeding or exposure should be checked by giving parched flour, rice-meal gruel, or boiled milk; and constipation, the other common evil, may be relieved by the use of castor oil and by injections of soapy warm water. In all cases of derangement the food for both dam and foal should at once be lessened, since nothing aids nature more at such times than reducing the work of the digestive tract.

456. Feeding the young foal.—By placing the feed box from which the dam eats her grain low, the foal, at about two months of age, will begin nibbling from the mother's supply and will soon acquire a taste for such food. Splan[1] writes: "With the colts all out to grass and doing well, it is time to separate the oldest of them from the younger and commence feeding them grain, which is done in this way: Build a pen in some suitable place which is the most convenient, making it high enough so that the mare will not try to jump it, and have the space from the ground to the bottom rail or board sufficient to allow the foal to pass under. Put in a handy gate or bars, then an ample feed trough. Lead your mares and foals singly into this enclosure and let them eat together 2 or 3 times and they will soon learn where the food is. Take out the mares, shut up the gate, leave the colts in. Keep a good supply of oats there, and you will find the foals there regularly running in and out getting their rations. To induce the dam to loiter about this place, keep a large lump of rock salt near it and occasionally a mess of oats, and there is no further trouble. In this way, at weaning time, which is at the age of 5 months, the colts have learned to eat, and the result is that when they are taken away from their dams they do not miss them so much."

457. Raising the orphan.—Johnstone[2] gives the following on feeding the orphan foal: "Get the milk of as fresh a cow as possible, and the poorer the butter fat, the better. . . . Take a dessert-spoonful of the best granulated white sugar and add enough warm water to dissolve it. Then add 3 tablespoonfuls of lime water and enough new milk to make a pint. Get an old teapot and scald it thoroly. Over the spout tie securely the thumb of an old kid glove, and with a darning needle pierce holes in the kid. Warm the milk to blood heat, pour a part of it into the teapot, and when it flows thru the spout into the thumb, an excellent imitation of the maternal teat

[1] Life with the Trotters. [2] The Horse Book.

will be formed, which the foal will suck promptly. Let him have half a teacup full every hour at first. It is a bothersome chore, but it must be done.'' (**389**) Lime water is helpful at all times, and castor oil may be used in checking the scours which so frequently trouble hand-fed foals. The quantity of diluted milk should be increased with the growing needs of the animal, and gradually full milk substituted. Gruels made by boiling peas and beans and removing the skins by passing the pulp thru a sieve are helpful, as is the jelly made by boiling linseed oil meal. Cooked wheat middlings or low-grade flour may also be used. As Johnstone says: ''The rearing of a motherless foal is mostly in the man or woman who essays the job.''

458. Feeding cow's milk.—Cow's milk may be used with advantage in feeding weak foals and those suffering from ailments. The foal may be taught to drink milk by pouring it upon meal. The young thing readily eats the moistened feed, and by tipping the pan it soon learns to drink the milk. At the Iowa Station[1] Wilson and Curtiss successfully fed whole milk and later separator skim milk to imported Percheron, Shire, and French-Coach weanling fillies shortly after their arrival from abroad and while out of condition. In changing from whole to separator skim milk the amount was reduced for a day or two to prevent scouring. Ten lbs. of separator skim milk was found equal to 1 lb. of grain. Grattan[2] reports favorably on the use of skim milk for foals, even when the milk is sour or lobbered. MacNeilage[3] objects to the use of cow's milk for foals, claiming ''no better means of manufacturing wind-suckers was ever devised, and it is rare that yearlings so brought out count for much as 2-year-olds and 3-year-olds''—a timely warning against the too free use of this food. (**301-2**)

459. Weaning the foal.—Weaning foals when 5 or 6 months old is not difficult if the preliminaries have been properly carried out. We follow Splan[4] again: ''Now we put on the halters and keep them on, leading the foals more or less while weaning them. Leave them in their boxes, 2 or 3 together, several days, and have the boxes open into a nice grass paddock. Let them run out and in, give them oats mixed with bran and sorghum cut up fine, and in a few days more turn them out in the fields away from their dams, where there is plenty of grass and water, and a large trough with feed in it constantly. They have been in the habit of taking milk a great many

[1] Bul. 18.
[2] Breeder's Gaz., 6, 1884, p. 796.
[3] Trans. Highl. and Agrl. Soc., 1890, p. 152.
[4] Life with the Trotters.

times a day, and they need food just as often. The best way is to keep plenty of mixed food for them, using cracked corn and oats, also unthreshed oats run thru a cutting-box, then mixed with bran and water enough to moisten it to make the bran adhere to the oats.''

460. After weaning.—Foals are nondescripts, for the rearing of which no definite directions can be given, but success will come if common sense, alertness, and patience prevail. A fair allowance of grain for the colt, measured in oats, is:

Up to 1 year of age, from 2 to 3 lbs.
From 1 to 2 years of age, 4 to 5 lbs.
From 2 to 3 years of age, 7 to 8 lbs.

Good bone and muscle are of first importance with the horse, and feeds which tend to produce these should be chosen. Nothing is superior to blue-grass pasture and oats. Among the concentrates, wheat bran, cotton-seed meal, linseed meal, buckwheat middlings, wheat middlings, soybeans, cowpeas, and Canada field peas are rich in nitrogenous matter, which goes to build muscle, and in phosphorus, a prime requisite of the skeleton. All the leguminous hays, alfalfa, clover, cowpea, etc., are rich in lime, the principal mineral component of the bones. A combination of such concentrates and roughages as these should furnish abundant bone- and muscle-building material.

The young horse which is not developing the proper skeleton may be fed substances especially rich in phosphorus and lime, such as 2 or 3 ounces daily of high-grade tankage containing ground bone, or 1 ounce daily of ground bone, ground rock phosphate (floats), or precipitated calcium phosphate. These recommendations are based on the results obtained with other farm animals. Unfortunately there are no definite experiments with horses to guide us at this time. (**89, 90, 95**)

461. The stallion.—The following from Sanders[1] is replete with good counsel in relation to the stallion:

''The food should mainly be good, sound oats—nothing is better; but this should be varied by an occasional ration of corn or barley; for horses, like men, are fond of a variety in their food, and an occasional change of diet is conducive to health. Wheat bran is an invaluable adjunct to the grain ration, and can never be dispensed with. It is the cheapest, safest, and best of all regulators for the bowels, and is especially rich in some of the most important ele-

[1] Horse Breeding, pp. 144–46.

ments of nutrition. No specific directions as to the quantity of food can be given. Some horses will require nearly twice as much as others; and the quantity that may be safely given will depend somewhat upon the amount of exercise in any given case. Some horsemen recommend feeding 3 and others 4 times a day; but in either case no more should be given than will be promptly eaten up clean. If any food should be left in the box, it should be at once removed and the quantity at the next time of feeding should be reduced accordingly. As a rule, it will be safe to feed as much as the horse will eat with apparent relish; and then, with plenty of exercise, he will not become overloaded with fat. The hay, as well as the grain feed, should be sound and free from mould and dust, and the stall should be kept clean, well lighted and perfectly ventilated.

"The amount of exercise to be given will vary somewhat with the condition and habit of the horse. If he be in thin flesh, and it is thought best to fatten him up, the exercise should be lighter than it otherwise would be; and on the other hand, if there is a tendency to become too fat, this may be corrected by increasing the amount of exercise that is given. . . . No draft horse, under ordinary circumstances, should have less exercise than 5 miles a day, and the roadster and running horse may safely have 6 miles, which in some cases should be increased to 8 or even 10.

"The point to be aimed at in the stable management of the stallion is so to feed, groom, and exercise as to keep the horse to the very highest possible pitch of strength and vigor. The idea which prevails among many stable grooms that feeding this or that nostrum will increase the ability of a horse to get foals is sheer nonsense. Anything that adds to the health, strength, and vigor of the horse will increase his virility or sexual power, simply because the sexual organs will partake of the general tone of the system; and on the contrary, whatever tends to impair the health and vigor of the general system will have a deleterious effect upon the sexual organs. A healthy horse needs nothing but good food, pure air, plenty of exercise, with due attention to cleanliness and regularity in feeding and watering; and when all these things are attended to properly, the drugs and nostrums that stable lore prescribes as 'good for a horse' would be better thrown to the dogs."

462. The brood mare.—Mares used only for breeding purposes do well without grain when on nutritious pasture. With insufficient pasture some grain should be given. The feed should not be concentrated in character, but should possess considerable bulk or volume.

That the mare may amply provide milk for her young there should be a liberal supply of foods furnishing crude protein, phosphorus, and lime. (**Tables III and V, Appendix**) Thru the proper combination of feeds the bowels should be kept natural—a little loose rather than otherwise at the time of parturition, when bran is particularly helpful. To confine a brood mare to a box stall without suitable exercise, while supplying an abundance of food, is too common a practice, and one carrying great risk. With the horse, above all animals, an abundance of exercise should go with liberal feeding. The labor of the brood mares should not be severe, nor of such nature as to keep them long from their foals, for then great hunger may be followed by surfeiting. Idleness, the bane of horse breeding, should be avoided whenever possible. Working mares are more certain of bringing good foals than idle ones.

463. Feeding the trotter.—The single requisite of speed makes the carrying of every pound of useless body weight, and more especially of feed, a serious matter in the management of the trotting horse. There is also to be considered the effect of the food on the character of the muscles formed from it, and especially on the nerve and mettle of the horse. For help in this line we can draw from no better source than Hiram Woodruff,[1] who tells how the trotter should be fed and managed.

When going into winter quarters, the feed of the trotter should be reduced fully one-half in order to prevent fattening, for too much fat on the intestines and about the heart makes the trainer no end of trouble in working it off. A few carrots may be given and a bran mash occasionally, with good clean, sweet hay. Horses whose legs must undergo blistering or firing should have feed of a cooling nature, mashes and carrots being in more abundance, with less oats, in order to reduce the tendency to feverish, inflammatory symptoms. Care must be taken not to permit the animal to get flabby or washy by too much soft food while undergoing treatment. Horses turned out to the field should be fed oats twice a day, for the exposure to the severity of the weather increases the need of heat-giving food. In the spring when shedding, bran mashes are in order to keep the bowels open. Flax seed and linseed meal should not be given, for they have a tendency to relax the system too suddenly and to cause the old hair to come away before the new coat is well started.

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[1] The Trotting Horse of America, pp. 90–105.

"With the beginning of the season (we quote directly from the author)[1] while the jogging, the first part of the trotting horse's preparation, is in progress, the strength of the feed may be increased, though not up to the extent that will be requisite when the work is made longer and sharper. He may have, during this first part of the preparation, from eight to ten quarts of oats a day, according to his capacity as a feeder, and the demands made by nature for supply of strong food under work. As the oats are increased, the horse will want less hay, but may still have all he will eat up clean. After taking his feed of oats, he will not consume as much hay in general; but some horses are such gluttons that it is necessary to limit them as to hay almost from the first. There are even some who will eat the straw of their bedding when they have had all the grain and hay that should be fed to them; and, with these, it sometimes becomes necessary to put on the muzzle long before the time for the trial or the race. No carrots are now to be given, and I believe corn to be unnecessary and often mischievous. It is heating, and does not contain as much of the stuff that goes to make up hard flesh and elastic muscle as oats. There may be instances, however, in which a light feeder can be got to eat up his oats, and a handful of corn as well, when the latter is mixed with them. In such a case it is well to give it; but in no case should corn be used as a substitute for the allowance of oats the horse in training ought to have.

"While the jogging and after preparation are going on, a bran mash now and then will be proper. Probably about once a week will be often enough and not too often; but this will be indicated by the condition of the horse's bowels and by his constitutional tendencies and requirements. If his bowels are relaxed, the use of the bran mash is not apparent; and if he is of the light, washy order, never having much substance, and easily melting away when put into sharp training work, mashes are to be given more sparingly than with one of the opposite character. The trainer is never to relax his vigilance of observation, or let his judgment go to sleep and trust to arbitrary rules. . . . During the fast work, preparatory to the coming trial, the horse will have been put upon his largest allowance of strong food. Some will not eat more than eight or ten quarts of oats a day; and it is necessary to be very vigilant and careful that these light feeders are not over-marked in work. Twelve or thirteen quarts is about what a good feeder ought to have.

[1] Loc. cit., p. 99.

Some will eat sixteen quarts of oats a day, but my belief is that three quarts of it does more harm than good."

Splan tells us[1] that Rarus, in the hottest part of the summer, consumed 15 lbs. of oats per day, which he regarded as the maximum for a strong, energetic horse.

All horsemen agree in regarding oats as the one grain suitable for animals where speed is sought regardless of cost of food. While this opinion prevails in this country, we should remember that the Arab horse usually subsists upon barley.

464. Feeding the carriage horse.—Style and action are prerequisites with the carriage horse, economy of feeding standing second. Oats easily lead among concentrates, for any good driver will tell us that the oat-fed horse exhibits mettle as from no other feed. For variety, rolled wheat or barley with bran may form a part of the ration. From 8 to 10 quarts of oats or their equivalent, divided into 3 feeds, should suffice for concentrates, the evening meal being the largest. A bran mash should be given at least weekly if bran is not more regularly used. The hay is usually fed long, for the carriage horse has plenty of time for his meals. From 10 to 12 lbs. of hay is a liberal allowance, bringing the total ration within 20 or 22 lbs. The carriage horse must be trim in body, and so cannot consume much bulky food, yet we should not forget that the ration must have volume in order that the digestive functions proceed normally. Carriage horses are usually overfed and exercised irregularly or too little, and mainly for these reasons their period of satisfactory service is often brief. On days when they are not driven, oats should be fed only at noon, with a bran mash morning and evening, no difference being made in the quantity of roughage fed.

465. The work horse.—Under favorable conditions, the regularity in work, feeding, and rest brings comfort and long years of usefulness to the work horse. In what has preceded, the feeds suitable for this animal have been quite fully considered. From 10 to 18 lbs. of concentrates should be fed daily, according to the severity of the labor, the total grain and hay averaging not less than 2 lbs. per 100 lbs. of horse. From half to two-thirds of the concentrates should be fed at the evening meal, mixed with a peck of moistened chaffed hay. The mid-day meal is sometimes omitted, especially with horses out on the street all day, tho most horsemen hold that some grain should be given then.

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[1] Life with the Trotters.

Girard[1] found that when hard-worked horses getting 19 quarts of oats with 14 lbs. of hay and straw without limit were stopped from work for 3 days and fed the same ration, paralysis, resulting in death, would often occur. By reducing the ration during idle days to 6 quarts of oats at noon and 6 quarts of bran mash both night and morning, with roughage as before, the trouble ceased.

466. Fattening horses.—The following from Craig and Brettell of the Iowa Agricultural College[2] describes the method of fattening horses in the corn belt for the Chicago markets:

"The horses are usually purchased in the fall, after the farm work is over, and are stabled and fed an abundant ration, care being taken to accustom them gradually to full feed in order to avoid colic. When on full feed the horses studied were given, per head, 10 to 14 ears of corn in the morning, at noon, and again at night, with 3 quarts of oats and bran 1:2 and hay ad libitum in the middle of the forenoon and also in the middle of the afternoon. Recognizing the importance of a long period of rest, no feed was given from 6 or 7 at night until 5 o'clock in the morning. The horses were watered twice a day and were given all they would drink. On account of the large number fed, the horses could not be exercised, but as a rule were kept idle in the stable until a few days before they were marketed. To insure good condition it was found advantageous to give 0.5–0.75 pint Glauber salts per head twice a week. Oil meal, it is stated, may also be given to good advantage, as it aids greatly in putting on flesh and also makes the skin soft.

"The importance of keeping mangers and feed boxes clean is insisted upon, and attention is especially directed to the need of examining the horses' teeth and removing with a float any sharp points which would make the gums sore and thus prevent the horses from masticating their feed properly.

"With such feeding and care satisfactory gains were generally realized. In one instance, it is stated, a horse fed in this manner made a gain of 5.5 lbs. per day for a period of 50 days, or 550 lbs. in 100 days. In several instances, with as many as a dozen horses, a gain of 3.75 lbs. per head per day was obtained throughout a period of 90 days." **(446)**

467. Hints on feeding.—Hard-worked horses must have rich food, for the richer the food the more easily is it digested, and the greater the proportion available for work. On the other hand, rich feed, if carelessly administered, brings increased danger. Idle horses or those

[1] Langworthy, Office of Expt. Sta., Bul. 125. [2] Breeder's Gaz., 35, 1899, p. 781.

at light work do best on light rations, and these should be less concentrated and contain more roughage. No other farm animal is so strongly the creature of habit as is the horse, and in no way is he more so than in the matters relating to food and its administration. Sudden changes in quantity and variety should be avoided. A quick change from oats to corn may bring on colic, but changing from corn to oats is less dangerous. An abrupt change from old to new hay, or from late- to early-cut hay, may bring trouble. Wilted grass is more dangerous than fresh grass. Any unusual feeding stuff, such as silage, roots, apples, etc., should be given in small quantities at first, and changes in kind and quantity should always be made gradually. It is best to mix and feed several kinds of concentrates together rather than feed them separately. Hay should be fed at the same time the concentrates are given, in order to properly distend the stomach and intestines. Thru carelessness or mistaken kindness the mangers are often kept filled with hay, and the horse gorges himself with this provender, a staring coat, labored breathing, and quick tiring being the least serious, tho probably the most noticeable results. There should be a definite, limited allowance of hay for the horse at each feeding time, given mostly at night. More horses are injured by feeding too much hay than too little.

With increasing age and continued use, the teeth of the horse elongate and often wear irregularly, leaving sharp points and ragged edges that cause pain and prevent the proper mastication of the provender. In extreme cases horses actually die of starvation because thru irregularly worn teeth they are unable to chew their food. Many horses that are poor in flesh and wear staring coats, despite a reasonable supply of food, owe their condition to poor teeth. The teeth of all horses should be frequently examined and properly cared for by the owner or by a veterinarian.

468. Supervision of feeding.—In stables where many horses are maintained, a group or row of animals should remain in the care of the same attendant, the whole establishment being under the watchful supervision of the superintendent. While we can estimate quite closely the amount of food to be given a hundred or a thousand horses, there should always be modifications and concessions to individual members of the establishment to be recognized and provided for by the guiding mind,—one horse should have a little more than the regulation allowance, and the next possibly a little less, the object being to keep each in the desired condition. Usually it is not well to leave the feeding of horses to their own driver, for he has his likes and dislikes, and the favorites are quite certain to receive more than their proper allowance of grain, while the others suffer. A watchful superintendent must ever be on the alert to see that each animal secures the needed provender.

469. Exercise.—The Arabs have a saying, "Rest and fat are the greatest enemies of the horse." The horse is par excellence the creature of motion, and in its feeding and management we should hold this point ever in view. The prudent horseman will bear in mind that correlative with liberal feeding there must be hearty exercise or severe labor, and that these conditions may be happily balanced. As soon as hard labor ceases, or constant and vigorous exercise is over, it will be found absolutely necessary to reduce the allowance of food if the proper balance is to be maintained. The idle horse should be limited to less than half the grain given while on regular duty, and in some instances it were better to give none, provided the roughage supplied be of good quality.

A colt fed heavily on suitable nutrients will grow rapidly and develop good bone and strong muscle, provided at all times there be a proper balance between exercise and feed. The highly-fed colt should be out of doors from 8 to 10 hours a day, and should move several miles each day either in the field, on the track, or both. A mature horse should be in the open air not less than 4 or 5 hours a day and should travel from 10 to 15 miles daily to maintain health.

II. Rations.

470. Rations.—The following rations by various authorities should be helpful in determining the amount of feed required by the horse under varying conditions:

A. *Rations from various sources.*

Trotting bred colts—Hiram Woodruff[1]

Weaning time
Oats, 2 lbs.
Hay, unlimited allowance

1-yr.-old
Oats, 4 lbs.
Hay, unlimited allowance

2-yr.-old
Oats, 6 lbs.
Hay, unlimited allowance

2-yr.-old in training
Oats, 8 lbs.
Hay, limited allowance

3-yr.-old in training
Oats, 8–12 lbs.
Hay, limited allowance

[1] The Trotting Horse of America.

Trotting horse — Splan[1]

On circuit
Oats, 10 lbs.
Hay, fair amount

On circuit, exceptional as with Rarus
Oats, 15 lbs.
Hay, fair amount

Horses variously used — Stonehenge[2]

Race horse
Oats, 15 lbs.
Hay, 6–8 lbs.

Hack
Oats, 8 lbs.
Hay, 12 lbs.

Horses variously used — Fleming[3]

Pony
Oats, 4 lbs.
Hay, moderate allowance

Hunter, small
Oats, 12 lbs.
Hay, 12 lbs.

Hunter, large
Oats, 16 lbs.
Hay, 10 lbs.

Carriage, light work
Oats, 10 lbs.
Hay, 12 lbs.

The draft horse — Sidney[4]

Heavy, hard work
Oats, 13 lbs.
Horse beans, 6 lbs.
Corn, 3 lbs.
Chaffed clover hay, 15 lbs.

The farm horse — Settegast[5]

Light work
Oats, 6–10 lbs.
Hay, 6–9 lbs.
Straw, 3 lbs.

Medium work
Oats, 10 lbs.
Hay, 10 lbs.
Straw, 3 lbs.

Heavy work
Oats, 13 lbs.
Hay, 12 lbs.
Straw, 3 lbs.

B. *Rations for army horses.*[6]

United States

Cavalry, wt. 1050 lbs.
Oats, 12.0 lbs.
Hay, 14.0 lbs.

Artillery, wt. 1125 lbs.
Oats, 12.0 lbs.
Hay, 14.0 lbs.

Mules, wt. 1025 lbs.
Oats, 9.0 lbs.
Hay, 14.0 lbs.

Great Britain

In quarters, wt. 1125 lbs.
Oats, 10.0 lbs.
Hay, 12.0 lbs.
Straw, 8.0 lbs.

Great Britain, con.

In camp, wt. 1125 lbs.
Oats, 12.0 lbs.
Hay, 12.0 lbs.

Cabs, wt. 1125 lbs.
Oats, 10.0 lbs.
Hay, 12.0 lbs.

Mules, heavy work, wt. 1025 lbs.
Oats, 10.0 lbs.
Hay, 12.0 lbs.
Straw, 8.0 lbs.

Mules in camp, wt. 1025 lbs.
Oats, 12.0 lbs.
Hay, 12.0 lbs.

France, peace footing

Reserve, wt. 1050 lbs.
Oats, 13.0 lbs.
Hay, 8.8 lbs.

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[1] Life with the Trotters.
[2] The Horse.
[3] The Practical Horse Keeper.
[4] Book of the Horse.
[5] Thierzucht, 2, 1888, p. 109.
[6] Collected by Langworthy and preserved in "A Digest of Recent Experiments on Horse Feeding," U. S. Dept. Agr., 1903, Office Expt. Sta., Bul. 125.

France, peace footing, con.

Line, wt. 1050 lbs.
Oats, 11.5 lbs.
Hay, 7.7 lbs.

Light cavalry, wt. 850 lbs.
Oats, 10.4 lbs.
Hay, 6.6 lbs.

Artillery and train, wt. 1075 lbs.
Oats, 12.4 lbs.
Hay, 8.5 lbs.

Mules, wt. 950 lbs.
Oats, 10.8 lbs.
Hay, 7.5 lbs.

France, war footing

Reserve, wt. 1050 lbs.
Oats, 14.7 lbs.
Hay, 8.8 lbs.

Line, wt. 1050 lbs.
Oats, 13.5 lbs.
Hay, 7.7 lbs.

Light cavalry, wt. 850 lbs.
Oats, 11.8 lbs.
Hay, 6.6 lbs.

Artillery and train, wt. 1075 lbs.
Oats, 14.2 lbs.
Hay, 8.5 lbs.

Germany, heavy ration

Garrison, wt. 1050 lbs.
Oats, 11.2 lbs.
Hay, 5.6 lbs.
Straw, 7.8 lbs.

March, wt. 1050 lbs.
Oats, 12.3 lbs.
Hay, 3.3 lbs.
Straw, 3.9 lbs.

Field, wt. 1050 lbs.
Oats, 12.6 lbs.
Hay, 3.3 lbs.
Straw, 3.9 lbs.

Germany, light ration

Garrison, wt. 1050 lbs.
Oats, 9.5 lbs.
Hay, 5.6 lbs.
Straw, 7.8 lbs.

March, wt. 1050 lbs.
Oats, 10.6 lbs.
Hay, 3.3 lbs.
Straw, 3.9 lbs.

Field, wt. 1050 lbs.
Oats, 11.2 lbs.
Hay, 3.3 lbs.
Straw, 3.9 lbs.

C. *Rations for various classes of work horses.*[1]

Omnibus horses

Paris, France, wt. 1240 lbs.
Corn, 10.8 lbs.
Oats, 8.1 lbs.
Hay, 8.7 lbs.
Straw, 8.2 lbs.

Fire company horses

Boston, Mass., wt. 1400 lbs.
Ground grain, 9.4 lbs.
Hay, 18.0 lbs.

Chicago, Ill., wt. 1350 lbs.
Oats, 4.0 lbs.
Hay, 15.0 lbs.

St. Louis, Mo., wt. 1350 lbs.
Oats, 10.0 lbs.
Bran, 2.5 lbs.
Hay, 7.0 lbs.

New York, N. Y., wt. 1350 lbs.
Oats, 12.0 lbs.
Hay, 9.0 lbs.

Express horses

Richmond, Va., summer, wt. 1400 lbs.
Corn, 4.7 lbs.
Oats, 5.3 lbs.
Bran, 0.8 lbs.
Corn meal, 4.2 lbs.
Hay, 15.0 lbs.

Richmond, Va., winter, wt. 1400 lbs.
Corn, 4.4 lbs.
Oats, 7.5 lbs.
Bran, 0.8 lb.
Corn meal, 0.2 lb.
Hay, 16.0 lbs.

Jersey City, N. J., wt. 1325 lbs.
Corn, 2.0 lbs.
Oats, 19.0 lbs.
Bran, 1.5 lbs.
Hay, 9.5 lbs.

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[1] Loc. cit.

Express horses, con.

Boston, Mass., wt. 1325 lbs.
Corn, 12 lbs.
Oats, 5.3 lbs.
Hay, 20.0 lbs.

Cab horses

New York, N. Y., wt. 1200 lbs.
Oats, 14.0 lbs.
Hay, 10.0 lbs.

Washington, D. C., wt. 1200 lbs.
Oats, 10.0 lbs.
Corn, 5.0 lbs.
Hay, 23.0 lbs.

San Francisco, Cal., wt. 1350 lbs.
Oats, 8.0 lbs.
Hay, 16.0 lbs.

Horses at severe work

Chicago, Ill., daily, wt. 1500 lbs.
Oats, 7.5 lbs.
Hay, 20.0 lbs.

Chicago, Ill., holiday, wt. 1500 lbs.
Oats, 2.0 lbs.
Bran, 2.5 lbs.
Oil meal, 0.2 lb.
Hay, 20.0 lbs.

South Omaha, Nebr., wt. 1500 lbs.
Oats, 15.0 lbs.
Hay, 12.0 lbs.

New York, N. Y., wt. 1600 lbs.
Oats, 23.0 lbs.
Hay, 12.0 lbs.

Horses at severe work, con.

Washington, D. C., summer, wt. 1600 lbs.
Oats, 19.0 lbs.
Hay, 13.0 lbs.

Washington, D. C., winter, wt. 1600 lbs.
Oats, 12.5 lbs.
Corn, 6.8 lbs.
Ground grain, 4.0 lbs.*
Hay, 10.0 lbs.

Farm horses, Stations

New Hampshire, wt. 1235 lbs.
Bran, 2.0 lbs.
Corn, 6.0 lbs.
Gluten meal, 6.0 lbs.
Hay, 10.0 lbs.

Massachusetts, wt. 1100 lbs.
Oats, 3.3 lbs.
Crushed corn, 2.7 lbs.
Provender, 6.0 lbs.
Wheat bran, 2.0 lbs.
Hay, 18.0 lbs.

New Jersey, wt. 1150 lbs.
Corn meal, 6.3 lbs.
Dried brewers' grains, 6.2 lbs.
Hay, 8.0 lbs.

Utah, wt. 1120 lbs.
Bran and shorts (1:1), 12.6 lbs.
Alfalfa hay, 16.0 lbs.

Utah, wt. 1230 lbs.
Oats, 12.0 lbs.
Timothy hay, 13.0 lbs.

The table shows that oats, hay, and straw are the only feeds used for army horses by the great nations. The reasons are plain: All forms of provender for such purposes must not only be palatable and safe, but also widely known articles of trade, easily collectible in vast quantities, readily inspected, and generally uniform in quality. They must not be easily subject to waste or deterioration during storage and transportation. The feeds employed best fill these rigid requirements, and hence they are tenaciously adhered to by the departments of war. In the city and on the farm a far wider range of feeding stuffs for the horse is not only possible but often advisable, as the widely collected experience in these chapters shows.

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* Bran 2, corn meal 1.6, cut hay 4 parts.

CHAPTER XX.

CALF REARING.

I. Findings of the Investigators.

471. Birth weight.—According to Krafft,[1] the weight of calves at birth is from one-twelfth to one-fourteenth the weight of the dam, or as follows:

Light-weight calves	48 to 66 pounds
Average calves	66 to 92 pounds
Heavy calves	97 to 110 pounds
Very heavy calves	115 to 128 pounds

472. Calf, lamb, and pig compared.—Linfield of the Utah Station[2] found that up to 14 weeks of age the calf takes less dry matter than the pig for 1 lb. of gain, and after that more, possibly because of the greater amount of roughage then used in the ration. Beach of the Connecticut (Storrs) Station[3] found that calves required 1.03, lambs 1.08, and pigs 1.36 lbs. of dry matter in whole milk for each lb. of gain made. (**102, 722, 816**)

473. Whole milk.—Martiny[4] found that from 3.5 to 6 lbs. of new milk was sufficient to produce a lb. of gain, live weight, with calves between the first and fifth weeks, while older ones required from 16 to 20 lbs.

At the Pennsylvania Station[5] Hunt fed 3 calves full milk containing 4.6 per ct. of fat for 161 days. They gained 1.77 lbs. each daily, requiring 8.8 lbs. of whole milk and 1 lb. of hay and 1 lb. of grain for each lb. of growth. (**301**)

474. Skim milk.—In experiments at the Rastede Dairy School[6] with 30 calves the average daily gain and the amount of skim milk required for 1 lb. of gain during fattening periods of different lengths were as shown on the next page.

It is shown that with a supply of milk adapted to the age of the calf the daily gains remained nearly the same, whether the fattening continued 20 or 90 days. With increase in age and weight, however,

[1] Lehrb. Landw., 3, 1890, p. 85.
[2] Bul. 57.
[3] Rpt. 1904, p. 118.
[4] Die Milch, 2, 1871, pp. 9–15.
[5] Rpt. 1891.
[6] Milchzeitung, 9, 1880, p. 214.

a larger quantity of skim milk was required to produce 1 lb. of gain. (**302**)

Skim milk required for 1 lb. gain by calves.

Length of period	Average live weight at end of period	Average daily gain	Skim milk for 1 lb. gain
Days	Lbs.	Lbs.	Lbs.
20–30	127	2.0	7.9
30–40	146	1.8	9.5
40–50	175	2.1	11.5
50–60	190	2.0	12.0
60–70	220	2.1	13.6
70–80	220	1.9	14.6
80–90	243	1.9	20.1
Over 90	338	2.3	18.0

475. Whole milk v. skim milk.—At the Utah Station[1] Linfield fed calves averaging about 70 lbs. whole milk, while others given whole milk at first were gradually changed to skim milk. The feed for 100 lbs. of gain is shown in the table:

Feeding calves whole milk and skim milk.

	Av. gain per day	Feed for 100 lbs. gain			Dressed wt. to live wt.
		Whole milk		Skim milk	
		Milk	Fat		
	Lbs.	Lbs.	Lbs.	Lbs.	Per cent.
2 calves fed whole milk	2.1	950	37	----------	65.0
7 calves fed whole milk and skim milk	1.8	360	14	830	58.3

It will be seen that the calves getting whole milk required 950 lbs. of milk, containing 37 lbs. of butter-fat, for 100 lbs. of increase, live weight. These calves yielded 65 per ct. of dressed carcass. Those fed at first whole milk and later skim milk required 360 lbs. of whole milk and 830 of skim milk for 100 lbs. of gain, and dressed but 58 per ct. Linfield states that skim milk fed to calves gave fully as large financial returns as when fed to pigs.

476. Pasteurized skim milk.—In two trials at the Ontario Experimental Station[2] Dean found that calves fed pasteurized skim milk (heated to 160° F.) made somewhat better gains than others fed unpasteurized skim milk. At the Kansas Station[3] Otis found practically no difference in the feeding value of pasteurized creamery skim milk and that fed directly from the hand separator, except that the pas-

[1] Bul. 57. [2] Rpt. 1899. [3] Bul. 126.

teurized skim milk caused less trouble from scouring. Patrons of creameries should insist that all skim milk returned from the creamery be first pasteurized, not only for the above reason, but especially to prevent the possible spread of tuberculosis.

477. Buttermilk.—At the Kansas Station[1] Otis found that buttermilk gave slightly less returns with calves than skim milk. Buttermilk caused less trouble from scours than skim milk. Porter of England[2] recommends the addition of a small amount of buttermilk to the whole-milk ration of the veal calf, during the third week of feeding gradually increasing the allowance until one part of buttermilk is fed with each 10 parts of new milk. (**303**)

478. Whey.—Graef[3] secured a daily gain of 2 lbs. with calves fed skim milk, while those getting whey gained from 1 to 1.4 lbs. At the Kansas Station[4] Otis changed calves from skim milk to whey when 3 to 5 weeks old, feeding 10 to 14 lbs. of whey daily with alfalfa hay, prairie hay, kafir meal, and sieved ground oats. The whey-fed calves were thrifty and healthy, tho less fat than those getting skim milk. Few can successfully rear calves on whey, which contains little nutriment, is more or less acid, and is usually loaded with germs that derange digestion. Whey should be fed as fresh as possible and under the strictest rules as to quantity, regularity, and cleanliness of the vessels employed. (**304**)

479. Substitutes for milk.—At the Kansas Station[5] Otis boiled hay, previously soaked in a tank, for 1 or 2 hours. It was then removed and the liquid which remained was concentrated by boiling, 12.5 lbs. of the hay yielding about 100 lbs. of "tea." With kafir meal, wheat middlings, and oil-meal jelly for concentrates the calves fed alfalfa-hay tea gained but 0.4 lb. daily and those fed mixed hay tea, 0.9 lb.—poor returns in both cases.

Stewart[6] gives the following satisfactory experience with a hay-tea ration for calves: "If the hay is cut early, when it has most soluble matter, and is of good quality, the tea will grow good calves, but this extract frequently has too small a proportion of albuminous and fatty matter. Yet, if the hay tea is boiled down so as not to contain too much water for the dry substance, calves will usually thrive upon it. We tried an experiment by feeding 2 gallons of hay tea, in which one-fourth of a lb. of flax seed and one-fourth of a lb. of wheat middlings had been boiled, to each of five calves 30 days old. This experiment was continued 60 days, with a gradual increase, during the

[1] Bul. 126.
[2] Jour. Bd. Agr. (London), 1, 1907, p. 730.
[3] Milchzeitung, 1880, p. 143.
[4] Bul. 126.
[5] Bul. 126.
[6] Feeding Animals, p. 246.

last 30 days, of the middlings to 1 lb. per day. These calves did remarkably well, gaining on an average a little over 2 lbs. per head per day."

480. Concentrates compared.—During trials lasting 60 to 90 days at the Iowa Station[1] Curtiss fed milk fresh from the farm separator, having a temperature of 90° F., to Short-horn and Holstein calves weighing 180 to 200 lbs. An average allowance of 15.4 lbs. of milk and 2.9 lbs. of hay was given to each, with either linseed oil meal, sieved ground oats, or cornmeal with a little flax seed. Eight calves were fed each ration with the following results:

Fresh separator skim milk with various concentrates for calves.

Average grain allowance	Av. total gain	Av. daily gain	Dry matter per 100 lbs. gain	Cost of gain per lb.	Nutritive ratio
	Lbs.	Lbs.	Lbs.	Cts.	
Lot I, Oil meal, 1.2 lbs.	109	1.47	339	2.8	1:2.6
Lot II, Oat meal, 1.5 lbs.	116	1.57	337	2.1	1:3.6
Lot III, Corn meal, 1.3 lbs. Flax seed, 0.1 lb.	116	1.56	330	2.2	1:4.0

Curtiss writes: "The results of all the investigations made at this station strongly indicate that it is not only unnecessary but poor economy and poor practice in feeding to use a highly nitrogenous product like oil meal in combination with separator skim milk. The practice has neither logical reason nor scientific theory for its support; and in the corn-belt states, with their surplus of corn and oats, there is no necessity for the purchase of a high-priced nitrogenous product to be used in supplementing the skim-milk ration."

Otis of the Kansas Station[2] found that calves fed whole corn were less subject to scours and did better than when given ground corn (corn chop). Ground kafir, however, gave better results than whole kafir.

At the Virginia Station[3] Fain and Jarnagin secured a gain of 1.4 lbs. daily when feeding calves cornmeal with skim milk, and 1.6 lbs., or 14 per ct. more, when whole corn was used. Barley was found to be an excellent grain to supplement skim milk. (**171**) Bran was used to great advantage in teaching the calves to eat grain, but no advantage, either in the rate of gain or the appearance of the calf, was secured from adding bran to a ration of shelled corn and skim milk. (**165**)

[1] Bul. 35. [2] Bul. 126. [3] Bul. 172.

Cottrell, Otis, and Haney of the Kansas Station[1] report that kafir meal, given dry, is particularly suited to feed with skim milk because its constipating nature overcomes the scouring tendency of the milk. (**183**)

From experiments at the Louisiana Station[2] Woodward and Lee conclude that on account of its laxative effect "blackstrap" or cane molasses cannot be used as a supplement to skim milk for calf feeding in sufficient quantity to be of any practical value. (**314**)

Kellner[3] states that buckwheat meal is said to produce the best results of any cereal used in veal making and to injure the quality of the flesh least. (**180**)

481. Saccharified starch.—Starch converted into sugar thru the action of diastase constitutes "saccharified starch," a food substance attracting attention in Europe. In experiments covering 3 years with 70 calves Hansen[4] found saccharified starch, obtained by treating starch with proprietary preparations containing malt extract, a cheap substitute for milk fat when fed with skim milk. Calves reared on skim milk and saccharified starch produced cheaper gains than from whole milk, made entirely satisfactory gains, were sleek and thrifty, and developed afterwards in a thoroly satisfactory manner. Feeding more than 0.8 lb. of saccharified starch per head daily leads to scouring. The entire withdrawal of whole milk from very young calves is not recommended. The use of saccharified starch is held to render skim milk of greater nutritive value and makes possible a somewhat earlier change from whole to skim milk. The above suggests the use of ground malt in calf feeding, since in malt the starch of the barley grain has been changed to sugar.

482. Miscellaneous.—At the Massachusetts Station[5] Lindsey found that cod-liver oil added to skim milk proved unsatisfactory, the calves sometimes refusing the combination. A cheap grade of oleomargarine was heated to 110° F. and mixed with skim milk by churning. It was found that 1 ounce of oil per quart of skim milk was all that the calf could take without indigestion being produced. Cotton-seed oil and corn oil to the amount of one-half ounce per quart of milk were fed without bad effect. A calf fed skim milk containing 1 part oleo and 2 parts brown sugar gained over 2 lbs. daily, with kidneys well covered with fat. Calves thus fed were superior to those receiving skim milk only, but not equal in fatness to sucking calves.

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[1] Bul. 93.
[2] Bul. 104.
[3] Ernähr. landw. Nutztiere, 1907, p. 458.
[4] Landw. Jahrb., 37, 1908, Sup. III, p. 235.
[5] Rpts. 1893, 1894.

483. Mineral matter.—In many cases calves otherwise well nourished suffer from the lack of lime or phosphorus, or both. Kellner[1] recommends the feeding of one-half ounce of chalk (carbonate of lime) daily to calves on milk or getting feeds low in lime, such as straw, roots, and the grains. Gouin and Andouard of France[2] as a result of long continued studies recommend feeding ground bone, such as is used in commercial fertilizers, to calves. Based on the studies with pigs by Hart, McCollum, and Fuller of the Wisconsin Station, it is reasonable to recommend that one-half ounce of ground rock phosphate (floats) be given daily to calves in place of chalk or ground bone. (**88-90**)

484. Water and salt.—Otis of the Kansas Station[3] found that unweaned calves when from 2 to 3 months old, drinking several times a day, consumed daily on the average 10 lbs. of water each. The importance of water for milk-fed calves is not usually appreciated. Generally there is also some demand for salt by the calf. (**87, 91**)

485. Dried blood.—Otis of the Kansas Station[4] found that sickly calves, given at first a teaspoonful and later a tablespoonful of dried blood with their allowance of skim milk, rapidly regained their health. Blood meal which has been especially prepared for calves is best. In all cases it should be carefully incorporated with the milk to prevent settling. (**306**)

486. Gains made by calves.—Otis of the Kansas Station[5] gives the following table, showing the weight, by months, of calves reared on skim milk, grain, and pasture from birth until one year of age:

Weight of calves from birth until one year old.

No. of calves	Age	Range in weight	Average weight	No. of calves	Age	Range in weight	Average weight
	Months	Lbs.	Lbs.		Months	Lbs.	Lbs.
23	Birth	59–108	77	38	7	288–461	403
45	1	70–154	111	28	8	332–507	455
56	2	88–199	144	21	9	370–575	515
60	3	111–248	181	20	10	427–645	578
60	4	148–290	229	20	11	444–730	626
54	5	183–362	287	19	12	476–770	669
43	6	228–425	349				

It is shown that calves averaging 77 lbs. each at birth attained an average weight of 669 lbs. at the end of 12 months, showing an average daily gain of 1.6 lbs. for the entire period. Whoever attains these figures in rearing calves should be well satisfied.

[1] Ernähr. landw. Nutztiere, 1907, p. 458.
[2] Expt. Sta. Rec., 19, p. 468.
[3] Bul. 126.
[4] Loc. cit.
[5] Loc. cit.

487. Rate of gain.—Otis of the Kansas Station[1] compared the cost of calves reared on skim milk or whole milk with that of others running with their dams at pasture. Those fed skim milk and whole milk were given in addition equal parts of corn meal and kafir meal, with alfalfa hay for roughage. After weaning, all were placed in the feed lot and given the same feeds.

Rate of gain of calves variously fed up to one year of age.

How fed	Before weaning				210 days in feed lot, after weaning	
	No. of calves	Length of time	Av. daily gain	Cost for 100 lbs. gain	Av. daily gain	Concentrates per 100 lbs. gain
		Days	Lbs.	Dollars	Lbs.	Lbs.
Skim milk	10	154	1.5	2.26	2.1	439
Whole milk	10	154	1.9	7.06	1.9	470
Running with dam	22	140	1.8	4.41	2.0	475

The skim-milk calves, tho not gaining so rapidly as the others up to weaning, cost less for a given gain than either of the other lots. During the 7 months in the feed lot the skim-milk calves made the most rapid gains and also the most economical gains, measured by the feed consumed. Otis reports that the 22 calves running with their dams lost 73 lbs. the week following separation at weaning time, requiring several weeks to recover this loss. In estimating the cost of the several lots before weaning, skim milk was valued at 15 cents per 100 lbs., and whole milk at 21.1 cents for each lb. of fat it contained. Hay was rated at $4 per ton, and concentrates at $10. The cost of a calf running with its dam until weaned was placed at $12, and of one raised on skim milk at $5.27.

488. Cost of rearing calves.—Norton of the Michigan Station,[1] on keeping account of all the feed consumed for 1 year by 57 calves of various dairy and beef breeds, secured the following results:

Average birth weight	81 pounds
Average weight at end of year	648 pounds
Average gain during the year	567 pounds
Average daily gain	1.6 pounds

The average amount of feed consumed by each calf during the year was:

Whole milk	405 pounds	Corn silage	1,057 pounds
Skim milk	3,968 pounds	Hay	1,007 pounds
Dried beet pulp	111 pounds	Roots	149 pounds
Grain	1,033 pounds	Soilage	148 pounds

[1] Bul. 126. [2] Bul. 257.

Norton estimates that the feed consumed by these calves cost $27.59 per head, or $4.87 per 100 lbs. of gain.

II. Rearing the Calf.

489. Feeding for beef.—Where prime beef is the sole object the calf should draw its milk direct from the dam, or be fed full milk. Where the calf remains with the dam her udder should, for a time, be stripped night and morning lest neglect bring garget and destroy her usefulness. If the calf is getting too much milk as shown by scouring, cut off part, remembering that the last drawn portion is the richest in fat, and that richness as well as quantity causes digestive troubles. (**123, 597**) Calves should suck three times daily at first, later twice. The greatest danger under this system comes at weaning time, when, if the calf has not been taught to eat solid food, it pines and loses weight. To avoid this, teach it early to eat shelled corn, whole oats, wheat bran, oil meal, hay, etc. The first departure from this simple and primitive method is putting two calves with each cow, which is feasible where the cow yields a good flow of milk.

The sucking calf should gain 3 lbs. per day for the first month, 2.5 lbs. the second, and 2 lbs. subsequently. Hunt's experiments show that pail-fed calves require from 8 to 9 lbs. of whole milk for each lb. of increase, gaining over 1.75 lbs. daily. While in some districts it is still best to rear the beef calf on whole milk from dam or pail, over large sections of the country it is now more profitable to sell the fat of the milk in butter or cream and rear the calf on skim milk with proper supplements. This method involves increased labor, skill, and watchfulness on the part of the feeder, but its success has been widely demonstrated. The method to be employed is not different from that detailed in the next article for the rearing of the dairy calf, except that the beef calf should be forced to more rapid gains thru more liberal feeding.

After weaning the beef calf, growth should be continued by feeding whole oats or whole corn and a little oil meal, together with plenty of bright clover or alfalfa hay, fodder corn, etc. Nothing equals grass for flesh building, and to approximate this in winter, silage or roots should be given to keep the bodies of the young things sappy and growing. The stockman should always bear in mind that the "calf fat" must never be lost when beef is the ultimate object.

Calves that fail to thrive when sucking the cow or when fed on rich milk should have their allowance reduced or should be given part skim milk. Lime water or wood ashes may possibly prove correctives in cases of trouble from this source. (**123**) The lime water used in such cases is made by dropping a lump of unslaked lime into a jug filled with water and keeping the jug corked. A tablespoonful or more of lime water should be given with each feed.

490. The dairy calf.—The fat of milk is so valuable that all calves designed for the dairy, as well as many intended for beef, should be reared on skim milk. The skim-milk calf is usually allowed to run with the dam 2 or 3 days, tho many dairymen never allow it to draw milk from the mother, claiming that if separated at once it learns more readily to drink from the pail. In any event the calf should always get the first milk or colostrum, which is designed by nature for cleansing the bowels and starting the digestive functions. (**297**) Warm, fresh, unskimmed milk should be fed from the pail 2 or 3 times daily until the calf is 2 or 3 weeks old, after which skim milk is gradually substituted, the change covering a period of a couple of weeks.

When the calf is a week or two old, add to its milk a small allowance of some fine concentrate such as low-grade flour, sieved ground oats, corn meal, or linseed-oil meal made into a jelly by boiling, continuing such feed 2 or 3 weeks while the stomach is small and incapable of utilizing coarser feed. As soon as possible, however, change to whole corn or whole oats, with or without a little linseed-oil meal fed dry in a convenient feed box.

The following by Otis of the Wisconsin Station[1] concisely covers the use of the several grains and roughages in rearing calves:

"Skim milk contains more protein and carbohydrates than whole milk. In selecting a grain to take the place of the fat that has been removed, it is not necessary nor is it advisable to get one rich in protein, as the skim milk furnishes this nutrient. While calves may do well on high-priced concentrates, they are unnecessarily expensive and give no better results than the cheaper carbonaceous grains, as corn, barley, oats, kafir, or sorghum.

"Calves will sometimes learn to eat the grain more readily if a little bran forms a part of the ration for a short time. A number of farm grains have been used successfully in feeding calves. The following list may serve as a guide to the calf feeder in making selections or combinations to suit his conditions:

"1. Corn meal gradually changed in four to six weeks to shelled corn with or without bran.

"2. Whole oats and bran.

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[1] Bul. 192.

"3. Whole oats and corn chop, the latter gradually replaced by shelled corn in four to six weeks.

"4. Ground barley with bran or shelled corn.

"5. Shelled corn and ground kafir or sorghum.

"6. Whole oats, ground barley, and bran.

"7. A mixture of 20 lbs. of corn meal, 20 lbs. of oat meal, 20 lbs. of oil meal, 10 lbs. of blood meal, and 5 lbs. of bone meal, changed to corn, oats, and bran when calves are three months old.

"8. A mixture of 5 lbs. whole oats, 3 lbs. bran, 1 lb. corn meal, and 1 lb. of linseed meal.

"The calf may be taught to eat grain by rubbing a little on its mouth when it is through drinking milk. From this it will soon learn to eat from the feed box. There is little danger of calves getting too fat on any of these grains while being fed skim milk. Should any of the dairy calves show a tendency to fatten, a little bran or oil meal can be added to the ration and the corn reduced or removed. After weaning from milk, greater care will be needed in selecting grains containing the right amount of protein and mineral matter for the proper development of bone and muscle.

"There is also little or no danger of the calf fed skim milk eating too much grain. The young calf makes better gains for grain consumed than the older calf, which is an additional reason for giving it all it will eat. Limiting the grain ration causes a loss in gain and is seldom to be recommended. The calf is possessed of a good set of grinder teeth and when four to six weeks of age is able to do most of his own grinding. A number of feeders have obtained excellent results with whole oats. Experiments indicate that calves do better and are less subject to scours when fed shelled corn instead of corn chop. Grains that are small and hard, like sorghum or kafir, give better results ground.

"When possible it is better to feed a mixture of two or three grains than one, but a large variety does not seem to be of any special merit. A number of calf meals may be purchased on the market. While these undoubtedly possess some merit, they are usually high priced and appear to possess no particular merits over a good combination of farm-grown grains. It is not advisable to mix grain with the milk. The calf needs to properly masticate it and not gulp it down before the starchy matter of the feed is acted upon by the saliva. This precaution will frequently avoid scours.

"Calves will eat roughage at about the same time they begin to eat grain, viz. two to three weeks of age, and will consume about the same quantity of each at first. As the calf grows older the proportion of roughage to grain increases, and by the time the calf is six months of age it will have consumed about three times as much roughage as grain. The quality of the hay should be of the best, always clean and bright. It can be placed in a rack in one corner of the calf pen. Any left uneaten should be removed at the next feeding time and a new supply added.

"The kind of hay may vary according to the needs and condition of the calf. Early cut blue grass is good, as is also hay from mixed grasses. Clover and alfalfa are frequently used to excellent advantage even with the young calf, although there is probably more danger from scours with these. Their importance, as the calf grows older, cannot be overestimated. Corn silage is also proving an excellent roughage for calves. It is usually safe to give the calf all the roughage it will eat.

"Some feeders have difficulty from scours in turning calves on pasture. This may be overcome by allowing the calves to graze for only a short time the first day and gradually increasing the time each day until they become accustomed to handling the green feed, or what is better, gradually get them used to green feed by an increasing daily allowance of soiling crops. Sudden changes in feeding should be avoided. It is doubtful if there is any gain in placing calves on pasture before they are four months of age."

The dairy calf should not be fed over 10 lbs. of full milk daily at first, ending with 15 lbs. The skim-milk allowance should start with 12 or 14 lbs., not exceeding 18 lbs. daily until the calf is 6 weeks old, and only in rare cases should it exceed 20 lbs. Skim milk is at its best when, still warm, it goes at once from the farm separator to the calf. Milk held for any length of time or chilled should before feeding always be warmed to blood temperature, as shown by the thermometer which careful feeders always use. Creamery skim milk should always be pasteurized before it is returned to the farm, that acidity be checked, and the dread danger of ever-threatening bovine tuberculosis removed.

The calf is best taught to drink milk from the pail by using the fingers. The various calf-feeding devices are unsatisfactory and usually dangerous, because the milk accumulates and putrefies in concealed places that cannot be easily cleaned. Hand-reared calves should be confined at feeding time in simple stanchions, to remain for a time after the milk is drunk in order to consume their grain allowance and pass the desire to suck each other's ears. It is important to have a fresh supply of suitable dry concentrates, preferably whole grain, in the feed box at this particular time. Dry feed then eaten takes up the saliva which is flowing freely in the mouth, stimulated by the warm milk. Where the calf is slow to take such feed, the grain or meal should be slipped into the mouth a few times in order that the young thing learn the taste thereof. All excess grain should be removed from the feed box after each meal lest it grow stale and mold.

Properly fed on skim milk and suitable grains and roughage in liberal supply, the thrifty calf should gain from 1.5 to 2 lbs. daily for the first 4 months. In no case should the calf intended for the dairy exceed this rate of increase, for any fixed tendency to lay on fat, induced by too heavy feeding with rich concentrates, will put the young thing into the beef class.

Where skim-milk calves do poorly, the blame usually rests with the feeder. The cause of the trouble will ordinarily be found in some one or more of the following conditions: Lack of sunlight and fresh air; unsanitary stalls or boxes that are not properly cleaned and disinfected; feeding too much milk, or at irregular intervals; feeding stale or chilled milk; feeding from pails that have not been scalded daily; feeding improper concentrates or allowing the excess to ferment and stale in the feed box.

491. Fall calves.—Where cattle are reared under natural conditions, the rule that the young be dropped in the spring will continue, but this practice is not necessarily the most successful in the older sections of the country. Fall-dropped calves come at a time when the little attentions they need can easily be given, and they occupy but little space in barn or shed. Subsisting on the mother's milk, or on skim milk with a little grain and hay, when spring comes the youngsters are large enough to make good use of the pastures. The result is progress from the start until fall, when they return to the barn or shed large enough and strong enough in digestion to make good use of the dry provender necessitated by winter conditions.

III. Feeding for Veal.

492. Essentials.—For the highest grade of veal whole milk is the sole feed allowed, and growth must be pushed as rapidly as possible, the whole process being completed before there is any tendency in the flesh to take on the coarser character of beef. The demand for fine veal is growing, and can be greatly increased by supplying a high-grade product. The farmers of Europe are far in the lead in this line of meat production, and Dutch butchers are extremely expert in judging whether the calf has received any other feed than whole milk. Only when whole milk has been used exclusively, is the white of the eye of the veal calf free from any yellow tint, and the insides of the eye-lids, lips, and nose perfectly white.

493. Scotch veal.—At Strathaven, Scotland, a region noted for the excellence of its veal,[1] the youngest calves receive the first drawn milk and the older ones the last and richer portion. Thus one calf is often fed portions of milk from 2 or 3 cows. After the third week they receive as much milk twice a day as they will take. Following feeding they are bedded, the stable being kept rather warm and dark. Lumps of chalk are placed where the calves have access to them. The fattening period continues from 5 to 7 weeks, when a dressed weight of 100 to 120 lbs. is secured.

In the vicinity of London veal calves fed for about 10 weeks in isolated pens, as in Holland, ordinarily dress 140 lbs.

494. Dutch veal.—In Holland, where unusually heavy, well-fatted calves are a specialty, the following practices are common, according to Forssell:[2] The new-born calf is placed in a stall 6.5 feet long by 1.6 ft. broad and about 5 ft. high, the stall being so narrow that it cannot turn around, tho it can lie and stand comfortably. The floor of the stall is of slats or perforated boards, and is littered daily so that the animal has a perfectly dry berth. The calf barn is kept dark. Two or 3 times daily the calves get as much milk as they will drink, and during the first 14 days only the dam's milk is fed. Eggs or other by-feeds are not given. The calf consumes on the average about 34 lbs. of full milk daily for the whole fattening period of 10 to 12 weeks, at the end of which time the veal is considered to be at its best. To prevent the calves from eating feed other than milk, they are muzzled if straw or other roughage is used for bedding. Finely-ground shells and sand are given to prevent scouring. The dressed weight ranges from 187 to 220 lbs., or according to Rost,[3] from 220 to 330 lbs. One lb. of gain is made in the beginning from 8 lbs. of milk and toward the close from 12 lbs., the average being 10 lbs.[4] The fat calf dresses from 55 to 60 per ct. of its live weight.

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[1] Molk. Zeit., 1894, p. 547.
[2] Fodret och Utfodringen, 1893, p. 155.
[3] Molk. Zeit., 1894, p. 547.
[4] Kraft, Landwirtschaft, 3, p. 163.

CHAPTER XXI.

GENERAL PROBLEMS IN BEEF PRODUCTION.

I. Quarters for Cattle.

495. Open shed v. confinement.—Waters of the Missouri Station[1] housed a bunch of dehorned fattening steers in comfortable, well-bedded quarters during winter. They were turned out for water at 9 o'clock each morning, remaining in the yard until 4 in the afternoon except during stormy weather, when they were out only long enough to drink. Another similar bunch was fed in an open shed located in a small lot. The average returns for 4 winters were:

	In barn	In open shed
Daily gain per steer	1.7 pounds	1.9 pounds
Gain per bu. of corn	4.9 pounds	5.2 pounds
Digestible matter eaten per lb. of gain	11.3 pounds	10.3 pounds

It is seen that the steers running in the open shed did better in all ways than those in the barn.

Ingle,[2] reviewing feeding trials in Britain, concludes that housed animals, compared with those in the open, eat more food and make greater daily gains in weight, each lb. of increase being obtained, however, from about the same amount of digestible matter.

After summarizing trials with steers fed in open yards or confined under cover at the Utah, Texas, Kansas, Missouri, Iowa, Minnesota, Ohio, and Pennsylvania Experiment Stations, Armsby[3] writes: "The experiments, . . . with one exception (Kansas), show fully as good results for the exposed as for the barn-fed animals. It seems clear, at least, that the value of shelter for fattening cattle has been exaggerated." **(733-4)**

Waters[4] closes the discussion of this subject thus: "There is apparently sufficient heat generated in the body in the mastication, digestion, assimilation, fermentation, etc., of this large quantity of food to maintain the normal temperature of the body. In fact it is not unreasonable to hold that under such circumstances a reasonable amount of cold is a benefit to such animals rather than a detri-

[1] Bul. 76.
[2] Trans. Highl. and Agr. Soc. of Scotland, 1909.
[3] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 108.
[4] Missouri Expt. Sta., Bul. 76.

ment. This is supposing that the coats of the cattle are kept dry. It is probable that the radiation of heat by an animal with a wet skin is in excess of the heat produced incidentally or as a natural result of the mechanical and chemical processes occurring in the body. In that case a portion of the food would have to be used to supply the heat to keep the animal warm. It is of more importance that fattening animals lie down regularly and during a large portion of the time than that they be protected from the cold. Abundance of sunshine and fresh air, a comfortable place in which to lie, and freedom from all external disturbances are ideal conditions for large and economical gains.'' (**93, 104, 828**)

496. Loose v. tied steers.—At the Ontario Station[1] Day found that box-fed steers made larger and cheaper gains, had better appetites, and did not get off feed as easily as tied steers. Trials at the Ottawa Station[2] by Grisdale were decidedly in favor of loose box feeding.

497. Self-feeder.—By the use of a large receptacle called a self-feeder, cattle may be supplied with concentrates twice a week. At the Illinois Station[3] Mumford and Allison fed 2 lots, each of 17 fleshy 3-yr.-old steers, the following rations for 89 days. Lot I was fed whole clover hay and concentrates separately at regular feeding periods twice daily, while Lot II was supplied chaffed (cut) hay mixed with the concentrates, the whole being fed in a self-feeder to which the cattle had access at all times.

Value of the self-feeder for fattening steers.

Average ration	Av. total gain	Av. daily gain	Feed for 100 lbs. gain	
			Concentrates	Clover hay
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, hand-fed				
Ground corn, 19.1 lbs.				
Oil meal, 2.9 lbs.				
Clover hay, 13.5 lbs.	266	3.0	737	451
Lot II, self-fed				
Ground corn, 21.5 lbs.				
Oil meal, 3.1 lbs.				
Chaffed clover hay, 12.8 lbs.	296	3.3	743	385

The table shows that the self-fed steers made larger gains than those fed by hand, and required 61 lbs. less hay for 100 lbs. gain. The self-fed steers consumed a heavier concentrate allowance, and were brought to full feed in a shorter time without any setback by

[1] Rpt. 1907. [2] Rpt. 1904. [3] Bul. 142.

gorging or overeating. Tho consuming more feed than Lot I, the self-fed steers made more economical gains, even after adding the cost of chaffing the hay. Both systems required about the same amount of labor, but by the use of the self-feeder the necessity of a skilled feeder was reduced. Mumford[1] reports that steers visit the self-feeder with remarkable regularity, and once accustomed thereto do not overeat. He holds that the system is often unjustly condemned because careless cattle feeders do not properly use it. (**731**)

498. The paved feed lot.—In parts of the corn belt the feed lot in winter often becomes a sea of mud and mire. Mumford of the Illinois Station[2] fed one carload of steers during winter in a brick-paved lot and another in an ordinary mud lot, both lots having access to an open shed, the bedding in which was kept dry. The paved-lot steers made no cheaper gains than the others. However, because of their dirty appearance, tho not inferior finish, the mud-lot steers sold for 10 cents less per 100 lbs. Pigs following the paved-lot steers gained 1 lb. more from each bushel of corn fed to the steers than did those following the mud-lot steers.

II. Wintering Cattle.

499. Wintering beef cows.—Mumford of the Illinois Station[3] divided a lot of grade Angus cows which had suckled their calves the previous summer and were thin in flesh into bunches of 10 each and fed them on approximately a maintenance ration during 140 days in winter. (**96**) Twenty-eight per ct. of the corn silage and 54 per ct. of the shock corn consisted of ears.

Wintering breeding cows on silage and shock corn.

Average ration	Av. wt. at beginning	Av. daily gain	Av. gain per head
	Lbs.	Lbs.	Lbs.
Lot I			
Corn silage, 16.7 lbs.			
Clover hay, 3.5 lbs.			
Oat straw, 9.6 lbs.	860	1.1	150
Lot II			
Shock corn, 8.7 lbs.			
Clover hay, 3.5 lbs.			
Oat straw, 10.8 lbs.	859	0.8	106
Lot III			
Corn stover (42 days), 21.7 lbs.			
Shredded stover (98 days), 10.3 lbs.			
Clover hay, 1.6 lbs.			
Oat straw, 8.2 lbs.	860	0.4	58

[1] Beef Production, p. 155. [2] Loc. cit., 146. [3] Bul. 111.

At the close of the trial the cows in Lot III were in poor condition, having made but small gain. The cows of Lots I and II, which had made good gains, appeared about the same until after calving, when those in Lot I, which had been fed silage, were in decidedly superior form. It required the feed grown on one-third of an acre to support a cow making fair gains for 140 days with Lots I and II, and that from one-fifth of an acre to little more than maintain a cow of Lot III.

500. Wintering yearlings without grain.—At the Missouri Station[1] during each of 4 winters Waters fed lots of 4 or 5 high-grade yearling Hereford and Short-horn steers each for periods of 49 to 92 days. These steers, rather thin in flesh and averaging about 725 lbs. in weight, were fed the following roughages of medium quality, without grain, with the results shown below:

Roughages for wintering yearling steers without grain.

Average roughage allowance	Roughage refused	Av. daily gain or loss
	Per ct.	Lbs.
Lot I, Timothy hay, 17.6 lbs.*	16.3	+0.31
Lot II, Whole corn stover, 31.3 lbs.*	40.8	−0.18
Lot III, Shredded corn stover, 23.6 lbs.†	35.8	−0.14
Lot IV, Ensiled corn stover, 47.4 lbs.†	4.6	+0.58
Lot V, Corn stover, 13.6 lbs., clover hay, 13.6 lbs.†	27.0	+0.44

*Four trials. †Two trials.

It is shown that yearling steers in thin condition made only a small gain when wintered on timothy hay alone. Those fed whole or shredded field-cured corn stover lost in weight, while on ensiled stover or stover and clover hay there were substantial gains.

501. Wintering yearlings with a limited grain allowance.—During 4 winters Waters[2] compared various roughages when fed to yearling steers without limit with a limited allowance of shelled corn. Lots of 4 steers each, similar to those fed in the preceding trials and averaging about 750 lbs. in weight, were fed the rations given below for periods of 66 to 120 days with the results shown on the next page.

The steers fed whole corn stover with an allowance of 3.8 lbs. of shelled corn per day lost 0.32 lb. each daily. Those fed equal parts of stover and clover hay gained 1.37 lbs. each daily, requiring only 400 lbs. of corn and 1,754 lbs. of roughage for 100 lbs. of gain. Waters points out that stover serves best when combined with a limited quan-

[1] Bul. 75. [2] Loc. cit.

tity of clover or other leguminous hay, a point of great importance. The steers fed clover hay made nearly twice as large and far more economical gains than those fed timothy hay, another fact of great value to the feeder. Alfalfa hay proved about equal to clover hay, and cowpea hay of slightly lower value. Millet and sorghum hay made a poor showing when fed with shelled corn.

Roughages for wintering steers getting a limited grain allowance.

Average roughage allowance	Shelled corn fed per day	Av. daily gain or loss	Feed for 100 lbs. gain	
			Shelled corn	Rough-age
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Whole corn stover, 29.3 lbs.*	3.8	−0.32	--------	--------
Lot II, Corn stover, 11.0 lbs., clover hay, 10.9 lbs.‡	5.3	1.37	400	1,754
Lot III, Clover hay, 19.0 lbs.†	6.0	1.97	305	966
Lot IV, Timothy hay, 16.6 lbs.‡	5.3	1.01	552	1,815
Lot V, Cowpea hay, 19.0 lbs.†	5.5	1.42	362	1,343
Lot VI, Alfalfa hay, 17.3 lbs.*	6.0	1.63	368	1,061
Lot VII, Millet hay, 13.1 lbs.*	6.0	0.37	1,613	3,516
Lot VIII, Sorghum hay, 25.8 lbs.†	6.0	0.91	809	2,921

*One trial. †Two trials. ‡Three trials.

Waters concludes: "One ton of timothy hay is worth as much as 3 tons of whole corn stover when each is the sole feed. (**665**) Shredding corn stover did not enhance its feeding value, and nearly as great waste occurred as with whole corn stover." While the steers fed whole or shredded field-cured corn stover did not maintain their weight, those fed silage made from corn cut at the same time and from which all the ears had been removed made small daily gains. More dry matter was given in the stover, but a large part was left uneaten, while nearly all the silage was consumed.

III. Pasturing Cattle.

502. Gains on grass alone.—Mumford and Hall of the Illinois Station,[1] from extensive inquiries in that state, report that cattlemen estimate the daily increase per head of steers during the grazing season at 1.66 lbs. for yearlings and 1.87 lbs. for 2-yr.-olds.

Waters of the Missouri Station,[2] gathering statistics from more than 1,000 successful cattlemen in Missouri, Illinois, and Iowa, found the average gains from cattle pastured for the 6-months period, May 1 to November 1, to be as shown on the next page.

[1] Cir. 79. [2] Cir. of Information, No. 24.

Assuming a pasture charge for yearlings of 75 cents per month, their gains cost approximately $1.60 per 100 lbs., while the 2-yr.-olds at a pasture charge of $1 per month would put on gains costing but little over $1.90 per 100 lbs. When we reflect that gains made by steers in winter cost from $6 to $10 per 100 lbs., the importance of wisely and fully utilizing the pastures in summer is apparent.

Average gain of steers for the 6-months season on grass.

State	By yearlings		By 2-yr.-olds	
	Per month	Per season	Per month	Per season
	Lbs.	Lbs.	Lbs.	Lbs.
Missouri	47	282	53	318
Iowa	48	288	52	312
Illinois	45	270	52	312

Skinner and Cochel of the Indiana Station[1] found thru extensive inquiry that in Indiana during summer feeding each grain-fed steer grazed over 1.1 acres of land on the average. Where no grain was given, each steer grazed over about 2 acres.

Lloyd of the Mississippi Station[2] reports that 2-yr.-old heifers, fed a light ration during the winter, when turned to pasture gained 1.3 lbs. each daily for 178 days on pasture alone. Steers of the same age, thin in flesh when turned to pasture, made daily gains of 1.4 lbs. for 178 days, while those full-fed the previous winter gained but 0.8 each day during 158 days.

Waters of the Missouri Station[3] states that gains are cheaply made on grass alone, but such gains are also low in selling value because the cattle are not usually fat enough to market and must be sold as feeders with sufficient margin for the buyer to profitably fit them for market.

503. Summer v. winter feeding.—Waters of the Missouri Station[4] reports the gains in 3 summer and 5 winter feeding trials as follows:

	Summer	Winter
Number of animals	88	105
Average length of feeding period, days	209	107
Concentrates per 100 lbs. of gain, lbs.	814	999
Roughage per 100 lbs. of gain, lbs.	grass	382
Average daily gain per steer, lbs.	2.37	2.13

Because of the longer feeding period the summer-fed cattle were much fatter than those fed in winter. Despite this the summer gains were made on 18.5 per ct. less grain.

[1] Cir. 12. [2] Rpt. 1903. [3] Bul. 76. [4] Loc. cit.

Mumford and Hall of the Illinois Station,[1] from extensive correspondence with feeders of their state, conclude that a bushel of corn will produce:

	Gain in winter feed lot	Gain in summer on pasture
With calves	8.9 pounds	10.0 pounds
With yearlings	6.5 pounds	7.6 pounds
With 2-yr.-olds	5.4 pounds	6.8 pounds

Waters[2] sets forth the following advantages from feeding grain to steers on pasture:

Grass is cheaper than hay.

Summer gains require less grain than winter gains.

Steers fatten more quickly.

Steers can be made thick and prime on corn and grass with greater certainty, more uniformity, and the smaller use of expensive supplements like cotton-seed meal and linseed meal.

Hogs following the steers make larger gains, and return more profit, with a lower death rate.

In summer the grain only is drawn; there is no roughage to handle.

The steers are usually fed but once daily.

The manure is scattered by the cattle themselves. **(827)**

IV. Influence of Age; Baby Beef; Long and Short Feed.

504. Feed and growth.—At the Maryland Station[3] for a period of 2 years Patterson recorded all feed, except pasture grass, eaten by 2 pure-bred Aberdeen-Angus steer calves. Weaned at 5 days, the calves were fed whole milk for 5 months, and had concentrates and hay at all times, running on pasture during the grazing season. The results are summarized in the table:

Feed, not including pasture, required by steers for growth.

	Wt. at beginning	Gain during year	Av. daily gain	Feed for 100 lbs. growth		
				Milk	Concentrates	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
First year						
Calf No. 1	105	447	1.2	430	290	200
Calf No. 2	97	455	1.2	410	270	190
Second year						
Calf No. 1		434	1.2		880	760
Calf No. 2		559	1.5		670	600

It is seen that during the first year calf No. 1 made an average daily gain of 1.2 lbs., requiring, in addition to pasture, an average

[1] Cir. 88.

[2] Mo. Expt. Sta., Cir. of Information, No. 24.

[3] Bul. 121.

of 430 lbs. of whole milk, 290 lbs. of concentrates, and 200 lbs. of hay for 100 lbs. of gain. During the second year no milk was given of course. The calves then required nearly 3 times as much concentrates and hay for a given gain as during the first year. Calf No. 2, which was smallest at birth, grew the fastest and made the cheapest gains. (**95**)

505. Cost of fattening influenced by age.—At the Ottawa Experimental Farms[1] in trials during 4 winters with 153 head in all, Grisdale compared the rate and cost of gains made by steers of different ages during feeding periods of about 6 months. The results are shown in the following table, partially as arranged by Waters:[2]

Rate and cost of gain for fattening steers of various ages.

	Av. wt. at beginning	Av. daily gain	Av. cost of 100 lbs. gain	For equal profit compared with calves	
				Purchase price per cwt. must be less by:	Or selling price per cwt. must be greater by:
	Lbs.	Lbs.	Dollars	Cents	Cents
Calves*	397	1.8	4.22	----	----
Yearlings	883	1.6	5.31	35	27
2-yr.-olds	1,011	1.8	5.62	43	33
3-yr.-olds	1,226	1.7	6.36	53	43

*Three trials.

It is seen that 6-months calves averaging 397 lbs. in weight made an average daily gain of 1.8 lbs. during the fattening period of about 6 months, yearlings to 3-yr.-olds averaging about the same. The feed cost for 100 lbs. of gain was $4.22 with the calves, and increased with the age of the animals, the gains made by the 3-yr.-olds costing $6.36, or 50 per ct. more than the calves, for each 100 lbs.

The greater cost of the gain by the older animals might have been offset by buying these steers as feeders at slightly lower prices per 100 lbs. than the younger animals, or by a small increase in their selling price when fattened, which would be reasonable because of their superior condition. If the yearlings could have been purchased for 35 cents per 100 lbs. less than was paid for the calves and sold at the same price per 100 lbs., or if after fattening they could have been sold for 27 cents more per 100 lbs., the increased cost of the gains by the yearlings would have been met.

Under the usual market conditions, young, unfinished animals cost enough more per lb. as feeders to counterbalance the lower feed-cost required to make them fat. Mature cattle fatten more quickly than do calves or yearlings. Hence when steers of different ages are fed

[1] Rpts. 1900–1904.

[2] Rpt. Mo. Bd. Agr., 1907.

for the same period, the older animals will reach a higher finish, and therefore usually sell for a higher price than the less highly finished calves or yearlings. Older steers also fatten more uniformly and require less careful attention. Waters concludes: "It may be accepted as final that so long as the professional feeder can buy the older cattle with sufficient margin to fully overcome the increased cost of gains made in his feed yard, he will consider it to his advantage to feed them in preference to younger animals." (**579**)

That the daily rate of gain with cattle on full feed is directly affected by the age of the animal is illustrated by the records of the fat-stock shows. Some of the results obtained in England are shown in the following table:

Age and weight of steers slaughtered at the Smithfield (England) Fat-Stock Show, 1888–95.[1]

	No. of animals	Age	Average daily gain	Live wt. at slaughtering	Dressed meat to live wt.
		Days	Lbs.	Lbs.	Per cent
Short-horn					
1 year old	5	642	2.11	1,355	66.13
2 years old	18	963	1.92	1,842	67.48
3 years old	16	1,321	1.70	2,251	69.38
Hereford					
1 year old	16	663	1.97	1,308	65.08
2 years old	13	1,020	1.78	1,817	67.15
3 years old	8	1,349	1.64	2,218	69.18
Devon					
1 year old	13	634	1.75	1,112	66.01
2 years old	19	1,045	1.51	1,583	67.73
3 years old	16	1,311	1.37	1,796	67.32
Aberdeen-Angus					
1 year old	26	668	2.04	1,366	65.37
2 years old	21	1,008	1.74	1,765	66.67
3 years old	2	1,346	1.59	2,138	67.39
Sussex					
1 year old	17	677	2.15	1,452	65.42
2 years old	18	989	1.86	1,837	68.18
3 years old	12	1,285	1.61	2,064	67.98
Red Poll					
2 years old	12	1,002	1.64	1,631	65.73
3 years old	6	1,362	1.49	2,022	65.77
Galloway					
2 years old	7	1,027	1.64	1,688	64.45
3 years old	4	1,344	1.47	1,969	64.84

506. Gains of steers and hogs following.—At the Indiana Station[2] during each of 2 winters, Skinner and Cochel fed for a period of 180 days 3 lots of steers, one of 20 calves, a second of 10 yearlings, and another of 10 two-yr.-olds as shown on the next page.

[1] Reported annually in the Live Stock Journal and Agricultural Gazette, London.
[2] Bul. 129.

The ration consisted of 6 parts shelled corn and 1 part cotton-seed meal, with clover hay and corn silage for roughage. Hogs followed the steers in each lot.

Influence of age of steers on gains of steers and shotes following steers.

Age of steers	Av. wt. at beginning	Av. daily gain	Feed given to steers for 100 lbs. gain			
			By steers			By hogs
			Concentrates	Clover hay	Silage	Concentrates
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Calves	521	2.0	555	126	506	6,597
Yearlings	888	2.3	774	162	652	4,286
2-yr.-olds	1,067	2.6	790	161	573	4,058

The calves required much less feed to produce 100 lbs. of gain than either the yearlings or the 2-yr.-olds. The rate of daily gain increased with the age of the steer, the 2-yr.-olds making the heaviest gains. The amount of feed required to produce 100 lbs. of pork was greatest for the hogs following the calves, and smallest with those following the 2-yr.-olds, showing that calves utilize their food more closely than mature steers.

Skinner and Cochel write: "High grade, blocky, early maturing beef calves showing both breeding and quality are necessary in making yearling beef. Quality and type are not so essential in feeding aged steers as in feeding calves, provided the purchase price is proportionate. The older cattle, if placed in the feed lot in equal condition and given a full feed, will be in higher condition than either yearlings or calves at the end of 6 months. More capital is required in feeding the same number of 2-yr.-old steers than either yearlings or calves. The profit per steer was greater in both tests on 2-yr.-olds than on either yearlings or calves." (**525**)

507. Heifers v. steers.—At the Iowa Station[1] Wilson and Curtiss conducted 2 experiments with steers and spayed and open heifers. The cattle topped their respective classes in the Chicago market, the heifers of the first trial selling for $4.75 and the steers for $5.75 per cwt. on the same market. In the second trial the heifers brought $4.25 and the steers $4.50 per cwt. All lots yielded practically the same amount of dressed carcass, but the heifers yielded about 1 per ct. more in the high-priced cuts of meat. But little, if any, benefit was derived from spaying heifers. (**836**)

[1] Bul. 33.

508. Baby beef.—At the Kansas Station[1] Cottrell, Haney, and Elling placed 130 calves, just weaned, in the feed lot during the latter part of October. Sixty were grade Short-horn, Hereford, and Angus range heifers. The rest were purchased locally or raised at the college farm. All were fed twice daily with great regularity, getting all the grain and roughage they would clean up within 3 hours after feeding. They were sheltered by a common board shed open to the south and were fed for 7 months with the results shown below:

Feed and 7-months gain of calves fed for baby beef.

Feed given	Av. gain per head	Feed per 100 lbs. gain	
		Concentrates	Roughage
	Lbs.	Lbs.	Lbs.
Lot I, Alfalfa hay and corn	407	470	544
Lot II, Alfalfa hay and kafir	379	524	626
Lot III, Prairie hay, corn $\frac{7}{8}$, and soy beans $\frac{1}{8}$	378	520	486
Lot IV, Prairie hay, kafir $\frac{7}{8}$, and soy beans $\frac{1}{8}$	342	594	539
Lot V, Skim-milk calves—alfalfa hay and corn	440	439	436
Lot VI, Whole-milk calves—alfalfa hay and corn	404	470	420
Average	392	503	509

The surprisingly small amount of feed for 100 lbs. of gain will be noted. The last of the following May, at which time they must have been from 12 to 14 months old, the entire lot averaged 800 lbs. in the college feed lot, and on shipping to Kansas City shrank 3 per ct.

509. Short- v. long-feed.—At the Indiana Station[2] Skinner and Cochel obtained the following results during long and short-feeding periods with 2 lots of 10 grade Short-horn and Hereford steers each. All were strictly grass-fed cattle, the short-fed steers carrying enough flesh to be sold as killers when the feeding began, the others being of the same quality but thinner in flesh:

The short-fed steers made the high average daily gain of 3.2 lbs., while those long-fed made lower daily but larger total gains. A greater proportion of concentrates was given the short-fed steers, and they required somewhat more corn but less roughage per 100 lbs. gain than did the long-fed steers. During fattening each long-fed steer consumed 55 bushels and each short-fed steer 34 bushels of corn. Valuing corn at 50 cents a bushel, and cotton-seed meal at $28, clover hay at $8, and corn silage at $2.50 per ton, each 100 lbs. of gain made by the short-fed steers cost $8.17 and by the long-fed

[1] Bul. 113. [2] Bul. 130.

steers $8.74. Combining the cost of steers and feed it was found that when finished the short-fed steers cost $5.21 and the long-fed steers $5.66 per 100 lbs. To break even, a margin or spread of $1.41 per 100 lbs. was required with the long-fed and half that with the short-fed cattle.

Data concerning short- and long-fed cattle.

	Lot I short-fed	Lot II long-fed
Length of feeding period, days	90	180
Av. weight at beginning, lbs.	1,176	1,011
Av. gain per head, lbs.	285	464
Av. daily gain per head, lbs.	3.2	2.6
Av. daily feed per head:		
Shelled corn, lbs.	21.2	16.7
Cotton-seed meal, lbs.	2.7	3.0
Clover hay, lbs.	3.2	3.9
Corn silage, lbs.	15.0	15.0
Av. feed per 100 lbs. gain:		
Shelled corn, lbs.	670	647
Cotton-seed meal, lbs.	86	116
Clover hay, lbs.	99	152
Corn silage, lbs.	474	582
Feed cost of 100 lbs. gain	$8.17	$8.74
Purchase cost of 100 lbs. of steer	4.50	4.25
Finished cost per 100 lbs. of steer	5.21	5.66
Spread, or amount necessary to break even	0.71	1.41

510. Lengthening the fattening period.—Other conditions being equal, the longer the fattening period the larger the quantity of feed required to produce a given gain. Georgeson of the Kansas Station[1] found the grain required for 100 lbs. of gain with fattening steers for different periods to be as follows:

	Grain for 100 lbs. gain	Increase of feed required
Up to 56 days the steers required	730 pounds of grain.	----------
Up to 84 days the steers required	807 pounds of grain.	10 per cent
Up to 112 days the steers required	840 pounds of grain.	15 per cent
Up to 140 days the steers required	901 pounds of grain.	23 per cent
Up to 168 days the steers required	927 pounds of grain.	27 per cent
Up to 182 days the steers required	1,000 pounds of grain.	37 per cent

We learn that while at first only 730 lbs. of grain were required per 100 lbs. of gain, for the whole 6-months period 1,000 lbs., or 37 per ct. more, were required. The heavy cost of thoroly fattening the steer and the importance of selling at the earliest possible date are here made plain. (**830**)

[1] Bul. 34.

511. Water drank.—Georgeson of the Kansas Station[1] kept a record of the water drank by fattening steers in winter with the following results:

Water drank by fattening steers in winter.

Feed given	Water drank		
	Daily per steer	Per lb. of gain	Per lb. of feed
	Lbs.	Lbs.	Lbs.
Lot I, Corn meal, bran, shorts, oil meal, with hay	79	33	2.5
Lot II, Corn meal, molasses, and corn fodder	73	56	2.4
Lot III, Oil cake, hay	91	57	3.4
Lot IV, Ear corn, corn fodder	56	27	1.8

We note that on the carbohydrate-rich ration of corn and corn fodder the steers drank but 1.8 lbs. of water for each pound of feed eaten, while on the highly nitrogenous ration of oil cake and hay they drank 3.4 lbs., or nearly twice as much. (**87**)

512. Variations in weight.—Fattening steers show surprising variations in weight from day to day, and even from week to week. Much data could be given on this point, but the following from one of Georgeson's experiments at the Kansas Station[2] will suffice:

Weekly variations in the weight of steers during fattening.

Date of weekly weighing	Weight of steer No. 1	Gain or loss	Weight of steer No. 2	Gain or loss	Weight of steer No. 3	Gain or loss
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
November 30	1,232	-------	1,190	-------	1,207	-------
December 7	1,269	37	1,205	15	1,240	38
December 14	1,280	11	1,213	8	1,236	−4
December 21	1,278	−2	1,226	13	1,244	8
December 28	1,325	47	1,250	24	1,270	26
May 2	1,545	-------	1,583	-------	1,567	-------
May 9	1,565	20	1,603	20	1,593	26
May 16	1,597	32	1,620	17	1,619	26
May 23	1,598	1	1,643	23	1,626	7
May 30	1,610	12	1,606	−37	1,593	−33

These variations, which are not extraordinary, show how difficult it is to know the true weight of a steer at any given time. Experiment stations now quite generally weigh the steer for 3 successive days, taking the average as the true weight of the steer on the second day. It has been suggested that the variations follow somewhat

[1] Bul. 39.   [2] Bul. 34.

the amount of water drank from day to day, but this explanation does not always seem sufficient. It seems more generally due to the irregular movement of the contents of the digestive tract, which movement is influenced by changes in the character and quantity of the food consumed, the exercise or confinement enforced, and the weather.

V. Value of Breed in Beef Making.

Every person with experience in the cattle business knows that "blood tells" in beef production. Where there is such unanimity of expression the fact must exist, but the reasons given are not always the same, and so are worthy of careful examination. They will be considered in their usual order of advancement.

513. Amount of feed consumed.—Occasionally the claim is yet advanced that well-bred cattle eat less than natives or scrubs. This opinion is not generally held by owners of pure-bred or high-grade stock, who know that their animals when gaining rapidly are hearty feeders, tho when mature they require only a small amount of provender for maintenance. Nothing in the tables given in this chapter warrants the statement that pure-bred or high-grade cattle of the beef breeds are small eaters.

514. Less feed for a given gain.—The second and more common claim is that beef-bred cattle make better gains on a given amount of feed than do dairy-bred or scrub cattle. Several stations have recorded the comparative gains of the various breeds from a given quantity of feed with the results presented in the table:

Concentrates required for 100 lbs. of gain with steers of several breeds.

Station	Steers in each lot	Length of period	Short-horn	Hereford	Angus	Red Poll	Galloway	Devon	Swiss	Holstein	Jersey	Native
	No.	Days	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Iowa, Bul. 20	2	92	659	874	744	753	977	663	712	870	861	------
Iowa, Bul. 28	10	180	965	------	947	------	------	------	------	------	------	------
Michigan, Bul. 44	2	365	557	561	------	------	581	477	------	565	557	------
Michigan, Bul. 44	2	365	796	916	------	------	763	755	------	939	807	------
Michigan, Bul. 69	2	540	493	552	------	------	612	478	------	665	------	------
Ontario, Rpt. 1892	1	365	597	793	698	------	553	495	------	686	------	491
Kansas, Bul. 51	1	161	777	------	------	------	------	------	------	------	------	876
Missouri, Bul. 23	4–6	540	706	742	661	------	------	------	------	------	------	631

It will be seen that while we can point to cases where the beef-bred steer produced 100 lbs. of gain with less feed than the dairy-bred or native steer, yet the largest amount of feed consumed by any animal for a given gain stands charged to one of the beef type. From the data, covering 8 feeding trials at 5 stations, we are unable to show that a pound of feed goes further in making gain with beef-bred animals than with those not especially bred for that purpose.

515. Early maturity.—The most common claim for superiority with the beef breeds is that animals so bred mature earlier than others. Consulting the figures given in the next table, we find that steers of the strictly dairy breeds reached as heavy weight in a given time as did several of the beef-bred representatives. Holstein steers made substantially as large daily gains as any of the others, and Jersey and native steers rivaled the Devons. So far as the data go, we have no evidence that beef-bred animals make more rapid growth than do others. The degree of maturity of the animal as a producer of beef is not wholly measured, however, by weight, so that this division of the subject cannot be considered as entirely covered by the data here presented in regard to daily gain.

516. Dressed carcass.—The animals of the various breeds, whose feed requirements for 100 lbs. gain are reported in Article 514, on being slaughtered showed the following percentages of dressed carcass to live weight:

Daily gain and dressed weight of steers of different breeds.

Breed	No. of animals	No. of stations	Av. age	Av. live weight	Daily gain from birth	Limits of dressed weight	Av. dressed weight
			Days	Lbs.	Lbs.	Per cent	Per cent
Hereford	11	4	983	1,515	1.54	63.0–68.0	65.0
Red Poll	2	1	1,000	1,520	1.52	63.8–66.5	65.2
Aberdeen-Angus	16	4	976	1,493	1.53	63.2–69.0	64.8
Swiss	2	1	1,000	1,570	1.57	64.8	64.8
Short-horn	26	5	1,011	1,510	1.50	62.1–68.0	64.4
Galloway	6	3	923	1,503	1.62	62.0–66.7	63.9
Devon	7	3	1,021	1,376	1.35	62.5–65.8	63.6
Ayrshire	1	1	1,095	1,320	1.20	----------	63.3
Sussex	1	1	1,021	1,625	1.59	----------	63.0
Holstein	6	3	937	1,469	1.57	60.6–64.4	62.6
Jersey	3	2	1,058	1,440	1.36	58.7–63.9	60.5
Native	9	3	1,038	1,259	1.26	57.9–61.5	60.2

The data referring to live weight at the time of slaughter and daily gain from birth have already been discussed. Let us now consider the dressed weights of cattle of the several breeds. The Red Polls gave the largest percentage of dressed carcass to live weight, but the figures are the average for 2 animals only, and the best of these is lower than the best of the representatives of 5 other breeds. Were as many animals included as there are of the Short-horns, for example, they would no doubt rank lower in the list.

By the last column of the table we learn that steers of the beef breeds yielded from 64 to 65 per ct. of dressed carcass, while those of the dairy breeds and the natives dressed only 60 to 63 per ct. Eleven Herefords fattened and slaughtered at 4 stations yielded 8 per ct. more dressed carcass to live weight than did 9 natives at 3 stations. The weights of the native and dairy-bred steers are so large as to indicate that they were as mature and as well fattened as their competitors. Here is the first marked difference in favor of the beef-bred over other cattle for beef production.

517. Loose tallow.—At the Iowa Station[1] Wilson and Curtiss found the quantity of fat about the internal organs of fat steers of the various breeds to be as shown in the table below:

Weight of carcass and loose tallow of steers of various breeds.

Breed	Average dressed weight	Loose tallow	Per cent of loose tallow to beef
	Lbs.	Lbs.	
Short-horn	1,092	145	13.3
Hereford	1,022	129	12.6
Red Poll	990	125	12.6
Galloway	1,088	147	13.5
Angus	1,137	157	13.8
Devon	815	123	15.0
Swiss	1,017	119	11.7
Holstein	862	155	17.9
Jersey	880	166	18.8

It is shown that the Short-horn steers, dressing about 1,100 lbs. each, yielded 145 lbs., or 13 per ct., of loose tallow, while Jersey steers averaging 880 lbs. yielded over 165 lbs., or 18.8 per ct. These figures are corroborated by similar findings at the Michigan[2] and Missouri[3] Stations. Commenting on the character of the carcasses of the various breeds slaughtered at the Michigan Station, Davenport wrote: "Note the excess of rough tallow in Walton (a Holstein steer) as compared with the others. Walton was 'all cow,' as the saying goes, and the fat about his kidneys was astonishing."

From these data we may conclude that there is a specific difference between the beef and dairy breeds in the distribution of fat within the body. It appears that the beef representatives place more of the fat between the fibers of the muscles. On the other hand, steers of the dairy breeds deposit proportionately more fat about the intes-

[1] Bul. 20. [2] Bul. 24. [3] Bul. 69.

tines and kidneys. Fat intimately mingled with the muscular fibers of the lean tissues renders such meat tender, juicy, and toothsome. Placed in separate masses anywhere about the body, and especially within the body cavity, it has but low value. Such storage is doubtless best for animals whose function is milk production, but it is certainly against their highest usefulness for beef. In this second characteristic, which sets beef animals somewhat apart from dairy animals, we have a remarkable example of specialization for a definite end, and this lesson is important and far-reaching.

518. Proportion of valuable parts.—Georgeson of the Kansas Station[1] and Wilson and Curtiss of the Iowa Station[2] closed breed feeding trials by forwarding the animals to Swift & Company, Packers, who reported the following percentages of cuts in the dressed carcasses:

Percentage of the various cuts in the dressed carcass.

	Kansas		Iowa	
	Short-horn	Native	Short-horn	Native
	Per cent	Per cent	Per cent	Per cent
Loins	16.6	17.0	17.1	16.6
Ribs	9.6	10.1	9.9	10.2
Rounds	22.9	22.4	22.9	23.3
Chucks	20.6	20.8	21.1	21.9
Plates	13.5	12.8	15.4	14.2
Shanks	6.1	5.8	5.7	6.4
Minor cheap parts	10.7	11.1	7.9	7.4

There is nothing in the figures to show that the carcasses of steers of the beef breeds yield a noticeably larger proportion of the high-priced cuts. Nor can it be otherwise; for the framework of animals of the different types can vary but little in the proportion of the several parts. Thin-fleshed steers do not cut up percentagely much different from those yielding thick-fleshed cuts. These thick-fleshed cuts, however, command a much higher price per pound than do the thin-fleshed cuts, thereby giving to the carcass that furnishes them a marked advantage in the market.

519. Judgment of the market.—The 18 steers representing 9 breeds fattened by the Iowa Station, as reported in Article 514, when shipped to Chicago, were passed upon by a committee of 3 stock buyers with the results shown in the table on the next page, where there is a difference between the highest and lowest valuation of $2.13 per cwt., or about 32 per ct.

[1] Bul. 51. [2] Bul. 20.

In the slaughter test of the Kansas Short-horns and natives referred to in Article 514 the loins of the best Short-horns were rated at 18 cents per lb. and of the natives as low as 14 cents.

	Average live weight	Experts' valuation per cwt.
Hereford	1,525 pounds	$6.63
Short-horn	1,660 pounds	6.38
Galloway	1,635 pounds	6.38
Aberdeen-Angus	1,725 pounds	6.38
Red Poll	1,520 pounds	6.28
Swiss	1,570 pounds	6.00
Devon	1,290 pounds	5.75
Holstein	1,410 pounds	5.00
Jersey	1,430 pounds	4.50

520. Quality.—Beyond that which can be expressed in figures or stated percentagely lies that indefinable something described by the word "quality" which enters into all objects of barter. No one can compare a bunch of well-fed beef-bred steers with one representing the dairy breeds or natives without being impressed by a difference not measured by the scales. Speaking of the breed tests, Wilson[1] writes: "The carcasses of the dairy breeds lacked in thickness of cuts, and the marbling of the fat and lean was not equal to that of the others (beef breeds)." Georgeson[2] writes: "The Short-horns gave the best returns, not simply because the gross weight of their carcasses was greater than that of the scrubs, but also because their meat was esteemed better by experts in the packing-house who were asked to judge of the quality and assign prices." Of the Ontario native Shaw[3] wrote: "There was a lack of thickness of carcass thruout, the deficiency in depth of rib and loin being very noticeable, and the absence of what may be termed fleshiness was conspicuous."

The matter at issue may be illustrated by a condition in the fruit world: No orchardist will hold that the Baldwin apple tree necessarily grows faster than the seedling apple tree, or that it will make wood and fruit on less material from soil and air. Neither will he hold that Baldwin trees necessarily yield more barrels of fruit than seedlings, nor that a given measure of Baldwin apples contains more juice or human food than the same measure of common seedling apples. Fruit growers do rightfully assert, however, that the market wants Baldwin apples and will pay more for them than for common seedling fruit, and that from this judgment of the market, be it reasonable or unreasonable, there is no appeal. Beef cattle have been bred for meat production—it would be passing strange if they did not excel for that purpose.

[1] Iowa Expt. Sta., Bul. 20.
[2] Kansas Expt. Sta., Bul. 51.
[3] Ontario Agr. Col., Rpt. 1892.

CHAPTER XXII.

VALUE OF THE VARIOUS FEEDING STUFFS FOR FATTENING CATTLE AS FOUND BY THE EXPERIMENT STATIONS—BRITISH FEEDING TRIALS.

I. The Concentrates.

521. Heavy v. light corn feeding.—Smith of the Nebraska Station[1] fed 2 lots, each of 10 steers grown under range conditions and averaging 978 lbs., the first for 140 and the second for 168 days, on light and heavy rations of corn together with alfalfa hay and corn stover, with the results shown in the table:

Heavy and light corn feeding for steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Corn, 22.3 lbs. Alfalfa hay, 4.9 lbs. Corn stover, 4.9 lbs.	2.4	339	922	403
Lot II Corn, 13.9 lbs. Alfalfa hay, 10.9 lbs. Corn stover, 7.2 lbs.	2.0	339	691	896

It is shown that the steers fed 22.3 lbs. of corn daily made an average daily gain of 2.4 lbs., and required 922 lbs. of corn for 100 lbs. gain. The lot getting 13.9 lbs. of corn daily consumed more roughage and less grain. They made the smaller gain of 2.0 lbs. daily, putting on the same amount of gain, 339 lbs., in 168 days that the other lot did in 140 days. The lighter fed steers required 231 lbs., or 25 per ct., less grain for 100 lbs. gain than those getting the heavy ration. These data admirably illustrate the fact that steers given a heavy allowance of rich concentrates, like corn, make a large daily gain, and attain a desired weight in a comparatively short time. Such increase is, however, secured by the excessive use of rich, expensive concentrates.

522. Soaked shelled corn v. dry corn.—At the Kansas Station[2] Georgeson divided a bunch of 10 thrifty steers, averaging 1,033 lbs.,

[1] Bul. 100. [2] Bul. 47.

into 2 lots of 5 each, giving to the first dry shelled corn and to the second soaked shelled corn, both lots receiving the same roughage. The statements of corn fed are based on the weight of dry shelled corn. Eight shotes, averaging 88 lbs. each, were placed with each lot of steers. At first they subsisted entirely on corn in the droppings, but later they were supplied additional grain. The table shows the result of the trial, which lasted 5 months.

Soaked and dry corn for steers.

Average ration	Av. daily gain	Feed for 100 lbs. gain by steers		Extra corn fed pigs for 100 lbs. gain	Total corn for 100 lbs. gain by steers and pigs
		Corn	Roughage		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Dry corn, 21.7 lbs. Mixed roughage, 10.8 lbs.	2.0	1,105	554	170	791
Lot II Soaked corn, 21.0 lbs. Mixed roughage, 11.1 lbs.	2.2	938	512	200	752

By the table it is shown that the steers getting soaked shelled corn made larger daily gains and required 15 per ct. less corn for a given gain than those fed dry corn. The pigs following the steers getting the dry corn required 30 lbs. less additional corn for 100 lbs. gain. The last column of the table shows that for each 100 lbs. of combined gain of steers and pigs there was a net saving of 39 lbs. of corn, or 5 per ct., by soaking it before feeding. Other trials with soaked and dry corn have not always shown results so favorable for soaked corn. (**339**)

523. Corn fed in various forms.—Mumford of the Illinois Station[1] fed 4 lots of choice feeders, averaging about 1,000 lbs. each, for 186 days. Lots III and V contained 10 steers each, and the other lots 15 steers each. Pigs following the steers worked over the droppings. Each lot was given clover hay for roughage, a limited allowance of gluten meal being fed in the first half and of oil meal in the second half of the trial. As the table shows, Lot I was fed ear corn; Lot II, corn-and-cob meal; Lot III, shelled corn; Lot IV, corn meal; and Lot V, ear corn and shock corn, this lot being fed no gluten meal.

Lot II, fed corn-and-cob meal, made neither larger nor more economical gains than Lot I, fed ear corn, while the pigs following the

[1] Bul. 103.

steers getting ear corn made decidedly better gains than those following the steers fed corn-and-cob meal. (**157**)

Lot III, getting shelled corn, made the poorest gains, due to the fact, Mumford tells us, that these steers did not masticate their corn so thoroly as the others. While about the same amount of concentrates was required for 100 lbs. gain as with the preceding lots, it must be remembered that the ear corn and the corn-and-cob meal rations contained over 17 per ct. cob. Thus shelled corn proved inferior to ear corn or corn-and-cob meal in beef production.

Feeding corn in various forms to steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain		Gain of pigs per 100 lbs. corn fed to steers
			Concentrates	Roughage	
Lot I	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Ear corn, 20.1 lbs.					
Gluten or oil meal, 2.9 lbs.					
Clover hay, 8.0 lbs.	2.3	434	986	344	1.7
Lot II					
Corn-and-cob meal, 20.0 lbs.					
Gluten or oil meal, 2.9 lbs.					
Clover hay, 8.1 lbs.	2.3	432	993	350	0.5
Lot III					
Shelled corn, 16.6 lbs.					
Gluten or oil meal, 3.0 lbs.					
Clover hay, 9.0 lbs.	2.0	370	984	454	3.6
Lot IV					
Corn meal, 16.6 lbs.					
Gluten or oil meal, 2.9 lbs.					
Clover hay, 8.7 lbs.	2.4	443	822	370	0.7
Lot V					
Ear corn, 13.5 lbs.					
Oil meal, 1.4 lbs.					
Shock corn, 14.7 lbs.					
Clover hay, 7.2 lbs.	2.1	388	991*	782	1.8

*Including ear corn in the shock corn.

The steers in Lot IV, fed corn meal, made the largest gains, and required 162 lbs. less concentrates for 100 lbs. gain than those fed shelled corn. Considering the low gains of the pigs following the corn-meal-fed steers, corn meal was no more efficient than shelled corn for combined beef and pork production. Ear corn proved the most economical form of corn for combined gains of steers and hogs. (**156, 845**)

Lot V, fed shock corn at first and ear corn during the finishing period, made larger gains than Lot III, fed shelled corn. In economy of combined gains of steers and pigs this ration ranked second. (**216**)

524. Soft corn.—Kennedy and Rutherford of the Iowa Station,[1] studying the feeding value of soft corn with 2 lots of 8 steers each, fed for 6 months, found that soft corn containing 35 per ct. of moisture at the beginning of the trial and 16 per ct. at its close made rather more economical gains than mature corn, taking dry matter as the basis, and that the cattle finished equally well on it. (**154**)

525. Gain by hogs from droppings.—Mumford of the Illinois Station[2] found that hogs placed behind steers fattening on corn supplemented with oil meal or gluten meal made the following gains wholly from the droppings of the steers:

Gain by hogs living on the droppings of steers variously fed.

Form in which corn was fed	Hogs per 10 steers	Increase by hogs per steer	Gain per 100 lbs. corn fed to steer	Feed cost returned by hogs†
	Number	Lbs.	Lbs.	Per cent
Lot I, Shelled corn	7	112	3.6	16.7
Lot II, Shelled corn fed in mud	7	86	2.8	12.9
Lot III, Shock corn and ear corn	6	74	1.8*	12.7
Lot IV, Ear corn	5	63	1.7	9.7
Lot V, Ground corn	3	21	0.7	3.0
Lot VI, Corn-and-cob meal	3	18	0.5	2.6
Lot VII, Silage and corn meal	1	6	0.2*	0.9

*Computed on basis of ear corn in silage and shock corn.
†Gain by hogs valued at $5 per 100 lbs.

It is seen that where shelled corn was fed, the 7 hogs following each 10 steers made a total gain of 112 lbs. from the droppings of each steer. From each 100 lbs. of corn fed to the steers the hogs gained 3.6 lbs., returning 16.7 per ct. of the value of the corn given to the steers. Where ground corn was fed, the hogs made but 21 lbs. of gain per steer and returned but 0.7 lb. increase for 100 lbs. of corn fed to the steers. Corn-and-cob meal made still poorer returns, and silage corn returned practically nothing. (**506**)

526. Low-grade wheat.—At the North Dakota Station[3] Shepperd and Richards fed 2 lots, each of 11 two-yr.-old steers of fair quality and averaging 1,035 lbs., for a period of 112 days. One lot received rejected wheat, while the other was given corn, poor hay forming the roughage in both rations.

The table shows that the steers required about twice as much ground low-grade wheat as ground corn for 100 lbs. gain. After the trial was closed, both lots were fed corn and bran 7 weeks longer, during which time the wheat-fed steers made the very large gain of 3.1 lbs. daily, due possibly to greater growth made in the first period,

[1] Bul. 75. [2] Bul. 103. [3] Bul. 73.

while those previously fed corn gained only 1.5 lbs. daily. Low-grade or rejected wheat should be used for growing rather than for fattening cattle. **(161)**

Rejected wheat compared with corn for steers.

	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concen trates	Roughage
Lot I	Lbs.	Lbs.	Lbs.	Lbs.
Ground wheat, 9.5 lbs. Wheat bran, 2.6 lbs. Hay, 17.1 lbs.	0.7	79	1,701	2,430
Lot II Corn meal, 9.5 lbs. Wheat bran, 3.0 lbs. Hay, 18.3 lbs.	1.5	165	847	1,240

527. Wheat, oats, and barley.—Linfield of the Montana Station[1] fed 4 lots, each of eight 936-lb. steers of only fair quality, the following rations for 101 days, to compare the value of wheat, oats, barley, and a mixture of these grains, when fed with clover hay. The wheat and oats were crushed, and the barley ground medium fine.

Wheat, oats, and barley for fattening steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Conc entrates	Roughage
Lot I	Lbs.	Lbs.	Lbs.	Lbs.
Wheat, 4.4 lbs. Clover hay, 23.7 lbs.	2.1	208	215	1,150
Lot II Oats, 4.4 lbs. Clover hay, 23.7 lbs.	2.1	211	212	1,130
Lot III Barley, 4.4 lbs. Clover hay, 23.7 lbs.	2.1	215	208	1,110
Lot IV Mixed grain, 4.4 lbs. Clover, 23.7 lbs.	2.4	238	183	1,000

The table is worthy of careful study by western stockmen who can avail themselves of the feeds employed. The several grains were about equally effective. The clover hay of the Rocky Mountain region often equals alfalfa hay in feeding value. **(169, 171)**

528. Barley v. bran and shorts.—At the North Dakota Station[2] Shepperd fed 2 lots, each of five 2-yr.-old, 1050-lb. range steers of

[1] Bul. 58. [2] Bul. 33.

good quality, for 84 days with the results shown below. One lot was fed ground barley, and the other a mixture of 2 parts wheat shorts and 1 part wheat bran, both lots receiving a small allowance of oil meal in addition.

Ground barley compared with wheat bran and shorts.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Barley, 14.4 lbs. Oil meal, 1.5 lbs. Hay, 16.9 lbs.	1.7	146	914	971
Lot II Bran and shorts, 13.0 lbs. Oil meal, 1.3 lbs. Hay, 17.2 lbs.	1.4	113	1,008	1,271

It is shown that the barley-fed steers made heavier daily gains and required less feed for a given gain than those getting wheat bran and shorts. The barley-fed steers reached a higher finish than those fed bran and shorts. Shepperd reports: "The difference in the quality or ripeness was greater than the difference in the rate of increase in weight." Bran should be used for producing growth rather than fat. (**165-6**)

529. Emmer v. shelled corn.—At the South Dakota Station[1] Wilson and Skinner fed 4 lots, each containing four 2-yr.-old grade Hereford steers, the rations shown below for 170 days to compare the values of emmer (speltz) and shelled corn for fattening steers.

Emmer (speltz) v. shelled corn for fattening steers.

Average ration	Average daily gain	Av. gain per head	Feed for 100 lbs. gain		Pork per steer
			Grain	Hay	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Shelled corn, 20.3 lbs. Prairie hay, 11.1 lbs.	2.4	406	848	466	63
Lot II Whole emmer, 18.9 lbs. Prairie hay, 10.7 lbs.	1.8	303	1,060	601	26
Lot III Ground emmer, 15.4 lbs. Prairie hay, 13.6 lbs.	1.5	262	988	882	14
Lot IV Whole emmer, 9.2 lbs. Shelled corn, 9.2 lbs. Prairie hay, 12.0 lbs.	2.0	344	912	594	40

[1] Bul. 100.

The table shows that the steers fed shelled corn gained 2.4 lbs. each daily, while those fed whole emmer gained but 1.8 lbs. and those fed ground emmer 1.5 lbs. each. The emmer-corn mixture gave better results than emmer alone. In this trial 100 lbs. of shelled corn was equal to 125 lbs. of emmer in feeding value. The lot fed ground emmer did not reach as high a finish as the other lots. Sixty lbs. of pork was produced per steer on the shelled-corn ration, 26 lbs. on the whole emmer ration, and only 14 lbs. on the ground emmer ration. (**178**)

530. Millet and emmer v. corn.—At the South Dakota Station[1] Wilson and Skinner fed 4 lots of 3 calves each for baby beef on separator skim milk until 6 months old. Beginning with an average weight of about 500 lbs., all were fed to the finish on clover hay and either corn, oats, Black Veronesh millet, or emmer (speltz). The results are summarized in the following table:

Feeding millet and emmer for baby beef production.

Grain fed	Av. daily gain	Av. gain per head	Grain for 100 lbs. gain			Av. selling price per 100 lbs.
			As calves	While on grass	Fattening period	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
Lot I, Corn	1.8	797	494	703	716	6.25
Lot II, Oats	1.8	759	474	828	628	6.00
Lot III, Millet	1.5	637	584	635	697	5.75
Lot IV, Emmer	1.7	727	628	516	725	5.85

It is seen that the corn-fed and oat-fed lots made the most rapid gains, and that the corn-fed lot brought the highest price in the Chicago market where they were sold. Millet produced smaller daily gains than emmer. In all cases the grain requirements for 100 lbs. of gain are low compared with those of more mature steers. On the plains of the West, where millet and emmer flourish, these grains are sure to increase in importance and prove useful factors in meat production. In this trial emmer produced a hard fat the same as did oats, and meat of as good a quality as that from corn. (**185**)

531. Kafir.—At the Kansas Station[2] Georgeson divided a bunch of 15 three-year-old grade steers into 3 lots of 5 each, feeding the concentrates given in the table. The grain was ground to such fineness that three-fourths of the meal passed thru a sieve of one-twentieth inch mesh. At first kafir stover and later corn stover and alfalfa hay were fed for roughage, only that actually consumed

[1] Bul. 97. [2] Bul. 67.

being reported. Shotes followed the steers during the 175-day trial.

Kafir meal compared with corn meal.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain		Corn fed to pigs for 100 lbs. gain
			Grain	Roughage	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Corn meal, 18.6 lbs. Roughage, 10.6 lbs.	1.9	326	997	569	397
Lot II Red kafir meal, 18.6 lbs. Roughage, 11.8 lbs.	1.7	299	1,086	688	361
Lot III White kafir meal, 18.6 lbs. Roughage, 12.4 lbs.	1.8	313	1,041	692	342

While the feeding value of Indian corn for steers has long been known, this was the first experiment in which kafir was thoroly tested for a long period under normal conditions. The table shows that kafir meal proved about 7 per ct. less valuable than corn meal as a feed for fattening steers. Burtis of the Oklahoma Station[1] writes: "A bushel of corn meal produced, when fed to steers, about three-quarters of a lb. more beef than did a bushel of kafir meal." Haney of the Kansas Station[2] found that when fed with either kafir hay or sorghum hay, kafir meal was not equal to corn meal, over 200 lbs. more kafir meal than corn meal being required for 100 lbs. gain when the roughage was kafir hay. (**183**)

532. Milo and kafir v. Indian corn.—At the Texas Station[3] Burns fed 3 lots, each of six 2-yr.-old grade Aberdeen-Angus steers averaging about 875 lbs. each, the following rations for 120 days to compare the feeding value of milo and kafir "chop" with corn "chop."

Milo and kafir compared with Indian corn.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain		
			Grain	Cotton-seed meal	Cotton-seed hulls
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Indian corn, 15.1 lbs. Cotton-seed meal, 3.0 lbs. Cotton-seed hulls, 12.6 lbs.	2.1	253	718	140	599
Lot II Milo, 15.1 lbs. Cotton-seed meal, 3.0 lbs. Cotton-seed hulls, 12.6 lbs.	2.1	255	714	139	596
Lot III Kafir, 15.1 lbs. Cotton-seed meal, 3.0 lbs. Cotton-seed hulls, 12.6 lbs.	2.5	297	612	119	510

[1] Rpt. 1901. [2] Bul. 132. [3] Bul. 110.

The milo, kafir, and corn were all ground to the same fineness. It is shown that under Texas conditions with cotton-seed hulls for roughage, kafir chop produced the largest and most economical gains and milo chop proved equal to Indian corn chop for fattening steers. There was no material difference in the quality of meat from the three lots. (**184**)

533. Rough rice and by-products.—In feeding trials with steers at the Texas Station[1] Craig and Marshall found that when feeding cotton-seed hulls for roughage 2.3 lbs. of rough rice was equal to 1 lb. of cotton-seed meal in the ration. Ten lbs. of rice bran proved equal to 6 lbs. of cotton-seed meal when forming two-fifths of the concentrates of the ration. Rice polish was about equal to cotton-seed meal when substituted for a portion thereof in the ration. Rice hulls proved to be without value. (**179**)

534. Velvet bean.—At the Florida Station[2] Scott fed velvet beans in the pod in comparison with other feeds as stated below to sixteen 700-lb. steers divided into 4 lots of 4 each for 84 days with the results shown in the table.

Feeding velvet beans in the pod, corn, cotton-seed meal, etc., to Florida steers.

Average ration per 1,000 lbs. of steer	Av. daily gain	Av. gain per head	Cost of 100 lbs. gain
Lot I	Lbs.	Lbs.	Dollars
Corn, 8.0 lbs.			
Velvet beans in pod, 12.0 lbs.			
Cotton-seed hulls, 10.0 lbs.	2.9	246	7.55
Lot II			
Corn, 10.5 lbs.			
Cotton-seed meal, 3.8 lbs.			
Crab-grass hay, 13.5 lbs.	2.6	217	9.07
Lot III			
Corn, 6.0 lbs.			
Cotton-seed meal, 5.0 lbs.			
Sorghum silage, 20.0 lbs.			
Cotton-seed hulls, 14.0 lbs.	2.7	225	10.65
Lot IV			
Cotton-seed meal, 6.5 lbs.			
Cotton-seed hulls, 25.0 lbs.	1.9	155	12.00

It is shown that the steers getting 12 lbs. of velvet beans in the pod per 1,000 lbs. of live weight, together with corn and cotton-seed hulls, made the high average gain of 2.9 lbs. daily for 84 days. While all gains were satisfactory, those of the steers fed velvet beans were the largest and cheapest. (**263**)

[1] Buls. 76, 86.

[2] Bul. 102.

II. By-products of the Mills and Factories.

535. Cotton seed v. cotton-seed meal.—Marshall and Burns of the Texas Station[1] divided one hundred 3-yr.-old grade Short-horn steers of good quality and averaging 1,115 lbs. into 2 lots of 50 each, feeding them for 84 days on the rations shown in the table.

Cotton seed v. cotton-seed meal when fed with kafir stover.

Average ration	Av. daily gain	Av. gain per head	Concentrates for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I			
Cotton seed, 5.2 lbs.			
Ground kafir, 21.6 lbs.			
Kafir stover, without limit	3.1	262	859
Lot II			
Cotton seed meal, 3.3 lbs.			
Ground kafir, 22.7 lbs.			
Kafir stover, without limit	2.4	203	1,074

It is seen that the steers getting cotton seed made the very large gain of 3.1 lbs. each daily, or 0.7 lb. more than those getting cotton-seed meal. The shrinkage of Lot I on shipping was 9.2 and of Lot II 7.5 per ct. In this trial with kafir stover for the roughage, cotton seed at $12 per ton proved more profitable than cotton-seed meal at $26 per ton.

At the same Station[2] Burns compared cotton seed and cotton-seed meal in a 90-day trial with 2 lots, each of 6 high grade Aberdeen-Angus steers averaging 963 lbs. Each lot was fed 16.0 lbs. of kafir chop and 12.8 lbs. of cotton-seed hulls per head daily in addition to cotton seed or cotton-seed meal, with the following results:

Cotton seed v. cotton-seed meal for fattening steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain			
			Kafir chop	Cotton seed	Cotton-seed meal	Cotton-seed hulls
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I						
Cotton seed, 4.0 lbs.						
Cotton seed meal, 1.0 lbs.						
Kafir chop, 16.0 lbs.						
Cotton-seed hulls, 12.8 lbs.	2.0	184	782	196	48	626
Lot II						
Cotton-seed meal, 2.9 lbs.						
Kafir chop, 16.0 lbs.						
Cotton-seed hulls, 12.8 lbs.	2.5	227	634	--------	116	508

[1] Bul. 97. [2] Bul. 110.

The results show that when 4 lbs. of cotton seed was substituted for 1.9 lbs. of cotton-seed meal, smaller and less economical gains were produced. In this trial it was found that with cotton-seed hulls for roughage cotton-seed meal was cheaper at $26 per ton than cotton seed at $12. **(188)**

536. Cotton-seed meal as a supplement.—At the Indiana Station[1] Skinner and Cochel fed 2 lots, each of ten 2-yr.-old steers averaging 1,010 lbs., on corn, clover hay, and corn silage for 180 days. The steers in Lot II received in addition a daily allowance of 3 lbs. of cotton-seed meal as shown in the table.

Cotton-seed meal as a supplement to corn, clover hay, and silage.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain			
			Concentrates		Roughage	
			Corn	Cotton-seed meal	Clover hay	Silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Shelled corn, 16.7 lbs. Clover hay, 4.0 lbs. Corn silage, 15.0 lbs.	1.9	334	902	....	215	808
Lot II Shelled corn, 16.7 lbs. Cotton-seed meal, 3.0 lbs. Clover hay, 4.0 lbs. Corn silage, 15.0 lbs.	2.6	464	647	116	152	582

The addition of cotton-seed meal to an already excellent ration so stimulated the appetite of the steers that they ate more corn, and as a result gained 0.7 lb. more daily than the other lot. It is shown that the feeding of 116 lbs. of cotton-seed meal effected a saving of 255 lbs. of corn, 63 lbs. of clover hay, and 226 lbs. of corn silage in making 100 lbs. of gain. Because of their better finish, the steers getting cotton-seed meal sold for 30 cents per 100 lbs. more than the others.

At the same Station[2] 2 lots, each of ten 2-yr.-old steers averaging 966 lbs., were fed 180 days to determine the value of cotton-seed meal as a supplement when fed with shelled corn and clover hay. The steers receiving cotton-seed meal gained 0.4 lb. more daily and required 120 lbs. less concentrates and 110 lbs. less clover hay for 100 lbs. gain than those receiving no supplement. **(188)**

537. Cotton-seed meal with pasture.—At the Texas Station[3] Craig and Marshall, feeding 2 lots of 19 yearling steers each for 196

[1] Bul. 129. [2] Bul. 130. [3] Bul. 76.

days on pasture, tested the value of a limited allowance of cotton-seed meal as a partial substitute for corn.

Cotton-seed meal as a supplement to corn for steers on pasture.

Average ration	Average daily gain	Av. gain per head	Concentrates for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I			
Corn, 3.7 lbs.			
Pasture	0.9	171	428
Lot II			
Corn, 2.8 lbs.			
Cotton-seed meal, 0.9 lb.			
Pasture	1.1	214	337

It is shown that the substitution of 0.9 lb. of cotton-seed meal for an equal weight of corn increased the daily gain by 0.2 lb., and effected a saving of 21 per ct. in the concentrates required for 100 lbs. of gain.

At the Mississippi Station[1] MacLean fed 20 thousand-lb., poor-quality grade steers cotton-seed meal mixed with an equal weight of cotton-seed hulls for 97 days in summer while grazing on mixed pasture. The steers made an average daily gain of 1.3 lbs., requiring 326 lbs. of cotton-seed meal and 328 lbs. of hulls for 100 lbs. of gain. These steers fed on pasture made more economical gains and returned a much greater profit than did a similar lot fed cotton-seed meal and hulls during the winter.

538. Linseed oil meal.—Smith of the Nebraska Station,[2] as a result of 3 trials with steers fed corn and prairie hay in comparison with others fed 90 per ct. corn and 10 per ct. linseed meal with prairie hay, found that it required 23 per ct. less concentrates for 100 lbs. gain when the ration containing linseed oil meal was used. For steer fattening linseed meal was rated a little higher than cotton-seed meal and much more valuable than wheat bran for supplementing corn fed with prairie hay or corn stover. Smith found that alfalfa hay furnished sufficient protein, and proved much cheaper than linseed oil meal with fattening steers, yet no form of hay can quite take its place in giving finish to such steers. (**200**)

539. Linseed meal, corn, and pasture.—At the Nebraska Station[3] Burnett and Smith pastured 2 lots, each of five 2-yr.-old steers, one receiving 17.8 lbs. corn meal per head daily and the other 16 lbs. corn meal and 1.8 lbs. linseed meal. The steers getting the linseed meal each gained 0.4 lb. more daily, consumed 200 lbs. less concentrates

[1] Bul. 136. [2] Bul. 100. [3] Bul. 85.

for 100 lbs. gain, and were much less troubled with scours than the lot receiving corn meal only. This trial shows the value of a protein-rich supplement for steers fed corn on pasture.

540. Dried distillers' grains.—May of the Kentucky Station[1] fed 2 lots, each of 4 Short-horn and Angus grade steers running on closely cropped blue grass pasture, the feeds shown in the table for 168 days.

Dried distillers' grains compared with corn-and-cob meal.

Average ration	Average daily gain	Av. gain per head	Concentrates for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I			
Corn-and-cob meal, 14.3 lbs.			
Dried distillers' grains, 5.4 lbs.			
Clover hay, without limit	2.2	375	882
Lot II			
Corn-and-cob meal, 23.0 lbs.			
Clover hay, without limit	1.8	300	1,287

It is seen that the substitution of 5.4 lbs. of dried distillers' grains for 8.7 lbs. of corn-and-cob meal in the ration brought 0.4 lb. more gain daily with each steer, with about 400 lbs. less concentrates required for 100 lbs. of gain. The high value of this feed used in a limited way and in proper combination is here shown (**317**)

541. Sugar-beet pulp.—Carlyle and Griffith of the Colorado Station[2] divided a bunch of forty-eight 956-lb. steers of mixed breeding and below average in quality into 4 lots of 12 each, giving alfalfa hay of poor quality to all without limit. Sugar-beet pulp was fed without limit to 2 lots twice a day. Coarse corn meal was fed for concentrates to Lots I and II, the allowance starting with 2 lbs. per steer daily and being gradually increased during the 100-day trial.

Value of wet beet-pulp in steer feeding.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain		
			Corn	Hay	Pulp
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I					
Beet pulp, 93.4 lbs.					
Alfalfa hay, 20.0 lbs.					
Corn, 6.6 lbs.	2.6	263	251	759	3,545
Lot II					
Alfalfa hay, 31.3 lbs.					
Corn, 6.6 lbs.	1.8	176	376	1,778	
Lot III					
Beet pulp, 97.3 lbs.					
Alfalfa hay, 21.9 lbs.	1.8	184		1,189	5,283
Lot IV					
Alfalfa hay, 41.5 lbs.	1.5	147		2,829	

[1] Bul. 108. [2] Bul. 102.

The table shows that each steer in Lot I consumed over 93 lbs. of beet pulp daily in addition to 20 lbs. of alfalfa hay and 6.6 lbs. corn meal. On this ration they made the excellent daily gain of 2.6 lbs. each, gaining 263 lbs. in 100 days. With alfalfa hay, beet pulp, and no grain, the steers of Lot III gained 1.8 lbs. against 1.5 lbs. daily for Lot IV on alfalfa hay alone. These investigators report that thruout the trial the pulp-fed steers were more uniformly thrifty than those getting no pulp. They estimate that for 2-yr.-old fattening steers 9 lbs. of wet sugar-beet pulp proved equal to 2.8 lbs. of alfalfa hay or 1 lb. of ground corn. (**309**)

542. Dried beet pulp.—Shaw and Norton of the Michigan Station[1] found as the results of three winter trials that dried beet pulp tended to growth with cattle rather than to fattening, and conclude that in the earlier part of the feeding period dried pulp can be fed advantageously in large quantities because of its cheapness and ability to produce rapid gains. During the finishing period, however, it should be largely replaced by corn meal. A 1000-lb. steer will not consume over 10 lbs. of dried beet pulp daily. (**311**)

543. Cane molasses.—At the Texas Station[2] Burns fed 2 lots, each of 6 high-grade 2-yr.-old Aberdeen-Angus steers averaging about 870 lbs., for 120 days. The steers in both lots were fed cotton-seed meal and cotton-seed hulls. Lot I received corn additional, while Lot II received cane molasses in place of part of the corn. The results of the trial are given below:

Cane molasses as a partial substitute for corn.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain			
			Corn	Molasses	Cotton-seed meal	Cotton-seed hulls
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Corn, 15.1 lbs. Cotton-seed meal, 3.0 lbs. Cotton-seed hulls, 12.6 lbs.	2.1	253	718	--------	140	599
Lot II Molasses, 6.6 lbs. Corn, 8.6 lbs. Cotton-seed meal, 3.0 lbs. Cotton-seed hulls, 12.6 lbs.	2.3	272	378	290	130	559

The results show cane molasses somewhat higher in feeding value pound for pound than corn where it replaces not more than one-half of the corn in the ration. When fed in this proportion it did not induce scouring.

[1] Bul. 247. [2] Bul. 110.

Craig and Marshall of the Texas Station[1] found that cane molasses had a feeding value with fattening steers of from 3 to 30 cents per gallon, the lower figure coming from its use in a ration already balanced. They state that the practice of Texan feeders is to mix cane molasses with water in equal parts, drive thru the feed lots, and spray the mixture on the feed in the bunks. Others mix it with meal and hulls before feeding. Some feeders restrict its use to 1 quart per steer daily, mixing it with the feed principally to render it more palatable and induce the cattle to eat more of other feeds. (**314**)

544. Sugar-beet molasses.—Ware[2] reports that beet molasses has been fed to oxen for about 30 years at the Hohenau sugar factory, Germany. During the first month 3.3 lbs. is fed per head daily, and after this 4.4 lbs., the molasses being mixed with beet pulp. The oxen so fed have better appetites than those fed no molasses, and fatten rapidly.

At the Utah Station,[3] when fed with alfalfa hay valued at $3.50 per ton, and bran and shorts at $14 per ton, beet molasses had a value of $2.35 per ton for fattening steers. (**312**)

III. A Comparison of the Various Dry Roughages.

545. Corn stover.—Smith of the Nebraska Station[4] conducted 2 feeding trials in which there were ten 2-yr.-old range steers averaging 957 lbs. in each lot. To one lot was given alfalfa hay for roughage, and to the other lot half alfalfa and half corn stover.

Corn stover fed in combination with alfalfa hay to fattening steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Corn	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Trial lasting 84 days				
Lot I				
Alfalfa hay, 22.2 lbs. Corn, 9.5 lbs.	2.1	173	460	1,075
Lot II				
Alfalfa hay, 11.2 lbs. Corn stover, 11.2 lbs. Corn, 9.6 lbs.	2.0	165	490	1,144
Trial lasting 168 days				
Lot I				
Alfalfa hay, 9.2 lbs. Corn, 18.6 lbs.	2.3	385	814	402
Lot II				
Alfalfa hay, 4.9 lbs. Corn stover, 4.9 lbs. Corn, 18.4 lbs.	2.4	402	789	456

[1] Bul. 86. [2] Cattle Feeding, p. 245. [3] Bul. 90. [4] Buls. 90, 93, 100.

The above table shows that corn stover (husked corn fodder) may advantageously take the place of part of the alfalfa hay in the ration for fattening steers. Incidentally there is brought out the interesting fact that the short-fed steers required less than 500 lbs. of corn for 100 lbs. of gain, while the long-fed steers, which were of course much better fattened, required 800 lbs. of corn for 100 lbs. of gain—69 per ct. more than the short-fed steers. (**549**)

Burnett and Smith of the Nebraska Station[1] report that field-cured corn stalks fed with corn and a little oil meal gave large and cheap gains. (**218**)

546. Clover v. timothy hay.—At the Indiana Station[2] Skinner and Cochel divided a bunch of heavy, fleshy grade steers weighing about 1,000 lbs. into lots of 10 each. Lot 1 was fed clover hay and shelled corn, while Lot II received timothy hay and shelled corn. The results of the 6-months trial are shown in the table:

Clover hay and shelled corn compared with timothy hay and shelled corn.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Clover hay, 8.3 lbs. Shelled corn, 19.5 lbs.	2.0	363	969	411
Lot II				
Timothy hay, 6.9 lbs. Shelled corn, 16.5 lbs.	1.6	282	1,054	438

The table shows that the clover-fed lot ate more grain and roughage than the timothy-fed lot, and made both larger and more economical gains, requiring about 9 per ct. less corn for a given increase. Thruout the experiment the clover-fed steers were in better condition, had better appetites, and were more regular feeders. The timothy-fed steers were irregular in their appetites, and even when eating a full feed seemed unsatisfied. At the close of the 6-months feeding period the average weight of the clover-fed steers was 1,373 lbs., and that of the timothy-fed steers 1,281 lbs. Waters of the Missouri Station[3] found that corn was worth about 8 cents per bushel more when fed with clover or cowpea hay to fattening steers than when fed with timothy hay. (**224, 254**)

547. Nitrogenous supplements in corn feeding.—Mumford of the Illinois Station[4] fed 3 lots of 13 common to medium quality steers averaging 917 lbs. for 126 days as follows: All were fed ear corn at

[1] Bul. 85. [2] Bul. 129. [3] Bul. 76. [4] Bul. 83.

first and later corn-and-cob meal. Lots II and III were fed timothy hay and corn stover for roughage. Lot I was fed clover hay, a nitrogenous roughage, and Lot III gluten meal, a nitrogenous concentrate. During the trial an average of 5.5 pigs, averaging 131 lbs. each, ran with each lot of 13 steers. The ration and returns are given in the table:

Value of nitrogenous supplements in corn feeding.

Average ration	Av. daily gain	Av. gain per head	Feed per 100 lbs. gain		Total gain	
			Concentrates	Roughage	Steers	Pigs
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I						
Clover hay, 11.6 lbs.						
Corn or						
Corn-and-cob meal, 18.5 lbs.	2.5	303	768	482	3,945	542
Lot II						
Timothy hay, 6.6 lbs.						
Corn stover, 3.9 lbs.						
Corn or						
Corn-and-cob meal, 17.5 lbs.	1.9	223	987	588	2,900	482
Lot III						
Timothy hay, 7.3 lbs.						
Corn stover, 3.9 lbs.						
Corn or						
Corn-and-cob meal, 13.6 lbs.						
Gluten meal, 2.6 lbs.	2.3	274	744	514	3,556	422

The table shows that when getting substantially the same allowance of corn-and-cob meal the steers of Lot I, receiving clover hay, made a daily gain of 2.5 lbs. each, while those of Lot II, given timothy hay and corn stover, gained only 1.9 lbs. daily, or 0.6 lb. less per steer. The 13 steers of Lot I, getting clover hay, gained over 1,000 lbs. more than those of Lot II, getting timothy hay and corn stover. The pigs following the clover-fed steers also gained more from the droppings than those following the steers fed timothy hay and corn stover. (**554**) Comparing Lots II and III we learn that substituting 2.6 lbs. of protein-rich gluten meal for 3.9 lbs. of corn-and-cob meal caused each steer in Lot III to gain 0.4 lb. more daily, with a total increased gain for the lot of over 600 lbs.

It is evident from this and the preceding trial that where carbohydrate-rich feeds, like corn, timothy hay, and corn stover, are used, the addition of a nitrogenous feed, like clover hay, gluten meal, or oil meal, materially increases the efficiency of the ration. Mumford reports that when slaughtered the steers fed timothy hay without a protein-rich supplement showed a high percentage of internal fat, without a corresponding percentage of dressed beef—a most significant and possibly fundamental fact. The successful use of farm-grown clover in place of the expensive purchased gluten meal should not be overlooked in studying this experiment.

548. Feeding alfalfa hay only.—Vernon and Scott of the New Mexico Station,[1] when feeding 2-yr.-old range steers averaging 550 lbs. each solely on alfalfa hay, secured a total gain of 205 lbs. per steer, with an average daily gain of 1.7 lbs., 1,100 lbs. of alfalfa hay being eaten for each 100 lbs. of gain. The marked economy of alfalfa for feeding steers for the local markets in the Western alfalfa districts is here shown. (**245**)

True and McConnell of the Arizona Station,[2] after 6 feeding trials, conclude that, where no concentrates are fed, alfalfa hay alone is about equal in feeding value to alfalfa hay combined with such roughages as corn, kafir, and sweet sorghum. Where water is abundant alfalfa hay is cheaper than the other roughages, but where it is in scant supply or the soil is excessively alkaline, kafir and the sweet sorghums form economical roughages in combination with alfalfa.

549. Alfalfa hay as the sole roughage.—Erf, Kinzer, and Wheeler of the Kansas Station[3] fed 2 lots, each of 10 high grade Angus steers averaging 959 lbs., for a period of 143 days. Both lots received the same allowance of concentrates, the roughages varying as shown in the table:

Alfalfa hay compared with mixed roughages for steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Alfalfa hay, 12.9 lbs. Corn, 19.4 lbs. Cotton-seed meal, 0.4 lb.	2.8	406	578	455
Lot II Alfalfa hay, 10.8 lbs. Prairie hay, 3.5 lbs. Sorghum and kafir stover, 2.5 lbs. Corn silage, 1.0 lb. Corn, 19.4 lbs. Cotton-seed meal, 0.4 lb.	2.3	333	715	743

It is shown that the steers getting alfalfa as their sole roughage each gained half a lb. more daily than those fed mixed roughage including alfalfa hay. While all gains were satisfactory, they were particularly high on the ration in which alfalfa was the sole rough-

[1] Bul. 57. [2] Bul. 50. [3] Bul. 130.

age. "Alfalfa hay and corn-and-cob meal form a most excellent ration for fattening steers," is the conclusion reached by these investigators. (**545**)

Burtis of the Oklahoma Station[1] reports that alfalfa-fed steers made about 16 per ct. faster gain and required from one-fourth to one-third less grain for a given gain than steers fed kafir stover.

550. Alfalfa hay v. prairie hay.—At the Nebraska Station[2] Smith fed 2 lots, each of ten 2-year-old grade Short-horn steers averaging 932 lbs., for 168 days on the rations shown in the table:

Alfalfa hay compared with prairie hay.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Grain	Roughage
Lot I	Lbs.	Lbs.	Lbs.	Lbs.
Alfalfa hay, 9.2 lbs. Shelled corn, 18.6 lbs.	2.3	385	814	402
Lot II				
Prairie hay, 9.7 lbs. Shelled corn, 17.9 lbs.	1.9	315	952	519

By the table we are shown that each steer receiving alfalfa hay and shelled corn made 0.4 lb. more gain daily and required 14 per ct. less grain for a given gain than those getting prairie hay. In a similar trial with yearlings,[3] it was found that 27 per ct. less grain was required when alfalfa hay was used in place of prairie hay.

551. Alfalfa v. sorghum and kafir hay.—At the Kansas Station[4] Haney found in trials with lots of 8 steers each fed 152 days that alfalfa was greatly superior to either sorghum hay or kafir hay when either corn-and-cob meal or kafir meal was fed as the concentrate. One bushel (70 lbs.) of corn-and-cob meal fed with alfalfa hay as roughage produced 11.8 lbs. of gain, while with sorghum hay it gave only 6.3 lbs. gain, and with kafir hay 7.1 lbs. gain. (**222**)

552. Alfalfa hay v. linseed oil meal.—Smith of the Nebraska Station[5] compared alfalfa hay with linseed oil meal in 2 trials conducted with a total of 40 steers, divided into 2 lots of 20 each. He concludes: "A relatively small quantity of alfalfa hay will supply sufficient protein to insure good gains on 2-yr.-old steers, and this can be produced on the farm much cheaper than it can be purchased on the market in the form of linseed meal or some other protein concentrate."

[1] Rpt. 1901.
[2] Bul. 90.
[3] Nebr. Sta., Bul. 85.
[4] Bul. 132.
[5] Bul. 100.

553. Alfalfa v. various roughages.—At the Nebraska Station[1] Snyder divided a bunch of 100 good grade steer calves averaging about 425 lbs. into 5 lots of 20 each. Each calf was fed 2 lbs. daily of concentrates, consisting of 2 parts corn and 1 part oats, together with roughage as shown in the table, the trial lasting 116 days:

A test of various roughages for steer calves.

Average ration	Av daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Alfalfa hay, 12.3 lbs.				
Concentrates, 2 lbs.	1.2	143	162	1,000
Lot II				
Alfalfa hay, 8.5 lbs.				
Sorghum hay, 8.5 lbs.				
Concentrates, 2 lbs.	1.2	140	165	1,416
Lot III				
Alfalfa hay, 7.5 lbs.				
Prairie hay, 7.5 lbs.				
Concentrates, 2 lbs.	1.1	133	174	1,315
Lot IV				
Prairie hay, 10.9 lbs.				
Concentrates, 2 lbs.	0.7	76	305	1,676
Lot V				
Sorghum hay, 14.3 lbs.				
Concentrates, 2 lbs.	0.4	46	504	3,666

It is shown that the best returns were from alfalfa hay and the poorest from sorghum hay, while a combination of the two proved satisfactory. The gains of the calves on the rations containing alfalfa were excellent, and 100 lbs. of increase was obtained with a surprisingly small amount of feed, showing that alfalfa hay is particularly useful with young, growing animals.

554. A Missouri comparison of roughages.—At the Missouri Station[2] Waters fed 4 lots, each of 4 two-yr.-old steers, the rations shown on the next page for 105 days to compare the value of various roughages for fattening steers.

It is shown that steers fed timothy hay produced much smaller and less economical gains than those receiving either clover or cowpea hay, or clover hay with corn stover. The steers fed the legume hays consumed nearly twice as much hay and also more corn than those fed timothy hay, but 22 per ct. of the corn required for 100 lbs. of gain was saved by using a legume hay in place of timothy hay. Waters states that hogs following steers getting legume hay do better

[1] Bul. 105. [2] Bul. 76.

than those following steers fed timothy hay, prairie hay, or corn stover. He concludes that the advantages of feeding legume hay, such as alfalfa, clover, or cowpea, are: Cheaper and more rapid gains; better finish and better selling qualities with increased hog gains; and manure richer in nitrogen. (**546-7**)

Various roughages for fattening steers compared.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Shelled corn	Roughage
Lot I	Lbs.	Lbs.	Lbs.	Lbs.
Timothy hay, 6.0 lbs. Shelled co r n,21.0lbs.	1.9	197	1,118	322
Lot II				
Clover hay, 11.4 lbs. Shelled corn, 23.5 lbs.	2.7	284	869	420
Lot III				
Cowpea hay, 11.4 lbs. Shelled corn, 23.4 lbs.	2.7	284	865	422
Lot IV				
Clover hay, 5.9 lbs. Corn stover, 2.1 lbs. Shelled corn, 23.5 lbs.	2.7	285	865	293

555. Velvet beans in the pod and crab grass.—At the Florida Station[1] Scott fed 2 lots, each of four 717-lb. steers from native cows and sired by a well-bred Short-horn bull, the rations shown below for 84 days. Both lots received corn, Lot I being fed cotton-seed meal in addition and crab-grass hay for roughage, and Lot II velvet beans in the pod and cotton-seed hulls for roughage.

Crab grass and velvet beans in the pod for roughage with Florida steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
Lot I	Lbs.	Lbs.	Lbs.	Lbs.
Crab-grass hay, 13.0 lbs. Corn, 9.9 lbs. Cotton-seed meal, 3.5 lbs.	2.6	217	518	503
Lot II				
Velvet beans, 11.2 lbs. Cotton-seed hulls, 9.4 lbs. Corn, 7.5 lbs.	2.9	246	258	703

It is seen that both lots of steers made most satisfactory gains, those getting velvet beans in the pod gaining somewhat more than the others. (**263**)

[1] Bul. 96.

556. Roughages with cotton-seed meal.—During each of three years, Duggar and Ward of the Alabama Station[1] fed 4 lots each of 5 grade 2-yr.-old steers for 84 days on the rations averaged below:

Comparison of roughages fed with cotton-seed meal.

Average ration	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Cotton-seed meal, 5.6 lbs.				
Cotton-seed hulls, 19.5 lbs.	734	1.6	366	1,347
Lot II				
Cotton-seed meal, 5.5 lbs.				
Shredded corn stover, 17.4 lbs.	708	1.2	578	1,847
Lot III				
Cotton-seed meal, 5.5 lbs.				
Cut sorghum hay, 2.2 lbs.	698	1.4	423	1,195
Lot IV				
Corn-and-cob meal, 2.2 lbs.				
Cotton-seed meal, 4.3 lbs.				
Cotton-seed hulls, 19.4 lbs.	737	1.7	396	1,191

The table shows that the steers fed cotton-seed hulls for roughage made larger and more economical gains than those fed either shredded corn stover or cut sorghum hay. When corn-and-cob meal was substituted for one-third of the cotton-seed meal with steers fed cotton-seed hulls for roughage, about the same returns were secured as with cotton-seed meal alone.

557. Legume hay with cotton-seed meal.—Craig and Marshall of the Texas Station[2] fed 4 lots of 5 yearling steers each on cotton-seed meal and rice bran with peanut, alfalfa, or cowpea hay or cotton-seed hulls for roughage. After 6 weeks the steers getting peanut hay developed looseness of the bowels and showed redness of the eyes and some swelling about the sheath; when changed to prairie hay the unfavorable symptoms disappeared and the gains increased. (**264**) Alfalfa hay fed with a large allowance of cotton-seed meal likewise produced scours, the steers gaining only 1.9 lbs. each daily. When shelled corn replaced a part of the cotton-seed meal they gained 2.7 lbs. each daily. When fed with a large allowance of cotton-seed meal, cowpea hay proved more satisfactory than either alfalfa or peanut hay, tho slightly less valuable than cotton-seed hulls. (**261**) Peanut, alfalfa, and cowpea hay, being rich in nitrogenous matter, serve their best purpose when combined with carbohydrate-rich concentrates such as corn, kafir, and milo. Where heavy nitrogenous cotton-seed

[1] Bul. 103. [2] Bul. 76.

meal is fed, these leguminous roughages should only be fed in limited amount, at most, along with such carbohydrate-rich feeds as corn, sorghum, milo forage, or cotton-seed hulls.

558. Grazing cowpeas and corn.—Bennett of the Arkansas Station[1] sowed cowpeas in a five-acre corn field. In October, after gathering the corn, steers were turned into a portion of the field to graze on the corn forage and cowpeas, with cotton seed accessible. When one-third of the field was grazed off, another portion was set aside, and so on until it was all grazed over. Six steers averaging 770 lbs. when turned into the field made an average daily gain of 2 lbs. each for 64 days, consuming 250 lbs. of cotton seed in that time, besides corn forage and pea vines with pods. Bennett states that allowing for all expenses the gains made by the steers cost but $1.60 per 100 lbs. Such practice tends to soil improvement as well as cheap meat production. (**261**)

IV. Silage; Roots.

559. Corn silage for steer calves.—Mumford of the Illinois Station[2] divided a bunch of 50 good, thrifty 8-months-old grade Hereford and Short-horn steer calves, weighing about 500 lbs. each, into 2 lots of 25 each. These were fed 88 days in the following manner: Each calf received 4 lbs. of mixed hay and 2 lbs. of oats daily; in addition, Lot I was given corn silage and Lot II unhusked shock corn. The corn forage used was from the same field, part having been placed in the silo and the remainder cured in the shock. The results of the trial are presented in the table. Ten shotes averaging 65 lbs. each were placed with each lot of calves.

Corn silage compared with shock corn for grade steer calves.

Average ration	Av. daily gain	Wt. of corn forage fed	Area of corn forage fed	Total gain of	
				Steers	Pigs
	Lbs.	Tons	Acres	Lbs.	Lbs.
Lot I Silage, 26.1 lbs. Mixed hay, 4.6 lbs. Oats, 2 lbs.	1.7	28.8	3.7	3,693	87
Lot II Shock corn, 13.2 lbs. Mixed hay, 4.0 lbs. Oats, 2 lbs.	1.4	14.6	5.3	3,133	587

The table shows that the silage-fed calves gained 560 lbs. more than those getting shock corn. Lot I consumed 28.8 tons of corn silage, grown on 3.7 acres. In the same time Lot II consumed 14.6 tons of

[1] Rpt. 1899. [2] Bul. 73.

shock corn, grown on 5.3 acres, or 43 per ct. more area than was required to furnish the corn silage. The silage-fed calves in Lot I gained 3,693 lbs. and the pigs following them only 87 lbs. The steers in Lot II, getting shock corn, gained only 3,133 lbs., but the pigs following them gained 587 lbs. Combining the gains of calves and pigs, the gross returns are practically equal for the two lots, but, measured by the area of land required, corn silage is 30 per ct. ahead of shock corn in feeding value. (**363**)

560. Corn silage v. stover.—At the Ohio Station[1] Carmichael fed 2 lots of grade Short-horn steers averaging 955 lbs. in weight to determine the value of corn silage when substituted for about half the dry roughage in the ration. The lots, containing 20 and 21 steers respectively, were fed for 140 days with the following results:

Corn silage for fattening steers.

Average ration	Av. daily gain	Feed for 100 lbs. gain			
		Concentrates	Silage	Stover	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Silage, 24.3 lbs. Mixed hay, 5.0 lbs. Stover, 0.8 lb. Shelled corn, 14.9 lbs. Cotton-seed meal, 1.7 lbs.	2.3	714	1,043	34	215
Lot II Mixed hay, 11.2 lbs. Stover, 1.7 lbs. Shelled corn, 17.8 lbs. Cotton-seed meal, 1.7 lbs.	2.3	845	....	72	485

The average daily gain per steer was the same for each lot. While the dry-fed steers required 845 lbs. of concentrates for 100 lbs. of gain, those fed silage required only 714 lbs. In this trial 1 ton of corn silage replaced 4.4 bushels of corn, 74 lbs. of corn stover, and 514 lbs. of mixed hay. Each pig following the dry-fed steers gained 0.16 lb. more daily than those following the silage-fed steers. Tho fed the full silage allowance up to the day before being shipped, the steers so fed showed no greater shrinkage than the others.

561. Corn silage v. clover hay.—At the Indiana Station[2] Skinner and Cochel compared corn silage and clover hay as roughages for fattening steers getting shelled corn and cotton-seed meal for concentrates. Three lots, each of ten 2-yr.-old grade Angus steers averaging

[1] Bul. 193.
[2] Bul. 136.

964 lbs., were fed for 180 days with the results shown in the following table:

Corn silage compared with clover hay for fattening steers.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain			Cost per 100 lbs. gain
			Concentrates	Clover hay	Corn silage	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
Lot I Clover hay, 9.5 lbs. Shelled corn, 17.4 lbs. Cotton-seed meal, 3.0 lbs.	2.3	409	895	412	------	11.44
Lot II Corn silage, 15.3 lbs. Clover hay, 5.0 lbs. Shelled corn, 16.8 lbs. Cotton-seed meal, 3.0 lbs.	2.3	421	848	212	655	10.93
Lot III Corn silage, 29.5 lbs. Shelled corn, 15.8 lbs. Cotton-seed meal, 3.0 lbs.	2.6	466	727	--------	1,139	9.39

It is shown that Lot III, receiving corn silage as their sole roughage, made the largest and most economical daily gains, requiring 19 per ct. less concentrates for 100 lbs. gain than Lot 1, fed clover hay. Lot II, fed clover hay and corn silage, made slightly larger and more economical gains than Lot I, fed only clover hay as roughage.

The silage-fed steers shed their winter coats earlier, distributed the fat more evenly over the carcass, obtained a higher finish, had a higher market value, and returned a greater profit than those fed no silage. Practically the same results were obtained in 2 previous trials at the same Station. From these trials Skinner concludes that a nitrogenous concentrate, such as linseed or cotton-seed meal, should be fed with corn silage.

562. The finish of silage-fed steers.—At the Virginia Station[1] Soule and Fain fed 6 lots, each of 10 steers and heifers of inferior quality, to compare the value of corn silage, timothy hay, and shredded corn stover, when fed with corn-and-cob meal and either linseed or cotton-seed meal. During 180 days the cattle fed silage made an average daily gain of 1.5 lbs.; those fed stover, 1.0 lb.; and those fed timothy hay, 1.1 lbs. The silage-fed cattle finished out better than those that were dry-fed. The silage was eaten with great relish and no loss, whereas 12 per ct. of the stover and 5 per ct. of the hay was wasted.

[1] Bul. 157.

In another trial[1] 40 grade Short-horn steers of fair quality were fed 149 days on an average ration of 8.8 lbs. of corn and cotton-seed meal, 2.1 lbs. of hay and corn stover, and 38 lbs. of corn silage. These steers made the excellent average daily gain of 1.8 lbs. each. When shipped to Jersey City they shrank no more than dry-fed cattle, and dressed 57 per ct. The meat was fully equal to that of Western corn-fed cattle, being of superior quality with good color, and the fat and lean being well blended. These investigators conclude that there is no justification for opposition to silage for finishing beef cattle. Owing to the laxative nature of corn silage they recommend feeding, along with it, 2 or 3 lbs. daily of shredded stover, timothy hay, or some other dry roughage, larger amounts not being necessary where good silage is used. (**278**)

563. Silage v. roots.—At the Ontario Agricultural College[2] Shaw fed 3 groups of 2 grade Short-horn steers each, giving corn silage to one lot, corn silage and hay to a second, and hay, turnips, and mangels to a third. The concentrates for all lots consisted of equal parts of ground peas, barley, and oats. Mixed timothy and clover hay was used.

Corn silage compared with roots.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain		
			Concentrates	Hay	Roots or silage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Silage, 57.5 lbs. Meal, 11.7 lbs.	1.9	277	616	-------	3,030
Lot II Silage, 30.6 lbs. Hay, 9.3 lbs. Meal, 11.1 lbs.	1.5	224	740	620	2,067
Lot III Roots, 43.1 lbs. Hay, 11.2 lbs. Meal, 11.1 lbs.	1.8	268	617	622	2,394

It is shown that the silage-fed steers made slightly better daily gains than those fed roots and hay, and much better gains than those getting both silage and hay. Day of the same College[3] concludes from 2 trials that silage has a somewhat higher feeding value than roots with fattening steers, the difference materially favoring silage when cost of production is considered. (**351-3, 656**)

564. Silage v. roots in Britain.—Ingle, summarizing 201 trials with fattening steers in Great Britain in all but 16 of which roots

[1] Virginia Expt. Sta., Bul. 173. [2] Rpt. 1891. [3] Rpts. 1901, 1902.

were fed, compares the average returns from all the trials with the gains secured in 6 trials in which silage was fed without roots, as follows:

	Average daily gain	Digestible matter in 100 lbs. gain
Average of all trials	1.8 pounds	900 pounds
Where silage was fed	1.8 pounds	763 pounds

In the 201 trials reported the fattening animals made an average daily gain of 1.8 lbs., requiring 900 lbs. of digestible matter for 100 lbs. of gain, while in 6 trials where silage was fed the daily gain was also 1.8 lbs., but only 763 lbs. of digestible matter was consumed for 100 lbs. gain. Ingle comments thus: "This is high testimony to the feeding value of silage compared with roots." (**567**)

565. Cassava and sweet potatoes.—At the Florida Station[1] Stockbridge fed 3 lots of 4 steers each averaging 446 lbs. for 70 days to test the value of sweet potatoes and cassava in beef production.

Cassava and sweet potatoes for fattening steers.

Average ration per 100 lbs. live weight	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Sweet potatoes, 35 lbs.				
Pea-vine hay, 10 lbs.				
Cotton-seed meal, 4 lbs.	1.8	124	226	2,541
Lot II				
Cassava, 35 lbs.				
Pea-vine hay, 10 lbs.				
Cotton-seed meal, 4 lbs.	2.1	144	195	2,188
Lot II				
Crab-grass hay, 20 lbs.				
Cotton-seed meal, 5 lbs.				
Corn meal, 5 lbs.	1.9	136	517	1,033

It is shown that cassava and sweet potatoes are satisfactory in beef production when combined with pea-vine hay and cotton-seed meal. The steers fed crab-grass hay required more than twice as much concentrates for 100 lbs. of gain as those in the other lots. (**288-9**)

566. Cotton-belt v. corn-belt ration.—At the Texas Station[2] Craig and Marshall fed 2 lots of 5 yearling steers each on the following rations for 100 days to compare a ration of cotton-seed meal and cot-

[1] Rpt. 1901. [2] Bul. 76.

ton-seed hulls with one composed of alfalfa hay and corn-and-cob meal, obtaining the results shown in the table:

Cotton-seed meal and hulls compared with corn-and-cob meal and alfalfa hay.

Average ration	Av. daily gain	Av. gain per head	Feed for 100 lbs. gain	
			Concentrates	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Cotton-seed meal, 5.7 lbs.				
Cotton-seed hulls, 22.4 lbs.	2.2	221	259	1,013
Lot II				
Corn-and-cob meal, 11.1 lbs.				
Alfalfa hay, 16.9 lbs.	2.5	253	440	669

Both lots made excellent gains, the alfalfa-fed steers averaging 0.3 lb. more per head daily than those fed cotton-seed meal and cotton-seed hulls. With both rations the amount of concentrates for 100 lbs. of gain was surprisingly small. The light-weight cotton-seed hulls, furnishing mostly carbohydrates, admirably supplemented the heavy nitrogenous cotton-seed meal. In the other ration, corn-and-cob meal, furnishing carbohydrates and fat, served as the concentrate, while the alfalfa hay furnished the required nitrogenous matter. These rations should be regarded as standard by cattle feeders whenever they can be used.

567. British feeding trials.—Ingle[1] has collated all the feeding trials with fattening steers reported in Great Britain between the years 1835 and 1908—201 in number. From this extended report the typical examples given on the next page are chosen as broadly illustrating the British system of fattening beef cattle.

The average weights of the bullocks given in the table is the mean of their weights at the beginning and close of the feeding trial.

The American cattle feeder who critically reviews the data given will be impressed first of all with the surprisingly small amount of concentrates employed in the ration. In the 201 trials presented by Ingle the largest amount of concentrates fed to any steer on one day was 13 lbs. In a few cases no concentrates were fed, but usually the allowance for each bullock was 6 or 7 lbs. per day. The rich nitrogenous concentrates such as linseed meal, cotton-seed meal, dried brewers' and distillers' grains, and peanut cake are the ones commonly employed, followed by barley and corn meal more sparingly used. Equally striking is the heavy use of roots, the amount fed ranging

[1] Trans. Highl. and Agr. Soc. of Scotland, 1909.

from 35 lbs. per head daily to above 150 lbs. in extreme cases. (**275**) The light feeding of concentrates and the heavy feeding of roots is accompanied by the large consumption of hay and straw, which the British feeder chaffs or cuts, and mixes with the pulped or sliced

Rations used by British farmers in beef production.

No. fed	Age	Breed	Length of feed	Average ration	Av. weight	Av. daily gain	Av. total gain
	Years		Days		Lbs.	Lbs.	Lbs.
10	3	Irish	88	Cotton-seed cake, 2.8 lbs. Corn meal, 2.8 lbs. Pasture	1,039	3.7	322
3	2-3	Gal.	100	Oat straw, 7.0 lbs. Swedes, 150.0 lbs.	1,003	1.4	143
6	—	Ab.-Angus	112	Cotton-seed cake, 3.0 lbs. Oat straw, 8.0 lbs. Mangels, 108.8 lbs.	1,054	1.9	211
4	2	Irish	133	Linseed cake, 8.7 lbs. Hay and straw, 8.0 lbs. Roots, 112.0 lbs.	1,170	2.1	280
4	2-5	Sh't-h'n	98	Linseed cake, 2.4 lbs. Corn meal, 2.0 lbs. Straw, 14.0 lbs. Swedes, 171.0 lbs.	1,452	3.0	292
10	1	Irish	112	Cotton-seed cake, 3.6 lbs. Dried brewers' grains, 5.8 lbs. Oat straw, 8.4 lbs. Turnips, 50.0 lbs.	1,015	1.3	149
8	3	Sh't-h'n	123	Cotton-seed cake, 5.0 lbs. Linseed cake, 3.0 lbs. Barley, 1.0 lb. Hay, 16.2 lbs. Swedes, 40.5 lbs.	1,326	2.4	294
4	—	Her.	107	Peanut cake, 2.7 lbs. Oats, 2.7 lbs. Barley, 2.7 lbs. Clover hay, 14.0 lbs. Swedes, 45.0 lbs.	1,294	2.2	235
4	3	Her.	112	Bean meal, 3.0 lbs. Oats, 3.0 lbs. Barley, 3.0 lbs. Straw, 4.1 lbs. Hay, 6.9 lbs. Swedes, 39.5 lbs.	1,261	2.4	263
5	—	Sh't-h'n-Irish	112	Linseed cake, 1.4 lbs. Cotton-seed cake, 2.4 lbs. Dried grains, 2.4 lbs. Corn, 4.4 lbs. Molasses, 2.0 lbs. Hay, 7.0 lbs. Oat straw, 7.0 lbs.	1,315	1.8	197

roots and meal before feeding. It will be further observed that the British farmer generally feeds quite mature bullocks, and that the feeding period is relatively short, ranging from 80 to 120 days. It is probable that the cattle are usually in good flesh when the feeding begins.

In studying these figures we should remember that it was the British farmer who originated and developed all the valuable breeds of beef cattle now scattered over the globe, and his ability and success in producing beef of high quality is unquestioned. We are shown that in Britain beef cattle are fattened on a surprisingly small allowance of rich concentrates combined with an abundance of roots, hay, and straw. This attainment of the British feeder should stimulate the experiment stations and progressive feeders of America to see if the large daily corn allowance now universally regarded as necessary in fattening cattle in this country may not be reduced. With the steadily increasing cost of corn there must, if possible, be a material reduction in the quantity of this grain entering into the rations of our fattening cattle. May this not be brought about thru the wider and more general use of hay from the legumes and succulent silage from the luxuriant Indian corn plant? (**768**)

CHAPTER XXIII.

COUNSEL IN THE FEED LOT.

Most of the cattle used in America for beef production are grazed in summer on lands not well adapted to tillage, thereby utilizing grass and herbage that would otherwise be largely wasted. In winter they run in the stalk fields or subsist on stover, poor hay, straw, etc., materials likewise largely unmarketable. Then there is the Great Plains region stretching from Mexico to British America, where vast numbers of cattle are carried to the fattening age. Mumford and Hall of the Illinois Station[1] tell us that 85 per ct. of the cattle that reach the Chicago market are not raised by those who finally fatten them. This indicates a most natural division of labor, for cattle are fattened mostly on corn, and where corn is abundantly produced there is little waste or low-priced grazing land, which is essential in economically producing feeding cattle.

568. Wintering the calf.—Calves designed for beef production should be carried thru the first winter on the best roughage available, such as clover or alfalfa hay, corn silage, corn stover, etc. During the 6 months of winter they should gain from 1 to 1.5 lbs. each daily, requiring the addition of 2 or 3 lbs. of corn and a little bran or oil meal to the ration. It is of the highest importance that during the first winter the young steer gain steadily, enlarging its framework but not laying on fat. (**488**)

569. The yearling.—Yearlings should have the best pasture available, in order that they gain steadily during the 6 months on grass. Mumford and Hall of the Illinois Station[2] found that yearlings increase about 1.6 lbs. daily during the pasture season of six months. Usually no grain should be fed during this period since such cattle make satisfactory and the most economical gains on grass alone.

During the second winter the coarser roughages may be advantageously used, tho there should always be liberal provision of clover or alfalfa hay since these render the other less palatable roughages more acceptable and efficient. Feeding corn silage containing some grain during the second winter will greatly tend to continuous growth but not to fattening. (**500-1**) Where cattle are to be grazed the

[1] Cir. 79. [2] Loc. cit.

second summer without fattening, the effort should be to grow as large a framework as possible the second winter, leaving the animal thin but thrifty. Mumford writes:[1] "The more cattle gain on concentrated feeds in winter the less they will gain on grass in summer. That is to say, if corn is fed liberally during the winter months the cattle will not make as large gains when turned to grass as they would were they wintered on roughage, and not the best roughage at that." (**502**)

Where cattle are to be fattened on pasture the summer following the second winter, a reasonable storage of fat toward the close of winter and in early spring will helpfully shorten the summer feeding period. In such cases feed liberally during the last of winter and in early spring with clover or alfalfa hay and silage rich in ear corn. These with a moderate grain allowance will warm the animals up, start fattening, and send them to grass in prime condition to make the most of the heavy feeding of grain which follows.

570. The fattening ration.—It is well to avoid an excess of protein with the fattening animal. Animals in thin flesh should at first be liberally supplied with protein in order that their muscular tissues may develop. For such animals, Kellner[2] holds that the nutritive ratio should be about 1:6, with from 12 to 15 lbs. of digestible nutrients daily per 1000 lbs. of live weight. (**142**) Experiments have shown that mature animals can be successfully fattened on much less crude protein than is set down in the Wolff-Lehmann Standards. Kellner[3] found that the gains of the mature ox remained unchanged whether 1 lb. of protein was fed with 4 or with 16 lbs. of carbohydrates, the total quantity of nutrients remaining the same. In such case the quantity of fat formed was in proportion to the nutrients digested in excess of the wants of the body. However, where less digestible protein is fed than 1 lb. to 8 or 10 lbs. of carbohydrates, the digestibility of the ration may be decreased. Kellner accordingly suggests that for mature fattening cattle the nutritive ratio should not be wider than 1:10 or 12. In regions where alfalfa hay or other nitrogenous feeds are abundant and low in price and the carbohydrates relatively high in cost, it may be profitable to feed a ration with a narrow nutritive ratio.

571. The fattening process.—Fat is concentrated fuel energy stored as surplus in the animal's body against the time of need. Impelled by a hearty appetite, under liberal feeding the steer at first lays on fat rapidly, storing it everywhere within the body—among

[1] Beef Production, p. 46.

[2] Ernähr. landw. Nutztiere, 1907, p. 420.

[3] Loc. cit., p. 418.

the fibers of the muscles, within the bones, the body cavity, etc. After a few weeks on liberal feed the appetite loses its edge, and the steer shows indifference and a daintiness in taking his food not at first noticed; every pound of increase now means the consumption of more food than formerly. The fattening process may be likened to inflating a collapsed football—the operation, easy and rapid at first, grows more and more difficult until the limit is reached. (**510**)

The increase of the growing animal is largely water, with some protein, some fat, and a little mineral matter; the increase of the fattening animal is nearly all fat, with a little water, and a trace of protein and ash. It takes far more food for a given increase with the fattening than with the growing animal. The laying on of fat calls for heavy feeding with rich feed and is always an expensive process. (**23, 98-100**)

572. Getting cattle on feed.—Mumford[1] recommends that cattle going on full feed be given all the clover or alfalfa hay they will eat without waste. In addition start with 2 lbs. of corn per steer per day, increasing 1 lb. daily until 10 lbs. is fed. After 3 days increase 1 lb. daily until 17 lbs. is fed; 15 days later let this be increased to 22 lbs. daily. Cattle getting from 12 to 15 lbs. of corn daily should have about 12 lbs. of clover or alfalfa hay per 1000 lbs. live weight; later only about one-fourth of the ration should be roughage.

Mumford reports successfully getting cattle to full feed by mixing corn meal and oil meal with chaffed clover hay in the self-feeder, where it was accessible to the cattle at all times. The full grain allowance was reached by gradually increasing the proportion of corn meal to roughage. This system saves grain, prevents the animals from gorging themselves, and gets them to full feed a couple of weeks sooner than the ordinary system. Where the feeding period is to cover 6 months, from 30 days to 6 weeks should elapse before the cattle are on full feed. In such cases proportionally more good roughage, such as clover or alfalfa, is fed. While the animals so managed do not make such rapid gains at first, near the close of the feeding period the gains are as large as ever and more economical and satisfactory.

573. Feeding corn.—Indian corn must continue to be the great fattening food for cattle in America. While we cannot vie with England in the luxuriance of her pastures, the advantages given the American farmer by the corn crop cannot be surpassed and place us in the very forefront in beef production. No other concentrate is

[1] Beef Production.

so relished by cattle as Indian corn, which is toothsome and palatable to a degree equaled by no other grain. Not only is corn loaded with starch but it carries much oil with but little fiber or other inert matter, the whole forming the best concentrate for quickly filling the tissues of the steer's body with fat, and thereby rendering the lean meat tender, juicy, and toothsome.

Whoever studies the practices of successful stockmen in the corn belt or reviews the work of the experiment stations will be convinced that getting corn to cattle in the simplest and most direct manner and with the least preparation and handling is, after all, the best and most economical way. Waters of the Missouri Station,[1] interviewing hundreds of the best and largest cattle feeders of Missouri, Iowa, and Illinois, found that 50 per ct. of all fed husked or unhusked ear corn, about 25 per ct. fed shelled corn, while the remainder fed crushed, soaked, or ground corn. Only 3 per ct. ground corn as a regular practice.

Corn is never so acceptable to the steers as when given unhusked on the stalk, for there is an aroma and palatability about the ear in Nature's own wrappings that every steer recognizes and appreciates. Such being the case, wherever possible let shock corn with its wealth of ears be thrown into the long feed racks standing in the open lot or under the shed and allow the steers to do their own husking and grinding. Where corn cannot be fed unhusked, ear corn should be given, whole, chopped, or split, as best suits the animal. Corn long stored in the crib becomes dry and hard, losing fragrance and aroma thru exposure to air and vermin. For summer feeding such grain should be specially prepared by soaking or possibly by grinding. Where necessary corn should be soaked from 12 to 18 hours, care being taken to change the water frequently and to keep the feed boxes clean and sweet. Old cattle can utilize ear corn, stover, and coarse feed in general more advantageously than can younger animals. (**523**)

574. Nitrogenous supplements to corn.—Corn is the richest of all available feeds in carbohydrates and fat; instead of specially preparing it for cattle by grinding or other treatment, it is usually best to feed it in ear form or shelled, along with some protein-rich supplement in order to bring out the full value of the carbohydrates and fat. If our experiment stations had taught nothing else, they would have paid for themselves many times in showing how the addition of a nitrogenous roughage like clover and alfalfa hay, or of some

[1] Bul. 76.

nitrogenous concentrate like linseed and cotton-seed meal, not only increases the feeding value of the corn with both the cattle and hogs which follow, but keeps the animals more healthy, shortens the feeding period, and gives a higher finish than is possible with corn alone, no matter how it is fed.

Mumford[1] points out a case at the Illinois Station, where steers fed clover hay in addition to corn brought 30 cents more per cwt. than others fed corn, timothy hay, and corn stover. At the Missouri Station,[2] Waters found that steers fattened on corn and timothy hay made a gain of 5 lbs. from a bushel of corn, while those fattened on corn, clover hay, and corn stover gained 6.5 lbs., a gain of 30 per ct.

Waters[3] points out that where cattle are being fattened on corn, the advantages in using the hay of some legume, such as clover, alfalfa, or cowpeas, instead of timothy, millet, sorghum, and straw, are:

1. Increased gains by the cattle.
2. Increased selling price of the cattle due to extra bloom.
3. Increased gain by hogs following the steers.
4. Increased fertility of the land where the feeding operations are conducted.

The better condition of the fields on which the leguminous crops are grown. **(546-553)**

Where the feeder cannot provide any leguminous roughage, such as clover or alfalfa hay, but must force his cattle to fatten on corn with timothy, sorghum, or kafir hay or corn stover for roughage, then there should be fed daily to each steer not less than 2 or 3 lbs. of some protein-rich concentrate like linseed or cotton-seed meal. Where some leguminous hay is being fed, it is not usually best to feed any protein-rich concentrate except during the last few weeks of the feeding period. (**535-539**)

Waters[4] tells us that 10 years of experience and experiments have demonstrated that when steers running on good pastures are being fattened on corn, it is not wise to feed rich supplements such as linseed or cotton-seed meal in any large amounts or for long periods. Giving 2 or 3 lbs. daily of linseed or cotton-seed meal during the last 60 or 70 days of feeding, puts on a bloom and finish above that which corn and blue grass alone can supply, thereby yielding profitable returns.

575. Corn silage.—Because of the unique and commanding position of the corn plant in America, it is usually unwise for the Ameri-

[1] Beef Production, p. 70.
[2] Bul. 76.
[3] Loc. cit.
[4] Mo. Sta., Cir. of Information, 24.

can beef producer to undertake growing roots for cattle as does the English farmer. Let him, instead, increase the corn crop and turn a portion of it into succulent silage which serves all the functions of roots for growing and fattening cattle, at but a fraction of the cost of roots. The time is at hand when cattlemen in the great corn belt of America should recognize the great possibilities, importance, and economy of corn silage from heavily eared corn for growing and fattening beef animals. While silage is highly useful in wintering beef cows and growing cattle, it is also needed in the feed-lot because it furnishes a most palatable, succulent roughage, greatly relished by cattle subsisting for the most part on corn, which is a heavy concentrate that needs some light juicy supplement like corn silage or roots to balance it up and lighten it in the digestive tract. Indian corn, along with clover or alfalfa hay, and a moderate allowance of succulent corn silage furnish a combination unequaled by any other for economy of production and the quantity of flesh it will build and the fat it will lay on. For growing cattle and those in the first stages of fattening from 30 to 40 lbs. of silage may be profitably fed to each 1,000 lbs. of steers. As fattening animals approach maturity, the silage allowance should be reduced to 20 or 25 lbs. daily per 1,000 lbs. of animal, tho some feed it freely till the steers leave the feed lot. (**559-564**)

576. Hogs following steers.—The following is condensed from Waters:[1] The number of hogs required to utilize the waste per steer will vary greatly with the character of the feed, the way in which it is prepared, and with the size and age of the cattle being fed. The range is from 2 to 3 hogs per steer on snapped corn, 1.5 per steer on husked ear corn, about 1 per steer on shelled corn, and 1 hog to 2 or 3 steers on crushed or ground corn.

Whatever favors rapid and profitable gains with cattle, other than the preparation of the feed, also favors the gains of the hogs following. For example, hogs make better gains following corn-fed steers getting clover, cowpea, or alfalfa hay than they do when the roughage is timothy, millet, or sorghum forage. Likewise feeding the steers linseed meal benefits the hogs that follow. It is almost as profitable to feed tankage or linseed meal to hogs following cattle as to those fattening directly on grain; this is especially true with hogs following cattle fed straight corn with timothy or stover for roughage in winter, or with cattle fattening on corn and blue grass or timothy pasture in summer.

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[1] Bul. 76, Mo. Expt. Sta.

Waters strongly recommends separate clover or alfalfa pastures accessible to hogs following fattening steers in summer; on this the hogs can graze at will after having cleaned up the waste from the cattle, instead of feeding on the steer pasture. He further recommends providing a field of cowpeas or soybeans on which the hogs may forage early in fall and so have this nitrogenous grain together with the corn they pick up from the steers. Any extra grain fed should be given to the hogs before the cattle are fed so that the hogs will not crowd around the feed troughs or under the wagon and team. In the best practice the hogs are fed in a near-by pen to keep them from the cattle while the latter are feeding. Whenever hogs begin to show maturity or fatness they should be supplanted by fresh ones, for fat hogs are unprofitable for following steers. The best hog for following cattle is of good bone, thin in flesh, weighing from 100 to 150 lbs. If shotes are used they should weigh 50–60 lbs. Sows in pig or young pigs should never be put in the feed lot.

Because of the narrow margin made in these times from fattening cattle on grain Waters recommends that where it is impossible to provide hogs to follows the steers the fattening of the steers be delayed until hogs can follow or be given up entirely. This advice does not apply to feeding weanling calves for baby beef because then the grain should be ground and fed with alfalfa, clover, cowpea hay, etc., in which case the animals utilize their feed so much more closely that hogs are not absolutely necessary. (**506, 525**)

577. Baby beef.—The following is condensed from Mumford:[1]

Profitable baby beef production requires experience, judgment, and skill of the highest order in the feeder. It is a mistake for the inexperienced to dip heavily into this art. To fatten young animals profitably, they must be good, they must be fed for a considerable time, and they must be made fat; this means that "tops" must be bought or bred. The most successful operators try to retain the "calf fat" or bloom of the young calf. The calf should be in good condition when fattening begins and should be induced to consume considerable roughage of high quality, such as clover or alfalfa hay and silage, during winter and rich pasture grasses in summer. Shelled, crushed, or sliced corn should be fed together with linseed meal, cotton-seed meal, or other protein-rich concentrates. If the corn is given whole, hogs may profitably follow. Oats are one of the best of feeds with which to start the calf on its way to fattening. The tendency of the calf and yearling is toward growth rather than fattening. In

[1] Beef Production, pp. 76–82.

baby beef production the young things must fatten as they grow; this can only be accomplished by the most liberal and judicious feeding, since it is extremely difficult to get calves and yearlings sufficiently fat for the market requirements. Heifer calves mature more quickly and may be marketed earlier than steers. It is seldom possible or profitable to get spring calves ready for the baby beef market before July of the following year; more frequently they are not marketed until October, November, or December when approximately 18 months old. (**508**)

578. Practical rations for fattening cattle.—The reader who wishes to know the quantity and proportion of the various concentrates and roughages in well balanced rations for fattening cattle will find his wants adequately met in the two preceding chapters, wherein are summarized the principal feeding trials at the different experiment stations, covering almost every form of concentrates and roughages in the list of feeding stuffs. Out of the many presented he should be able to find several that approximate his individual conditions.

579. Spread or margin.—The gains made by cattle while fattening cost from $6.00 to $10.00 per cwt. for the feed consumed. As such gains cost more per cwt. than the cattle will sell for per cwt., it is necessary that the selling price of cattle per cwt. after they have been fattened be higher than the purchase price or market value of the same cattle before the fattening process began. This difference is called the "spread" or "margin." The principle of the spread may be illustrated thus: If a 1000-lb. steer is bought by the feeder at $4.00 per cwt., its cost is $40.00. If this steer during fattening gains 400 lbs. at a cost of $30.00, each cwt. of gain has cost $7.50. The steer, now weighing 1,400 lbs., has cost $70.00 and must bring $5.00 per cwt. to even the transaction. The requisite cost of feed spread in this case is $1.00 per cwt., which is the sum necessary to break even.

As Waters of the Missouri Station[1] sets forth, the margin or spread is affected, first of all, by the length of the feeding period. Cattle that are fed for long periods and made thoroly fat necessitate a larger spread than those fed for but a brief period with a limited amount of costly feed. Calves and yearlings fatten with less feed than older cattle and so make cheaper gains, but their first cost is usually more per cwt. than that of more mature cattle. Plain cattle require a larger spread than those of high quality. Waters' ex-

[1] Bul. 76.

periments show that the summer gains of fattening cattle cost only about four-fifths as much as winter gains; hence a smaller margin is necessary with summer-fed cattle. The higher the price of the feeds employed in fattening the greater is the spread required. Thin fleshed animals require less margin than those partially fat when feeding begins.

From statistics gathered from feeders in Missouri, Iowa, and Illinois, Waters[1] found that an average spread of $1.02 is required to cover the entire cost of fattening cattle in summer—that is, they must sell for $1.02 per cwt. above the purchase price to break even on cost of production. For the 6 months of winter feeding with 2-yr.-olds, Waters holds that a spread of $1.50 per cwt. is necessary. Skinner and Cochel of the Indiana Station[2] found that with Indiana cattlemen it cost $4.80 per cwt. for summer gains and $7.20 per cwt. for winter gains, and that an average spread of $1.07 per cwt., or 20 cents per cwt. per month, was required. (**505**)

580. Order and quiet.—On these important points Mumford[3] writes: "As soon as the fattening process begins, the cattle should be fed at certain hours and in the same way. This cannot be varied 15 minutes without some detriment to the cattle. The extent of injury will depend upon the frequency and extent of irregularity. . . . The even-tempered attendant who is quiet in manner and movement invariably proves more satisfactory than the erratic, bustling, noisy one. The cattle soon learn to have confidence in the former and welcome his coming among them, while they are always suspicious of the latter, never feeling quite at ease when he is in sight. Under the management of the former, the cattle become tame and quiet, even tho more or less wild at the outset; while under the latter, wild cattle become wilder and tame cattle become timid. The writer has observed a wide difference in practice among feeders as to their manner of approaching fattening steers. Some are brusque in manner, rushing up to the steers and scaring them up quickly, while other (and I am bound to say more successful) feeders approach the cattle with the greatest care and consideration, getting the cattle up, if at all, as quietly as possible. Pastures for cattle in quiet, secluded places are more valuable for fattening cattle than are those adjacent to the public roads or adjoining pastures where horses or breeding cattle run." (**93**)

581. The eye of the master.—The ability to fatten cattle rapidly and profitably is a gift, to be increased and strengthened by expe-

[1] Loc. cit. [2] Cir. No. 12. [3] Beef Production, pp. 92–3.

rience and study. The ability to carry a steer through a six months' fattening period without once getting him "off feed" is possessed by many a stockman; but how this faculty is attained is something he cannot always impart to others. In general, when the steer has reached full feed, all the grain he will readily consume should be supplied, but any left in the feed box, to be breathed over, is worse than wasted.

Scouring, the bane of the stock feeder, should be carefully avoided, since a single day's laxness will cut off a week's gain. This trouble is generally induced by over-feeding, by unwholesome food, or by a faulty combination in the ration. Over-feeding comes from a desire of the attendant to push his cattle to better gains, or from carelessness and irregularity in measuring out the feed supply. The ideal stockman has a quick discernment which takes in every animal in the feed lot at a glance, and a quiet judgment which guides the hand in dealing out feed ample for the wants of all, but not a pound excess. Cattle of the same age, or at least those of equal size and strength, should be fed in the same enclosure. Weak animals, and those unable for any reason to crowd to the feed trough and get their share, should be placed where they can be supplied in quiet.

The droppings of the steer are an excellent index of the progress of fattening. While they should never be hard, they should still be thick enough to "pile up" and have that unctuous appearance which indicates a healthy action of the liver. There is an odor from the droppings of thrifty, well-fed steers known and quickly recognized by every good feeder. Thin droppings and those with a sour smell indicate something wrong in the feed yard. The conduct of the steer is a further guide in marking the progress of fattening. The manner in which he approaches the feed box; his quiet pose while ruminating and audible breathing when lying down, showing the lungs cramped by the well-filled paunch; the quiet eye which stands full from the fattening socket; the oily coat,—all are points that awaken the interest, admiration, and satisfaction of the successful feeder.

582. Frequency of feeding.—Mumford writes:[1] "The majority of cattle feeders prefer feeding their cattle grain and roughage twice a day in winter and grain once a day in summer. Feeding once a day in summer is practiced largely as a matter of convenience and not because it is believed to be better for the cattle. For the most part the same reasons that make it desirable to feed grain twice a day in winter apply in summer with equal force."

[1] Beef Production, pp. 93–4.

583. Water.—Fattening cattle should not only have an abundant supply of uncontaminated water at all times, but it should be easily accessible. The water for hogs running in the same lot should be separate and so set off that the steers cannot have access to it, nor should hogs drink from the water troughs of the cattle. While it is best to have water before cattle at all times, they readily adapt themselves to taking a fill once daily and thrive. The water provision should not be less than 10 gallons per day per head for mature cattle. (**87, 452**)

584. Salt.—Animals fed large quantities of rich nutritious food, such as fattening steers receive, show a strong desire for salt, and this craving should be reasonably satisfied. Kühn[1] recommends 1 ounce of salt per day for a steer weighing 1,000 lbs. at the beginning of the fattening period, 1.3 ounces at the middle, and 1.7 ounces near the close. Whether granular or rock salt be supplied is merely a matter of convenience. Some give salt once or twice a week, others keep salt before their cattle at all times. As in other matters of feeding, habit rules, and a plan once adopted should be followed without deviation.

Mumford and Hall of the Illinois Station[2] state that some feeders report favorably on a mixture of equal parts of salt and wood ashes, which the steers eat slowly and with seeming benefit. (**91**)

585. Labor cost of fattening.—Mumford[3] gives the following in concise form: "For the purpose of securing a definite basis from which to work, we may assume what has been repeatedly accomplished in practice, that one man and team, or their equivalent, can care for and feed 200 cattle together with the hogs following. This includes not only feeding the grain, but also hauling hay or other roughage to the feed lot from nearby stacks or mows, providing bedding, attending to water, and looking after the wants of steers affected with injuries, lump-jaw, lice, and itch. With this assumption as a basis the following statement is possible:

Man, 6 mo. at $40.00 (wages $25, board $15)	$240.00
Team and wagon, 6 mo. at $40 (maintenance $15, feed $25)	240.00
Total cost labor, 6 mo.	$480.00
Cost per steer	2.40"

The returns of hogs following steers fed whole corn will under favorable conditions usually offset the labor cost of caring for fattening steers and the hogs following them.

[1] Ernähr. d. Rindviehes, 9th ed., p. 325.
[2] Cir. 92.
[3] Beef Production, pp. 33–4.

According to Mumford the manure produced by steers during the 6 months' feeding ranges from 3 to 4 tons, worth, on many farms, from $9.00 to $18.00 per steer. These factors should be considered in counting the cost and returns of fattening steers.

586. Preparing for shipment.—Clay,[1] than whom there is no better authority, writes: "A day or two previous to shipping, feed the cattle in a pen, and feed hay only. The secret of shipping all classes of cattle is to place them on the cars full of food but with as little moisture as possible. A steer full of water is apt to have loose bowels and show up badly in the yards; properly handled cattle should arrive in the sale pens dry behind and ready for a good fill of water; not very thirsty but in good condition to drink freely. Many shippers think that by salting their cattle or feeding them oats they can fool the buyers, but it always goes against them to use unnatural amounts. As to feed on the road, nothing equals good sweet hay, which excels corn or other grains because it is easily digested and does not fever the animal. Of water in mid-summer, care must be taken to supply the animal wants, whereas in winter a steer can go for many hours without a drink. Cattle should arrive at the sale yards at from 5 to 8 A. M., appearing on the scene as near the latter hour as possible, since they always look better just after they have been fed and watered."

587. Shrinkage.—Mumford[2] reports that 130 choice feeding steers, averaging 1,006 lbs. each when shipped from the Chicago Stockyards to Champaign, Ill., 128 miles, shrank on the average 53.3 lbs. These steers were fed for 6 months and gained 480 lbs. each on the average; when shipped back to the Chicago Stockyards they showed an average shrink of 22.5 lbs.

Carmichael of the Ohio Station,[3] on shipping steers from Wooster, Ohio, to Pittsburg, Penn., about 150 miles, found a shrinkage the second day of 3.5 per ct. for silage-fed and 4.9 per ct. for dry-fed steers.

Kennedy and Marshall of the Iowa Station,[4] shipping 1300-lb. steers which had been about 90 days in the feed lot, from western Iowa to the Chicago Stockyards, found a shrinkage of about 60 lbs. per head for those fed corn and hay, and 90 lbs. for those fed corn on grass.

587a. Production cost of beef.—With the close of the nineteenth century America witnessed the passing of the range steer as a prime factor in the low cost of beef production which had down to that time

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[1] Live Stock Report, Chicago, Sept. 28, 1894.
[2] Beef Production, pp. 30–1.
[3] Bul. 193.
[4] Bul. 66.

prevailed. In these latter times, raising the steer in summer on more or less expensive pasture lands, and fattening him in winter on feeding stuffs produced by expensive labor on lands of high selling value, we find beef high in price compared with the past, and the price is still advancing. That this must continue is made plain by a study of the feed cost of production under existing conditions. Elsewhere are given data (**102, 504, 590-1**) bearing on this subject, and the following is presented to still further illustrate and accentuate the fact that beef especially is produced only by and thru the consumption of large quantities of feed, much of which is now expensive in character.

To ascertain the total quantity of feed which is required to grow and fatten a steer the Ontario Agricultural College[1] confined an ox from birth to maturity in a well-bedded stall, giving exercise, when required, by leading. Account was kept of all water and food supplied, and of the voidings, with the following results:

	Pounds
Weight of steer at end of 36 months	1,588
Water drank	42,449
Milk consumed	3,862
Roots consumed	7,270
Grain consumed	5,857
Roughage consumed	20,957
Excrement voided	46,560

It is shown that at the end of 36 months the steer so fed weighed 1,588 lbs. Such a steer would yield about 1,000 lbs. of dressed carcass. Accordingly, each pound of meat as sold by the butcher required about 4 lbs. of milk, 7 lbs. of roots, 6 lbs. of grain, and 21 lbs. of roughage, or 38 lbs. of food of various kinds in addition to 42 lbs. of water for each lb. of gain.

When we realize that all this food must be grown, harvested, housed, and fed out in small quantities twice daily to the animal during a period covering 3 years, and that there are many other factors of expense, we see that the price which the producer now gets for the live steer is less rather than more than it should be. It is doubtful if any other article of universal use and necessity is continuously sold on so narrow a margin over cost, if any, as the live fatted steer.

[1] Rpt. 1893.

CHAPTER XXIV.

THE DAIRY COW—SCIENTIFIC FINDINGS.

I. Studies of Animal, Feed, and Water.

588. Gestation period.—Wing of the New York (Cornell) Station[1] found the average of 182 recorded gestation periods for the cow to be 280 days, ranging from 264 to 296 days. About an equal number of births occurred on each day from the 274th to the 287th inclusive. The gestation period was not different for the sexes.

589. Birth weight of dairy calves.—Beach of the Connecticut (Storrs) Station[2] found the birth weight of calves from mature cows of the dairy breeds to be as follows:

Birth weight of calves of the dairy breeds.

Breed	No. of animals	Av. wt. of dam	Birth weight	Wt. of calf to dam
		Lbs.	Lbs.	Per cent
Holstein	4	1,190	107	9.0
Ayrshire	7	965	77	8.0
Guernsey	8	1,024	79	7.7
Jersey	11	898	67	7.4

590. Economy of the dairy cow.—The following table, adapted from Lawes and Gilbert,[3] compares the economy of the cow and the ox in converting the products of the fields into human food:

Relative returns by the cow and the fattening ox in one week.

	Protein	Fat	Carbohydrates (sugar)	Mineral matter	Total dry matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Weekly returns from cow when yielding:					
10 lbs. milk daily	2.56	2.45	3.22	0.52	8.75
20 lbs. milk daily	5.11	4.90	6.44	1.05	17.50
30 lbs. milk daily	7.67	7.35	9.67	1.57	26.25
40 lbs. milk daily	10.22	9.80	12.89	2.09	35.00
50 lbs. milk daily	12.78	12.25	16.12	2.61	43.76
Weekly returns from ox when gaining:					
10 lbs. weekly	0.75	6.35	----------	0.15	7.25
15 lbs. weekly	1.13	9.53	----------	0.22	10.88

[1] Bul. 162. [2] Rpt. 1907. [3] Jour. Roy. Agr. Soc., Eng., 1895.

We learn that the fattening ox, when making the substantial gain of 15 lbs. weekly, produces 1.13 lbs. of protein or nitrogenous substance, mostly in the form of water-free lean meat. In the same time the cow yielding 30 lbs. of milk daily produces 7.67 lbs. of casein and albumin, or nearly 6 times as much nitrogenous substance. While the ox is laying on 9.53 lbs. of fat, the cow puts 7.35 lbs. of fat in her milk. She also secretes 9.67 lbs. of milk sugar, against which there is no equivalent substance produced by the ox. Changing this sugar to its fat equivalent, (**68, 131**) the cow is shown to yield somewhat more fat or fat equivalent than the ox. The ox stores 0.22 lb. of ash or mineral matter, largely in his bones, while the cow puts into her milk 1.57 lbs. of ash, or over 6 times as much.

We have shown in Art. 102 that for each 100 lbs. of digestible nutrients consumed the cow yields about 6 times as much edible solids in her milk as the sheep or steer yields in its carcass.

591. Cow and steer compared.—Trowbridge of the Missouri Station analyzed the entire body of a 1250-lb. fat steer fed at that Station. At the same Station a Holstein cow gave in one year 18,405 lbs. of milk. The following table by Eckles[1] shows the total dry matter found in the body of the steer and in the milk:

	Dry matter in 18,405 lbs. milk	Dry matter in 1,250-lb. steer
Protein substance	552 pounds	172 pounds
Fat	618 pounds	333 pounds
Sugar	920 pounds	None
Mineral matter	128 pounds	43 pounds
Total	2,218 pounds	548 pounds

The steer's body contained about 56 per ct. water, leaving 548 lbs. of dry matter, which included not only all the edible dry lean meat and fat, but also every part of the body—horns, hoofs, hair, hide, bones, tendons, and all internal organs. In one year the cow produced 2,218 lbs. of dry matter which was wholly digestible and suitable for human food. In that time she produced enough protein to build the bodies of 3 such steers, fat enough for nearly 2, and mineral matter enough for the skeletons of 3, besides 920 lbs. of milk sugar as nutritious and useful for humans as the same weight of cane sugar.

Eckles writes: "These figures show the remarkable efficiency of the cow as a producer of human food. It is because of this economical use of food that the dairy cow and not the steer is kept on high-

[1] Hoard's Dairyman, Feb. 25, 1910.

priced land. When land is cheap and feed abundant the meat-producing animals predominate, but when the land becomes higher in value and feed expensive, the farmer turns to the dairy cow.''

592. Disposition of food.—Jordan[1] holds that a typical dairy cow, weighing 870 lbs., when eating 15.5 lbs. of digestible matter daily and yielding 20 lbs. of milk, disposes of her food daily as follows:

Energy required to maintain the body	13 therms	43.3 per ct.
Energy expended in manufacture of milk	9 therms	30.0 per ct.
Energy in 20 lbs. of milk	8 therms	26.7 per ct.
Total energy in 15.5 lbs. digestible matter	30 therms	100.0 per ct.

It is shown that a well nourished dairy cow uses about 43 per ct. of the food she consumes to support her body, 30 per ct. in the work of converting food into milk, and that nearly 27 per ct. finally appears as milk. This shows the cow to be a more efficient machine than either the horse or the steam engine. (**112, 817**)

593. Dairy v. beef type.—The following from Smith[2] concisely covers a vital point for the advanced dairyman: ''Unlike the beef animal, which is its own storehouse, placing its product within its carcass, the dairy cow gives up each day that which she produces. She has been developed along lines quite opposite from those of the beef animal. In her development, performance, as indicated by the quality and quantity of milk given, has been the chief guide in making selections. The most perfect beef cows are not economical milkers, and the best dairy cows are not satisfactory beef makers. The two functions are quite different, making it impossible to develop both to the highest degree in one animal.'' (**686**)

594. Fat globules.—Collier of the New York (Geneva) Station[3] placed the average secretion of milk by the cows of the station herd at 0.7 lb., or 19.6 cubic inches per hour. He found that the one-thousandth part of a cubic millimeter of average milk contained 152 fat globules, and accordingly that the average station cow secreted 138,210,000 fat globules each second thruout the day of 24 hours while giving milk. Babcock[4] tells us that a quart of average milk contains not less than 2,000,000,000,000 fat globules. These figures are beyond comprehension and should intensify our interest in the marvelous processes of life. They lead us to ponder on the infinite division which food must undergo during digestion.

[1] Rural New Yorker, Sept. 9, 1899.
[2] Profitable Stock Feeding, p. 38.
[3] Rpt. 1892.
[4] Wis. Expt. Sta., Bul. 18.

595. Composition of milk.—Wing[1] presents the average composition of cows' milk in several countries as given by standard authorities:

	American (Babcock)	English (Oliver)	German (Fleischmann)	French (Cornevin)
	Per ct.	Per ct.	Per ct.	Per ct.
Water	87.17	87.60	87.75	87.75
Fat	3.69	3.25	3.40	3.30
Casein	3.02	3.40	2.80	3.00
Albumin	0.53	0.45	0.70	----
Sugar	4.88	4.55	4.60	4.80
Ash	0.71	0.75	0.75	0.75
	100.00	100.00	100.00	99.60

596. Milk of the various breeds.—Wing,[2] gathering data from various American experiment stations, presents the following average composition of the milk of the several breeds of cows:

Breed	Solids Per ct.	Fat Per ct.
Jersey	14.70	5.35
Guernsey	14.71	5.16
Devon	14.50	4.60
Short-horn	13.38	4.05
Ayrshire	12.61	3.66
Holstein-Friesian	11.85	3.42

It is shown that the Jersey and the Guernsey give the richest and the Ayrshire and the Holstein-Friesian the poorest milk. The quantity of milk given by cows of the different breeds is almost inversely proportional to the fat content, so that the total quantity of solids and fat is nearly the same for all dairy breeds.

597. First and last drawn milk.—At the New York (Geneva) Station[3] Van Slyke analyzed the successive portions of milk drawn from a Guernsey cow with the following results:

Composition of the successive portions of milk as drawn.

	Weight of milk	Fat	Casein	Albumin
	Lbs.	Per cent	Per cent	Per cent
First portion	3.2	0.76	2.67	0.62
Second portion	4.1	2.60	2.57	0.64
Third portion	4.6	5.35	2.49	0.61
Fourth portion	5.8	9.80	2.39	0.58

We learn that the first milk drawn is very poor in fat, each succeeding portion increasing in richness of fat, while the casein and

[1] Milk and Its Products, p. 17.
[2] Loc. cit., p. 33.
[3] Jour. Am. Chem. Soc., 30, p. 1173.

albumin show little change. Those who let the calf have the first milk drawn and reserve the strippings keep the richest milk. (**299**)

598. Effects of age.—Wing of the Cornell Station[1] recorded the following yields of 8 cows beginning as 2-yr.-olds and extending thru their fourth lactation period:

Effects of age on the yield and composition of milk.

Age at beginning of lactation period	Av. milk yield per year	Ratio to maximum milk yield	Yield of fat per year	Ratio to maximum fat yield	Av. fat in milk
Years	Lbs.	Per cent	Lbs.	Per cent	Per cent
2	6,022	76	215	81	3.57
3	6,767	86	238	90	3.52
4	7,710	98	264	100	3.42
5	7,895	100	265	100	3.35

The average yield of the 2-yr.-old heifers in their first lactation period was 6,022 lbs. of milk and 215 lbs. of fat. With succeeding years up to the fifth there was an increase of both milk and fat, the increase being small after the third lactation period. Ranking the fourth lactation period at 100, the milk yield for the heifer period was 76 per ct.

Thorne of the Ohio Station[2] found the cow the most economical producer at 7 years of age, slowly declining thereafter. Beach of the Connecticut Station[3] places the yield of heifers at 70 per ct. of that of mature cows. Dairymen usually rate 2 heifers equal to 1 cow, which is reasonable because of the extra expense of care and keep. The milk of the heifer is usually slightly richer than when she becomes a mature cow, but because of the greater quantity the mature cow yields more fat.

599. Effect of advancing lactation.—Woll of the Wisconsin Station[4] has condensed, in the table on the next page, the findings of the New York (Geneva) Station with 14 cows of 6 breeds, giving the dry matter consumed and the yields of milk and fat, month by month, from freshening until the cows went dry.

The table shows that immediately after freshening the cow gives richer milk than later. It then grows poorer for a month or two, and after that slowly increases in richness until she becomes dry. We further learn that during the first month after a cow freshens a given quantity of feed gives greater returns in milk product than

[1] Bul. 169. [2] Rpt. 1893. [3] Bul. 29. [4] Bul. 116.

later, and that as a rule the further advanced a cow is in lactation the more food she requires for a given quantity of milk. When first fresh the cow usually draws on her own body substance for nutrients used in milk production, and later she is nurturing an unborn calf.

Effect of advancing lactation on economy of production.

Month	Daily yield		Fat	Dry matter eaten daily	Dry matter eaten to produce:		
	Milk	Fat			100 lbs. milk	1 lb. solids	1 lb. fat
	Lbs.	Lbs.	Per cent	Lbs.	Lbs.	Lbs.	Lbs.
First month	25.1	0.98	4.02	23.6	94	7.1	24.1
Second month	26.0	0.95	3.74	27.0	104	8.2	28.6
Third month	23.8	0.84	3.71	28.9	122	9.5	34.4
Fourth month	21.2	0.79	3.84	29.0	137	10.5	36.8
Fifth month	19.6	0.73	3.87	28.5	146	11.1	39.3
Sixth month	19.8	0.75	3.90	29.3	148	11.2	39.4
Seventh month	19.0	0.72	3.94	28.5	150	11.2	39.7
Eighth month	16.0	0.60	3.89	28.0	175	13.0	46.5
Ninth month	12.5	0.48	3.92	28.0	224	16.1	58.3
Tenth month	9.4	0.41	4.19	26.5	282	19.4	65.3
Eleventh month	5.6	0.26	4.58	24.3	436	28.1	95.5

The combined studies of Carlyle and Woll at the Wisconsin Station,[1] Beach at the Connecticut (Storrs) Station,[2] and Linfield of the Utah Station[3] on the normal monthly decrease in the milk flow are averaged in the following table:

Period	Per cent	Period	Per cent
First month	---	Sixth month	6.1
Second month	5.8	Seventh month	8.5
Third month	8.4	Eighth month	10.9
Fourth month	7.3	Ninth month	12.3
Fifth month	6.7	Tenth month	11.9

It is shown that the monthly decrease in milk flow ranges from about 6 to 9 per ct. up to the eighth month. The decrease then rapidly becomes larger until it amounts to about 12 per ct. in the ninth and tenth months, after which the cows are generally dried off. This table enables one to calculate the probable yield of a cow during any month she is giving milk.

600. Period of greatest yield.—Haecker of the Nebraska Station[4] studied 239 lactation periods with cows at the Nebraska and Minnesota Stations, the records beginning 4 days after calving. He found that 90 per ct. of the cows made their best records during the first 10 weeks of lactation, and over one-half during the first month. The

[1] Bul. 102. [2] Bul. 29. [3] Bul. 68. [4] Bul. 76.

greatest number gave the most milk during the third and the most fat during the second week after calving.

601. Loss in weight.—Haecker of the Minnesota Station[1] found that during the early stages of lactation cows lose rapidly in weight. In one case the average decrease for 15 cows was 49 lbs. per cow for the first week, with an average daily loss per cow of 2 lbs. for the first 7 weeks. During this time the cows yielded products in excess of what the food furnished—in some instances twice as much. Such excess of yield gradually decreased until the eleventh week, when cows of pronounced dairy temperament reached equilibrium between the food nutrients consumed and dairy products yielded, while others required a longer time to reach equilibrium.

602. Meager and liberal feeding.—For a full year Wing and Foord of the Cornell Station[2] recorded the milk and fat yield of a herd of poorly nourished cows as kept by a farmer on a New York farm. The herd was then moved to the Station where it was liberally fed for 2 years; then it was returned to the farmer who fed them poorly as before. Below appear the average returns of 7 cows so studied:

	First and fourth years on farm	Second and third years at Station
Average weekly yield of milk per cow	109 pounds	155 pounds
Average weekly yield of fat per cow	4.7 pounds	7.1 pounds
Average fat in milk	4.45 per ct.	4.70 per ct.

Here is an increase thru good feed and care of 42 per ct. in the quantity of milk and 51 per ct. in the quantity of fat over that obtained by the farmer. Under improved conditions the fat in the milk of these cows increased 0.25 of 1 per ct., or 5.6 per ct. quantitatively. When again subjected to the hard conditions enforced upon them by the poor farmer, the cows fell back to their old record. (**704**)

603. Excessive v. low feeding.—Eckles of the Missouri Station[3] fed one heifer liberally on rich rations from birth until she calved, while another was kept poor and thin. After calving, the milk of the well-fed heifer tested over 4 per ct. fat and that of the thin one about 3 per ct. For several weeks after calving the fat heifer declined in weight, the fat percentage remaining constant. When at length her weight became stationary the percentage of fat declined somewhat. The thin heifer did not lose in weight after calving, and the fat in her milk did not decrease. When she began to gain on liberal feeding, the fat percentage of her milk slightly increased. In the end the milk of the two heifers was about equally rich.

[1] Bul. 79. [2] Bul. 222. [3] Hoard's Dairyman, July 9, 1909.

In another case a mature cow so fed as to be excessively fat at calving was for a time thereafter given food only sufficient for a dry cow. Beginning with 21 lbs. of milk daily she was giving 19.5 lbs. at the end of 30 days of poor feeding, during which time she lost 115 lbs. in weight. Eckles estimates that the 43 lbs. of fat and 53 lbs. of other solids yielded in the milk during this time must have come from her body tissues. During this period her milk averaged 6.9 per ct. fat. Within 48 hours after her feed was later increased it declined about 2 per ct.

604. Withholding lime.—At the Wisconsin Station[1] Hart, McCollum, and Humphrey fed an 1150-lb. cow producing about 30 lbs. of milk daily a liberal ration save that it lacked lime. It was found that there went into the milk daily about 20 grams of lime (CaO) and into the solid excrement and urine, principally the former, about 30 grams, the latter loss being due to the normal changes (metabolism) taking place in the body. In all about 50 grams, or nearly 2 ounces, of lime disappeared daily from the body of this cow, only one-half of which could have been furnished by the lime in the food. During the trial, which lasted 110 days, this cow maintained a good flow of milk and continued to put the normal amount of lime into it. It was calculated that during the trial she gave off in milk and excrement 5.5 lbs. more lime than she received in her food. It was estimated that her skeleton contained about 24.2 lbs. of lime at the start, and this being true, this cow gave up in 110 days about 25 per ct. of all the lime in her skeleton! Here is a striking illustration of the overpowering force of maternity. (**89**)

605. Protein-rich rations.—The extensive experiments of the Copenhagen Station,[2] covering observations with about 2,000 Danish cows and extending over 10 years, appear to show that the normal fat percentage of the milk was raised possibly as much as 0.1 per ct. thru the influence of the highly nitrogenous rations fed. While such an increase is too small to be recognized by the dairyman in his practical work, it is possibly of deep significance and far-reaching importance for the student and breeder looking to the permanent enrichment of the milk of a strain or breed of dairy cattle.

606. Feeding fat.—In 2 trials at the Cornell Station,[3] Wing fed tallow to 10 cows while on pasture or on winter feed. Beginning with a small amount, the allowance of tallow was gradually increased

[1] Research Bul. 5.
[2] Rpt. 45; Woll, Wis. Sta., Bul. 116.
[3] Bul. 92.

until each cow was consuming about 2 lbs. daily, this allowance being continued for several weeks. The table gives the results with 1 cow:

Effect of feeding tallow on milk and fat production.

	Tallow fed daily	Av. daily milk yield	Fat in milk	Av. daily fat yield
	Oz.	Lbs.	Per cent	Lbs.
Preliminary week	----------	25.9	4.4	1.14
First week	7	27.3	4.7	1.29
Second week	13	26.3	4.8	1.25
Third week	20	24.6	4.9	1.19
Fourth week	27	23.6	5.0	1.19
Fifth week	30	21.8	4.8	1.04
Sixth week	32	21.2	4.9	1.03
Seventh week	30	20.3	5.0	1.01
Eighth week	32	23.4	4.7	1.10
Ninth week	32	22.6	4.6	1.03
Tenth week	32	19.8	4.5	0.89
Eleventh week	----------	21.9	4.2	0.91
Twelfth week	----------	21.3	4.3	0.90

It will be seen that the first effect of feeding tallow to the cow was to increase the percentage of fat in the milk so that it was richer by 0.6 of 1 per ct. on the fourth week of the trial. There was a smaller flow of milk, however, so the total increase of fat was insignificant. With some of the cows there was practically no change.

After feeding stearin and cotton-seed-, palm-, corn-, cocoanut-, and oleo-oil to cows, Woods of the New Hampshire Station concluded that the first effect of such feeding is to increase the percentage of fat in the milk, but on continuing such feeding the milk tends to return to its normal condition. Woods holds that the increase in fat is not due to the oils, but to the unnatural character of the food. Hills of the Vermont Station[1] found oil emulsions, at best, no more effective than unemulsified oils.

607. Effects of drought.—Van Slyke of the New York (Geneva) Station,[2] studying the milk supply of cheese factories during a drought, found that the general effect was to rapidly diminish the flow of milk. The fat increased, while the casein, and especially the albumin, diminished. Tho percentagely small, the changes were in the direction of giving the milk the appearance of having been watered—a point of importance with milk inspectors.

608. Turning to pasture.—The Copenhagen (Denmark) Station[3] for 10 successive years studied the changes in milk when turning cows from winter stables to spring pastures. In all 1,961 fall-calving cows

[1] Rpt. 1899. [2] Bul. 68. [3] Rpt. 45; Woll, Wis. Expt. Sta., Bul. 116.

on 8 different farms were used. The yield and composition of the milk for ten-day periods preceding and following the turning to pasture are reported below:

Yield and composition of milk before and after turning to pasture.

	In stable in winter			On pasture in spring		
	Per. I	Per. II	Per. III	Per. IV	Per. V	Per. VI
Av. daily milk yield, pounds	21.2	20.7	20.2	21.7	21.7	20.3
Av. per ct. fat	3.15	3.18	3.21	3.47	3.34	3.30
Av. per ct. solids not fat	8.72	8.73	8.74	8.90	8.93	8.93

We note that the effect of turning from winter stables to spring pastures was to increase at once the milk flow by over 7 per ct., the percentage of fat by about 8 per ct., and that of the other solids by nearly 2 per ct. While the increased milk flow was maintained, the percentage of fat fell back to normal after the cows had been about 20 days on grass. The small increase in solids not fat seems to have been more permanent.

Linfield of the Utah Station[1] observed that cows turned on pasture early in the season while the grass was soft and lush lost in weight for a short time, due probably to the extreme flushing of the system. This result, however, had no effect on the milk production. Where the grasses were more mature when the cows were first turned on them no material loss in live weight was noted.

609. Work.—Dolgich[2] found that moderate exercise tended to increase the quantity of milk and all the constituents except casein, which was slightly decreased, while excessive exercise decreased nearly all the constituents. Light work decreased the quantity of both milk and milk solids, while excessive work decidedly decreased the flow and injured the quality, the casein not coagulating and some of the food-fat appearing unaltered in the milk. (**392**)

610. Feeding concentrates on pasture.—Shelton and Cottrell of the Kansas Station[3] found that feeding grain to cows on pasture did not directly pay, even tho the yield of milk was increased as much as 31 per ct. Moore of the Mississippi Station,[4] on feeding 3 lbs. of cotton-seed meal and 4 lbs. of wheat bran daily per cow to a dairy herd on pasture, found that the increased milk flow did not justify the expense, tho the firmness of the butter was greatly improved by

[1] Bul. 68.
[2] Molkerei Zeitung, 17, 1903, p. 191.
[3] Rpt. 1888.
[4] Bul. 70.

feeding the cotton-seed meal. At the Utah Station[1] Linfield found that cows getting some concentrates while on pasture, at first showed no great advantage therefrom; later the effects of such feed became apparent, the difference being very marked by the following winter.

Roberts of the Cornell Station[2] found that cows fed concentrates while on luxuriant pasture gave less milk and no more fat than those on grass alone. With luxuriant pasture except for a short period, both lots did equally well. Grain-fed cows that were fed grass for soilage gave just enough more milk than others fed no grain to pay for the concentrates fed. The study was transferred to a nearby dairy farm. A herd of 16 cows lightly fed the previous winter was divided into 2 lots of 8 cows each, all grazing on the same pasture. Each cow in Lot I was given 4 quarts daily of rich concentrates, while those in Lot II received none. When the grass began to fail in August soilage was fed. The returns for 22 weeks are as follows:

	Lot I Pasture with concentrates	Lot II Pasture without concentrates
Concentrates fed, pounds	5,200	------
Milk yield, pounds	22,629	17,698
Excess of milk in favor of Lot I, pounds	4,931	------
Gain in weight per cow, pounds	166	113
Average per cent fat in milk	4.67	4.70
Average per cent total solids	14.08	14.19

In this trial the pastured cows getting concentrates gave 28 per ct. more milk than those getting no concentrates, and each pound of concentrates fed returned about 1 lb. of milk.

The following year no concentrates were fed to either lot while on pasture. The 6-months yield from 6 cows that remained in each lot was as follows:

	Lot I Fed concentrates previous year	Lot II Fed no concentrates previous year
Average yield per cow, 6 months, lbs.	3,440	2,960
In favor of Lot I, lbs.	480	-----

Tho getting no concentrates, Lot I returned 480 lbs., or 16 per ct., more milk than Lot II. Roberts holds that this was due to feeding concentrates the preceding year. The benefits were especially marked in the case of the heifers, the 2- and 3-yr.-olds fed concentrates the year before developing into better animals than their mates which had been fed no concentrates the previous year while on pasture.

We may conclude that there are no immediate advantages in feeding concentrates when the pastures are ample, while if they are poor

[1] Bul. 68.

[2] Buls. 13, 22, 36, 49.

or scant the increased milk flow will fully and directly compensate for the concentrates or soilage fed. The residual effects from concentrate-feeding on pastures, as pointed out by Roberts and Linfield, are most important and should not be overlooked. Where the pastures are short, unless soilage crops or concentrates are fed, the milk flow will surely decrease, and, even should the pastures improve later, the cows cannot be brought back to their normal milk flow. The greater value to the pastures of the droppings from concentrate-fed cows will often prove the deciding factor with thoughtful dairymen.

611. The proper concentrate allowance.—A knowledge of the proper amount of concentrates or grain which should be fed the cow is of great economic importance. Linfield of the Utah Station,[1] where alfalfa hay is largely fed for roughage, states that any excess over 6 lbs. of concentrates in the ration usually increases the cost of production. Stewart and Atwood of the West Virginia Station,[2] feeding timothy hay and corn silage for roughage, found that any increase in concentrates beyond 5 or 6 lbs. per cow daily did not bring corresponding returns. Hills of the Vermont Station,[3] after years of study of rations in which mixed hay and corn silage usually formed the roughage, concludes that it does not pay to feed the dairy cow less than 4 nor over 8 lbs. of concentrates daily. Woll and Carlyle in 2 trials at the Wisconsin Station[4] found when mixed hay and corn silage formed the roughage that 8 lbs. of concentrates gave as good returns in milk and fat as 12 lbs.

Attention is directed to the comparatively small allowance of concentrates recommended by the various investigators. The reader should not fail to note that where small allowances of concentrates proved the most economical the roughage fed was always ample in quantity and desirable in quality, corn silage carrying more or less grain, and clover or alfalfa hay usually being employed. Where the roughage allowance is meager or of poor quality, more concentrates should be fed. (**706, 714**)

612. Water.—At the Pennsylvania Station[5] Armsby found that cows averaging about 750 lbs., fed fresh grass in stalls where the temperature averaged 70° F., drank about 60 lbs. of water each daily. Others fed dry grass where a temperature of 73° F. prevailed drank 107 lbs. When at the Wisconsin Station[6] the same investigator found that cows drank more water on protein-rich than

[1] Bul. 43.
[2] Bul. 106.
[3] Rpts. 1900–1905.
[4] Rpts. 1899–1900.
[5] Rpt. 1888.
[6] Rpt. 1886.

on protein-poor rations. Collier of the New York (Geneva) Station[1] found that cows obtained 4.6 lbs. of water in feed and drink for every pound of milk they yielded, and that dry cows drank but 65 per ct. as much as those giving milk. In general the water provision for dairy cows should be about 100 lbs., or 12.5 gallons, per head per day.

Hayward of the Pennsylvania Station[2] and Hills of the Vermont Station[3] found no advantage in keeping water continuously before cows instead of allowing them to drink once daily. Hills of the Vermont Station[4] found no benefit from warming the water when the cows were comfortably housed. **(87, 452)**

613. Effects of dehorning and tuberculin testing.—Woll and Humphrey of the Wisconsin Station,[5] studying the results at 11 experiment stations, conclude that dehorning dairy cows causes a temporary loss of about 8 per ct. in yield of milk and an insignificant loss in yield of butter fat. Beach of the Connecticut (Storrs) Station,[6] after dehorning the Station herd, writes: "The worry, pain, and cruelty of animals to their mates is eliminated when these instruments of torture are removed, and the lack of fear and the quiet contentment of the individuals of the herd are at once noticeable. The benefits from dehorning dairy cattle cannot be accurately measured, but there is an almost unanimous opinion in its favor among those who have practiced it in their herds."

Studies at the Wisconsin Station[7] show that subjecting cows to the tuberculin test has practically no effect on the yield of milk and butter fat.

614. Spaying.—Nicolas,[8] after continued experiments with spayed and unspayed cows, concludes that such practice is not warranted by the results. The quality of the milk from spayed cows is better than that of the cow not pregnant, but poorer than that of the pregnant cows. Spaying results in richer milk, tho the quantity is not increased. Others have held not only that the milk of spayed cows was richer, but that by spaying the lactation period was lengthened by from 12 to 15 months.

615. Minor points.—Lane of the New Jersey Station[9] found that cows getting 3 feeds daily consumed more roughage and gave slightly more milk than those getting 2 daily, but the increase barely paid for

[1] Proc. of "New York Farmers," 1892–3.
[2] Bul. 56.
[3] Rpt. 1907.
[4] Loc. cit.
[5] Rpt. 1905.
[6] Rpt. 1902.
[7] Rpt. 1905.
[8] Soc. de L'Aliment. Rationelle du Betail, 1898.
[9] Rpt. 1900.

the extra labor and feed. Grisdale of the Ottawa Experimental Farms[1] found 2 feeds as effective as 3 in maintaining the milk flow. It is reasonable to hold that 2 generous feeds daily are sufficient for the dairy cow with her roomy digestive apparatus. (**701**)

On feeding dairy cows wet and dry concentrates, Grisdale[2] found a small difference in favor of the dry feed.

Carlyle of the Wisconsin Station[3] found that changing milkers had no appreciable effect upon the yield of milk or fat. Linfield[4] concludes that any change in milk yield is due to the individuality of the milker, not to the mere change of the milkers. Grisdale of the Ottawa Experimental Farms[5] found that irregularity in the intervals between milking slightly reduced the quantity and quality of the milk. The quantity of milk drawn after the longer interval was greater, but its fat percentage lower than that of the milk drawn after the shorter interval. The conclusion was reached that, were the changes not sudden, the effect due to the difference in the length of the intervals between the milkings was negligible.

Hills of the Vermont Station[6] found that cows milked thrice daily gave the most and poorest milk in the morning, less and the richest milk at noon, and the least milk and of medium quality at night. He states that usually it will not pay to milk cows thrice daily, tho a temporary increase in the flow of milk is produced thereby. Dean of the Ontario Agricultural College[7] concludes that milking thrice daily is unprofitable with cows giving a good flow, while it might be profitable with very heavy milkers.

The "Hegelund method" consists in so manipulating the cow's udder after milking as to bring down all remaining traces of milk. By this system, Woll of the Wisconsin Station[8] found that the daily milk yield of a herd of 24 cows was increased 4.5 per ct. and the fat yield 9.2 per ct. The average daily gain per cow was 1 lb. of milk and nearly 0.1 lb. of fat, and these gains seemed to be maintained thruout the whole lactation period.

Hills of the Vermont Station[9] as the result of 2 tests concludes that there is no benefit from grooming cows so far as milk yield is concerned, tho it may lessen the bacterial content of the milk.

II. The Influence of Feed on Milk.

616. Feed and milk yield.—The quantity of milk the cow yields depends indirectly on the inherent tendency or constitution of the

[1] Rpt. 1904.
[2] Ottawa Expt. Farms, Rpt. 1901.
[3] Rpt. 1903.
[4] Bul. 68.
[5] Rpts. 1901, 1902.
[6] Rpt. 1907.
[7] Rpt. 1898.
[8] Rpt. 1902.
[9] Rpt. 1900.

individual as fixed by breed and selection, and directly on feed, care, and environment. In the state of nature the cow provides only sufficient milk for the nourishment of her young, even tho her feed be abundant. When she is liberally fed, the modern dairy cow, produced thru long-time selection and breeding, secretes far more milk than her calf can utilize. So generous is the dairy cow that few dairymen feed to the limit of profitable production. Within wide limits, then, the quantity of milk a dairy cow yields is directly dependent on the feed and care she receives. (**602**)

617. Feed and richness.—Down to the most recent times it was universally held that milk varied in richness, or percentage of fat, from milking to milking, according to the feed and care the cow received. We have now come to know that the milk of each cow possesses a fixed inherent composition, and that normally the richness of milk is not the immediate sequence of feed and care. No longer does the man whose milk falls below standard some morning at the factory hide behind the statement that he "forgot to give the cows their grain last night." The Babcock milk test has silently but effectually dispelled this illusion so long held by dairymen. In confirmation of this view the following is offered:

The Jersey cow gives milk which is relatively rich in fat, and the Holstein milk that is relatively low in fat. No kind of feed or care will cause the Jersey to give milk like that of the Holstein or the reverse. Were a piece of skin, clothed with yellow hair, taken from the body of a Jersey cow and grafted on to the body of a Holstein cow, we should expect the grafted portion to continue growing yellow Jersey-like hair. In the same way, were it possible to graft the udder of a Jersey cow on to the body of a Holstein, we would expect the Holstein to then give Jersey-like milk. It is not the body of the cow or the digestive tract, but the glands of the udder that determine the characteristics of the milk yielded by each individual cow. After all, this is what we should expect, for if milk varied with every slight change of food and condition, the life of the young, dependent on such milk, would always be in jeopardy. (**602-3, 606-9**)

618. Fat variations.—Accepting the fact that the percentage of fat in milk is relatively constant, there are nevertheless many comparatively small variations from the normal, among which are the following: The milk of the heifer is usually slightly richer than that of the cow when mature; (**598**) immediately after freshening, especially if the cow is in high condition, (**599**) and again when drying off, the milk is richer than normal. The cow in very poor condition may give milk below or above the normal in richness; (**602**) defective, unusual, or scant feed may force the cow to give abnormally rich or poor milk; (**603**) feeding large quantities of fat may temporarily increase the fat in milk; (**606**) excitement or work may cause the milk to be richer or poorer than normal; (**609**) the shorter the period between milkings, the richer the milk; (**615**) morning's milk is usually richer than night's milk; the first drawn milk is the poorest and the last drawn the richest. (**597**) In general, all changes in environment, care, or food which affect the cow are mainly reflected in the quantity and, in some degree, in the quality of the milk she yields. Often when the percentage of fat increases, the quantity of the milk decreases so that the total yield of fat is not increased. (**596-9**)

619. Effects of feed on fat composition.—The fat of milk is a composite of many kinds of fat, such as palmitin, olein, stearin, butyrin, etc. While the kind of feed given the cow does not materially change the total per cent of fat in her milk, it does in some cases seem to alter the relative proportion of the several component fats or in some way change the composition of the fat, as shown by the resultant butter. We know that butter produced from cows fed cottonseed meal is hard and tallowy, with a high melting point, while linseed meal and soybeans tend to produce a soft butter with a low melting point.

Many years ago investigators began diligently to study the influence of feed on the composition of the fat of milk, and their work is still in progress. No basic conclusions have yet been reached, and we are forced to agree with Frear,[1] who years ago, after reviewing all available data, wrote: "They (the data) do not, however, suffice either for the framing of a theory as to the relation of the several food constituents to the fats of milk, or for the quantitative measure of the influence of a given food." (**605-6, 643**)

620. Flavor, odor, and color.—Milk and its products possess qualities cognizable only to sight, taste, and smell. The Guernsey breed excels in producing a milk with a yellow fat. The grain of corn, pasture grass, carrots, and some other feeding stuffs impart a yellowish tinge to milk fat. Due to minute quantities of volatile oils they contain, onions, leeks, turnips, rape, etc., impart an objectionable flavor to milk, possibly apparent to all people, while the flavors imparted by green rye or corn silage are detected by some but pass unnoticed by many. (**362**) When cows are first turned to pasture, we at once observe a grass flavor in the milk and butter, tho it soon disappears;

[1] Agr. Science, 1893.

but whether it has really disappeared or we only fail to notice it, we do not know. It is possible that after a time the cow more completely eliminates such volatile oils than at first. Bad flavors can be largely avoided by feeding whatever causes them immediately after milking so that the volatile oils they furnish, which are the source of the trouble, can the more completely escape from the body before the next milking.

It is possible that the facility with which flavors and odors pass from feed to milk or are eliminated from the body when once within it varies with different cows. The flavors and aroma of butter are mostly due to fermentation of milk sugar, so that this matter rests only in part on feeding.

Sometimes, long after a cow has freshened, her milk grows bitter and distasteful thru no influence of feed. It is doubtful if the progeny of such cows should be reared.

It is probable that the milk of every cow, aside from the influence of feed, possesses a distinctly individual flavor too delicately fine to be observed by most humans. It may be that in the future, when the grosser problems now perplexing dairymen have been solved, it will be found that certain cows yield a peculiarly palatable milk. If this should prove to be the case, then thru selection there may be established breeds or families possessing this ultra-refined and most desirable quality.

The whole subject of odors and flavors in milk and dairy products generally is greatly complicated by the fact that there is a wide range in the ability of individuals to detect and distinguish them. Flavors or odors plainly evident to one person are unnoticed by another. Often odors and flavors charged to feed or cow are due to stable contamination of milk after it is drawn from the cow.

CHAPTER XXV.

STATION TESTS WITH FEEDING STUFFS FOR DAIRY COWS.

I. Value of the Various Grains for Cows.

621. Ear corn v. corn-and-cob meal.—Lane of the New Jersey Station[1] compared broken ear corn with an equal weight of corn-and-cob meal with the results shown in the table:

Ear corn compared with corn-and-cob meal.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Ear corn, 6 lbs.	Corn stover, 10 lbs.		
Wheat bran, 6 lbs.	Hay, 9.4 lbs.	20.2	0.89
Lot II			
Corn-and-cob meal, 6 lbs.	Corn stover, 10 lbs.		
Wheat bran, 6 lbs.	Hay, 9.4 lbs.	22.1	0.93

The table shows that the returns from corn-and-cob meal exceed those from ear corn by 9.4 per ct. for milk flow and 4.5 per ct. in the yield of fat. These returns in favor of grinding corn are not materially different from those secured with fattening steers and swine. (**157**)

622. Corn meal as the sole concentrate.—At the Maryland Station[2] Patterson fed cows on corn meal as the sole concentrate during the entire lactation period, while others were given a mixture of corn meal, gluten feed, and wheat bran in such quantity as to form with the roughage, chiefly dry fodder and soilage corn, a balanced ration. The next year the rations were reversed so that each cow was on both sides of the trial. The average yearly returns were as follows:

	Yield per cow Milk	Butter
When corn meal only was fed	3,150 pounds	152 pounds
When mixed grains were fed	4,195 pounds	221 pounds

It is shown that the returns were about 45 per ct. greater when feeding a balanced ration of mixed grains than with corn meal as the exclusive concentrate. Only when the roughage is rich in crude protein should corn constitute the sole concentrate in the ration of the dairy cow, and even then more variety would be better. (**156**)

[1] Rpt. 1898.
[2] Bul. 84.

623. Wheat meal v. corn meal.—At the Maine Station[1] Bartlett fed 6 cows for three 21-day periods, giving to each for concentrates 2 lbs. cotton-seed meal and either 5 lbs. wheat meal or 5 lbs. corn meal daily. The returns in milk and fat were practically the same for both rations, showing that wheat meal and corn meal are equal in feeding value for the dairy cow. (**161**)

624. Wheat v. barley and oats.—At the Copenhagen (Denmark) Station[2] Friis compared ground wheat with a mixture of equal parts of ground barley and oats as a feed for dairy cows. The herds on 6 estates were divided into 3 equal lots. Each cow was given a basal ration of 3.3 lbs. wheat bran, 1.8 lbs. oil cake, 30 lbs. mangels, 10 lbs. hay per day, and straw without limit. In addition, Lot I was fed 5.2 lbs. of the barley-oats mixture; Lot II was fed 2.6 lbs. of the barley-oats mixture and 2.6 lbs. of wheat; and Lot III 5.2 lbs. of wheat. The average daily milk yield per cow is shown in the table:

Wheat compared with a mixture of oats and barley for cows.

	Lot I	Lot II	Lot III
	Grain mixture only	Half grain mixture, half wheat	Wheat only
	Lbs.	Lbs.	Lbs.
Milk yield, preliminary period	26.3	26.3	26.4
Milk yield, experimental period	23.0	22.8	23.2
Milk yield, post-experimental period	21.0	21.0	22.0

It will be seen that, when fed alone, ground wheat had practically the same value as equal parts of ground barley and oats. (**161, 171**)

625. Rye meal v. corn meal.—Hayward of the Pennsylvania Station,[3] in a feeding trial with 3 cows during 3 periods of 35 days each, compared rye meal with corn meal, obtaining the results shown in the table:

Rye meal compared with corn meal as a feed for dairy cows.

Average ration		Average daily yield per cow: Milk	Fat
		Lbs.	Lbs.
Lot I Rye meal, 3.5 lbs. Cotton-seed meal, 2.5 lbs. Linseed meal, 2.0 lbs.	Timothy hay, 12 lbs.	16.7	0.73
Lot II Corn meal, 3.5 lbs. Cotton-seed meal, 2.5 lbs. Linseed meal, 2.0 lbs.	Timothy hay, 12 lbs.	17.3	0.77

[1] Rpt. 1895. [2] 34th Rpt., 1895. [3] Bul. 52.

The table shows that when 3.5 lbs. of rye meal was substituted for an equal weight of corn meal in the ration the milk flow and fat yield decreased. We may conclude that rye meal is somewhat less valuable than corn meal for the dairy cow. (**177**)

626. Oats v. wheat bran.—Woll of the Wisconsin Station[1] compared ground oats with wheat bran in a feeding trial with 4 cows lasting 47 days with the results shown in the table:

Ground oats compared with wheat bran.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Ground oats, 10 lbs.	Clover hay, 6 lbs.		
Corn meal, 2 lbs.	Corn stover, without limit	23.3	1.03
Lot II			
Wheat bran, 10 lbs.	Clover hay, 6 lbs.		
Corn meal, 2 lbs.	Corn stover, without limit	20.8	0.93

The table shows a return of about 11 per ct. more milk and fat from ground oats than from wheat bran. The high feeding value of oats for the dairy cow is well illustrated in this trial. However, because of the high price this grain now commands, most dairymen cannot afford to use it in any large way.

Hills of the Vermont Station[2] found that oat feed was about as valuable as equal parts of bran and corn meal for dairy cows. (**169**)

627. Emmer.—Wilson and Skinner of the South Dakota Station,[3] when feeding brome hay and corn silage for roughage, found that cows produced 1 lb. of butter fat for each 15.5 lbs. of corn or barley meal fed, while 17.5 lbs. of ground emmer (speltz) were required, a difference of 13 per ct. in favor of barley or corn meal. (**178**)

628. Kafir meal.—In a trial with 18 cows for 7 weeks, Cottrell and Skinner of the Kansas Station[4] found that 8 lbs. of kafir meal and 20 lbs. of alfalfa hay made the cheapest dairy ration for Kansas conditions. When fed with prairie, timothy, or sorghum hay or corn fodder, kafir tends to dry up the cows, and if fed abundantly to fatten them. (**183**)

629. Sorghum meal.—During three 20-day periods Cook of the New Jersey Station[5] fed cows rations composed of 5 lbs. corn stover, 20 lbs. brewers' grains, 5 lbs. wheat bran, and 9 lbs. of either sorghum

[1] Rpt. 1890.
[2] Rpt. 1907.
[3] Bul. 81.
[4] Bul. 93.
[5] Rpt. 1882.

meal or corn meal for each 1,000 lbs. of live weight, with the following average returns:

	Daily milk yield per cow
Period I, Ration containing corn meal	28.1 pounds
Period II, Ration containing sorghum-seed meal	24.6 pounds
Period III, Ration containing corn meal	27.0 pounds

It is shown that when the full sorghum-seed meal ration was fed the yield of milk dropped, while on changing from sorghum-seed meal back to corn meal there was an increased milk flow. These trials show that sorghum-seed meal is at least 10 per ct. less valuable than corn meal for milk production. (**181**)

630. Soybean v. cotton-seed meal.—At the Tennessee Station[1] Price compared ground soybeans with cotton-seed meal for milk production with 2 lots each of four 2- and 3-yr.-old heifers, fed the following rations alternately during 3 periods of 30 days each:

Ground soybeans v. cotton-seed meal.

Average ration		Average daily yield per cow	
		Milk	Fat
Lot I		Lbs.	Lbs.
Ground soybeans, 2.3 lbs.	Corn silage, 24.7 lbs.		
Corn-and-cob meal, 2.3 lbs.	Alfalfa hay, 10.3 lbs.	14.4	0.81
Lot II			
Cotton-seed meal, 2.3 lbs.	Corn silage, 23.5 lbs.		
Corn-and-cob meal, 2.3 lbs.	Alfalfa hay, 10.0 lbs.	13.6	0.77

It is shown that ground soybeans gave slightly better results than cotton-seed meal.

At the Massachusetts (Hatch) Station[2] 2 lots of 4 cows each were fed 6 weeks by the reversal method. To a basal ration of hay, silage, and bran, an allowance of either ground soybeans or cotton-seed meal was added in practically equal amounts. The ground soybeans proved slightly superior to the cotton-seed meal as a milk and fat producer, and the butter was of better quality.

Otis of the Kansas Station[3] found that, when soybeans formed one-half the concentrates, the butter from such feeding was so soft that it was impossible to work it satisfactorily even tho chilled with ice water. Since cotton-seed meal produces a hard butter and soybeans a soft butter, the two in combination should form a most useful and exceedingly rich nitrogenous concentrate for dairy cows. (**201, 643**)

[1] Bul. 80. [2] Rpt. 1894. [3] Bul. 125.

631. Velvet bean.—Scott of the Florida Station,[1] during a feeding trial extending from January to April in which either velvet beans in the pod or cotton-seed meal was fed to cows along with a basal ration of wheat bran and sorghum silage, secured the following returns:

268 lbs. velvet beans in the pod, with bran and silage, produced 935 lbs. milk
95 lbs. cotton-seed meal, with bran and silage, produced 937 lbs. milk

It will be seen that, fed with bran and silage, 268 lbs. of velvet beans in the pod produced substantially as much milk as 95 lbs. of cotton-seed meal. Scott reports that the Florida farmer can produce 5 tons of velvet beans for the cost of 1 ton of cotton-seed meal. (**263**)

II. By-products of the Flour Mills; Glucose, Oil, and Sugar Factories; Distilleries; and Breweries.

632. Wheat bran.—The Copenhagen Station[2] conducted feeding trials with 447 cows on several Danish farms as follows: To one lot was fed a mixture of equal parts of ground barley and oats; to a second a mixture of half wheat bran and half mixed grains; and to a third wheat bran alone. The results are summarized below:

Wheat bran compared with a mixture of ground oats and barley.

	When the ration contained—		
	Mixed grains	Half grains, half bran	Wheat bran only
Average daily milk yield per cow, lbs.	21.9	22.1	22.1
Average solids in milk, per ct.	11.7	11.8	11.8
Average fat in milk, per ct.	3.0	3.1	3.1

The results show that wheat bran fed alone is fully as valuable as a mixture of equal parts of ground barley and oats. Bran, however, should rarely be so fed, but always in combination with some feed rich in starch, such as corn, rye, barley, etc., and with some legume roughage to furnish lime, which it lacks. (**165**)

633. Wheat shorts v. wheat bran.—The Copenhagen Station[3] conducted trials with 240 cows on several farms in which wheat shorts (presumably of good quality) was fed in comparison with wheat bran. The shorts gave slightly larger returns, tho the difference was small. Combining the results of this trial with those in the preceding article, we may conclude that wheat bran, wheat middlings, and good

[1] Bul. 102. [2] 29th Rpt., 1894. [3] Loc. cit.

wheat shorts are of equal feeding value for the dairy cow, and practically equal to a mixture of ground barley and oats. (**166**)

634. Buckwheat middlings.—Hills of the Vermont Station[1] reports that buckwheat middlings in the ration produced from 8 to 11 per ct. more milk than did an equal allowance of half corn and half wheat bran. At ruling prices buckwheat middlings made cheaper milk and butter than did linseed and cotton-seed meal or corn meal and bran. Buckwheat middlings seemed to increase the quantity of fat in the milk, tho the quality of the butter was somewhat impaired when the middlings were fed in large quantities. Hayward and Weld of the Pennsylvania Station[2] found that, for milk and butter production, buckwheat middlings, dried brewers' grains, and cerealine are equally valuable when judiciously fed as part of a balanced ration. None of these foods had a detrimental effect upon the flavor or quality of the milk or butter. (**180**)

635. Gluten meal.—Hills of the Vermont Station[3] fed 6 cows for 20 weeks, comparing gluten meal with a mixture of equal parts of corn meal and wheat bran. He found that 100 lbs. of dry matter in the form of gluten meal, substituted for an equal amount of dry matter in a mixture of equal parts corn meal and wheat bran, increased the yield of milk and total solids 12.5 per ct. (**158**)

636. Gluten feed.—Cooke of the Vermont Station[4] fed 2 cows the following rations alternately for periods of 18 days each to compare gluten feed with the same weight of a mixture of corn meal and wheat bran:

Gluten feed compared with wheat bran and corn meal.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Ration I			
Gluten feed, 4 lbs.			
Wheat bran, 2 lbs.	Cut hay, 8 lbs.		
Corn meal, 2 lbs.	Corn silage, without limit	21.5	1.08
Ration II			
Wheat bran, 4 lbs.	Cut hay, 8 lbs.		
Corn meal, 4 lbs.	Corn silage, without limit	18.7	0.93

The table shows a gain of 15 per ct. in milk and 16 per ct. in fat thru substituting gluten feed for an equal weight of corn meal and bran, equal parts. The high value of gluten feed is here shown. (**158**)

[1] Rpt. 1907. [2] Bul. 41. [3] Rpt. 1895. [4] Rpt. 1892

637. Hominy feed.—Hills of the Vermont Station[1] found that hominy feed in the ration for dairy cows was fully equal to wheat bran, but somewhat less valuable than gluten meal or a mixture of equal parts of cotton-seed meal and linseed meal. (**158**)

638. Germ-oil meal.—In a feeding trial with 4 cows at the Vermont Station,[2] Hills compared a mixture of equal parts of germ-oil meal and wheat bran with one composed of 1 part cotton-seed meal, 1 part linseed meal, and 2 parts wheat bran. In a second trial the germ-oil meal and bran mixture was compared with ground oats. The roughage consisted of mixed hay and corn silage. In both trials the returns were in favor of the germ-oil meal. (**158**)

639. Oil cakes v. grain.—The Copenhagen (Denmark) Station[3] compared the feeding value of a mixture of ground barley and oats with a mixture of equal parts by weight of palm-nut, rape-seed, and sunflower-seed cake fed to 240 cows on several farms. In each series of trials 3 lots of cows were fed as follows: Lot I, three-fourths grain mixture, one-fourth oil cake; Lot II, one-half grain mixture, one-half oil cake; and Lot III, one-fourth grain mixture, three-fourths oil cake.

Comparative feeding value of oil cake and mixed grains.

	Lot I, ¾ grain ¼ oil cake	Lot II, ½ grain ½ oil cake	Lot III, ¼ grain ¾ oil cake
Average daily milk yield, lbs.	21.7	22.9	23.4
Average per ct. of milk solids	11.9	11.9	11.8
Average per ct. of fat	3.2	3.2	3.2

The table shows a decided increase in milk flow following the larger use of oil cake in the ration. It was calculated that for each 100 lbs. of oil cake substituted for the same amount of mixed grains there was a gain of 66 lbs. of milk, provided the oil cake did not constitute more than half of the concentrates of the ration. Feeding oil cake to this extent in the ration therefore proved economical. European dairymen wisely use the various forms of oil cakes (oil meals) in the rations for their cows. All the vast quantity of cotton-seed and linseed cake now going abroad should find use on American farms. (**536-9**)

640. Linseed meal v. cotton-seed meal.—At the Pennsylvania Station[4] Waters and Hess compared old-process linseed meal with cotton-seed meal. Nine cows were used, the ration at first consisting of

[1] Rpt. 1904. [2] Rpt. 1901. [3] Rpt. 1892. [4] Rpt. 1895.

cotton-seed meal, wheat meal, and corn stover fed without limit. Later linseed meal was substituted for the cotton-seed meal:

Linseed meal compared with cotton-seed meal.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Linseed meal, 6.0 lbs.			
Chopped wheat, 6.0 lbs.	Corn stover, 9.3 lbs.	15.1	0.78
Lot II			
Cotton-seed meal, 5.3 lbs.			
Chopped wheat, 6.7 lbs.	Corn stover, 9.3 lbs.	16.2	0.77

The cows receiving the cotton-seed meal produced somewhat more milk but no more fat than those getting linseed meal. Hills of the Vermont Station[1] found that cotton-seed meal seemed to possess a small tho measurable advantage over linseed meal for dairy cows. In view of these findings it is reasonable to hold that linseed meal is slightly less valuable than cotton-seed meal. Linseed meal tends to produce a soft butter and therefore may sometimes be advantageously fed in rations which would otherwise produce a tallowy butter. (200)

641. Cotton-seed meal.—At the South Carolina Station[2] Michels and Burgess fed 21 cows for 3 alternate periods averaging 27 days each on the rations shown below. Both lots received all the corn silage they would consume. In the second period 5.1 lbs. of cotton-seed meal formed the sole concentrate, while in the first and third periods 3.4 lbs. of wheat bran replaced 1.7 lbs. of cotton-seed meal.

At the New Jersey Station[3] Lane fed 4 cows for 66 days on either cotton-seed meal or a mixture of equal parts of wheat bran and dried brewers grains. The results of both trials are shown in the table on the next page.

From the South Carolina trial we learn that when 1.7 lbs. of cotton-seed meal was replaced by 3.4 lbs. of wheat bran the yield of milk and fat was slightly decreased. In the New Jersey trial, where corn silage and corn stover formed the roughage, 4.5 lbs. of cotton-seed meal did not prove quite equal to 10 lbs. of a mixture of wheat bran and dried brewers' grains. Michels concludes that 1 lb. of cotton-seed meal is equal to 2 lbs. of wheat bran for milk

[1] Rpt. 1907. [2] Bul. 117. [3] Rpt. 1903.

production, while Moore of the Mississippi Station[1] holds that 1 lb. of cotton-seed meal is only equal to 1.5 lbs. of wheat bran.

Cotton-seed meal compared with various feeds.

Average ration		Average daily yield per cow	
		Milk	Fat
South Carolina Station		Lbs.	Lbs.
Lot I			
Cotton-seed meal, 5.1 lbs.	Corn silage, 34.8 lbs.	16.4	0.71
Lot II			
Wheat bran, 3.4 lbs.			
Cotton-seed meal, 3.4 lbs.	Corn silage, 32.1 lbs.	15.9	0.68
New Jersey Station			
Lot I			
Cotton-seed meal, 4.5 lbs.	Corn silage, 36 lbs.		
	Corn stalks, 6 lbs.	22.7	0.96
Lot II			
Wheat bran, 5 lbs.	Corn silage, 36 lbs.		
Dried brewers' grains, 5 lbs.	Corn stalks, 6 lbs.	23.9	0.95

In a feeding trial with 24 cows lasting 120 days at the Virginia Station,[2] Soule and Fain, comparing cotton-seed meal and gluten meal, found that the relative amount of digestible crude protein contained in these feeds was a fair measure of their feeding value. At the Texas Station,[3] in trials with 18 cows lasting 56 days, Soule found that 6 lbs. of cotton-seed meal fed daily as the sole concentrate proved more effective and gave larger profits than the larger allowance of 7 to 10 lbs. Moore of the Mississippi Station[4] found 100 lbs. of cotton-seed meal equal to 171 lbs. of cotton seed in feeding value for dairy cows. (**190**)

642. Cocoanut cake.—Hansen of the Royal Agricultural Academy, Germany,[5] found that cocoanut cake and the residues from the manufacture of palm oil produced practically the same amount of milk as wheat bran, but increased to a marked extent the fat content of the milk. Palmnut cake obtained by pressure had the same influence as palmnut meal obtained by extraction. (**204**)

643. Soybean cake.—Gilchrist[6] of the Armstrong College, England, found soybean cake slightly superior to cotton-seed cake for milk production. In an experiment lasting 6 weeks, Hansen of the Royal Agricultural Academy, Germany,[7] found soybean cake and

[1] Bul. 70.
[2] Bul. 156.
[3] Bul. 47.
[4] Bul. 60.
[5] U. S. Dept. Agr., Expt. Sta. Rec., 17, p. 901.
[6] Mark Lane Express, 100, 1909, p. 667.
[7] Deutsche Land. Presse, 36, 1909.

linseed cake of practically equal value for milk production when added to a basal ration of hay, bran, and sugar-beet chips. Tho a daily allowance of 4 to 7 lbs. of soybean cake was fed, no ill effects resulted. (**201**)

Lindsey of the Massachusetts Station[1] found that soybean meal from which the oil had been extracted did not modify the composition of the milk nor exert a marked influence on the body of the butter. The feeding of soybean oil temporarily increased the percentage of fat in the milk and produced a softer, more yielding butter. (**630**)

In view of the present vast importance of the soybean in the Orient and its rapidly increasing use in Europe and America, these various trials are significant and suggestive.

644. Wet beet pulp.—Wing and Anderson of the Cornell Station[2] found that cows will eat 50 to 100 lbs. of fresh beet pulp per day in addition to 8 lbs. of grain and 6 to 12 lbs. of hay. The dry matter in wet beet pulp proved equal to the dry matter in corn silage. The milk-producing value of beet pulp as it comes from the factory is about one-half that of corn silage. Beet pulp may have a higher value than given above if no other succulent food is supplied. The fermented pulp appears to be more palatable and satisfactory, tho even fresh pulp seems to stimulate the consumption of dry roughage. There are occasional reports of beet pulp tainting the milk. Buffum and Griffith of the Colorado Station[3] found 2 lbs. of fresh beet pulp equal to 1 lb. of sugar beets for dairy cows. (**309**)

645. Dried beet pulp.—Billings of the New Jersey Station[4] fed 2 lots of 2 cows each alternately for two 15-day periods on dried beet pulp and corn silage with other feeds as given below:

Dried beet pulp compared with corn silage.

Average ration	Average daily yield per cow	
	Milk	Fat
Lot I	Lbs.	Lbs.
Dried beet pulp, 9 lbs. Mixed hay, 10 lbs. Rich concentrates, 10.5 lbs.	33.6	1.39
Lot II		
Corn silage, 45 lbs. Mixed hay, 5 lbs. Rich concentrates, 10.5 lbs.	30.2	1.25

It will be seen that, where 9 lbs. of dried beet pulp and 5 lbs. mixed hay replaced 45 lbs. of corn silage, the cows gave 3.4 lbs., or

[1] Rpt. 1908. [2] Bul. 183. [3] Bul. 73. [4] Bul. 189.

11 per ct., more milk. Woll and Humphrey of the Wisconsin Station[1] place dried beet pulp at two-thirds the value of wheat bran. (**311, 755**)

646. Dried molasses-beet pulp.—Billings of the New Jersey Station[2] found dried molasses-beet pulp equal in feeding value to dried beet pulp for dairy cows. Dried molasses-beet pulp proved almost as valuable as an equal weight of hominy meal, the cows eating the dried molasses-beet pulp with more eagerness and remaining in better health. The milk from cows fed on dried molasses-beet pulp at first had a sweet taste, which soon passed away. Humphrey and Woll of the Wisconsin Station,[3] when feeding 3 lbs. of dried molasses-beet pulp against 2 lbs. of wheat bran, found that 12 per ct. more milk was produced on the dried molasses-beet pulp than on the bran. Hills of the Vermont Station,[4] on substituting 2.7 lbs. of dried molasses-beet pulp for an equal weight of wheat bran, secured a slightly greater milk flow. "Occasionally a cow showed some looseness of the bowels, due apparently to the feed, but nothing serious was noted." (**312, 755**)

647. Dried distillers' grains.—Lindsey of the Massachusetts Station[5] compared dried distillers' grains with gluten feed in trials with 6 cows, covering 2 alternate periods of 4 weeks each. The ration and daily returns per cow are given in the table:

Dried distillers' grains compared with gluten feed.

Average ration		Average daily yield per cow	
		Milk	Fat
Lot I		Lbs.	Lbs.
Dried distillers' grains, 3.7 lbs.	Blue grass hay, 10.7 lbs.		
Wheat bran, 3.0 lbs.	Rowen hay, 10.7 lbs.	25.8	1.23
Lot II			
Gluten feed, 3.7 lbs.	Blue grass hay, 10.6 lbs.		
Wheat bran, 3.0 lbs.	Rowen hay, 10.7 lbs.	24.3	1.18

It will be seen that the ration containing dried distillers' grains produced 1.5 lbs., or 6 per ct., more milk than that containing the gluten feed. Hills of the Vermont Station[6] found that dried distillers' grains produced 5 per ct. more product than dried brewers' grains. A mixture of 1 part wheat bran and 2 parts dried distillers' grains produced 4 per ct. more milk and fat than did dried distillers' grains alone. Dried distillers' grains produced one-eighth more milk

[1] Rpt. 1905.
[2] Rpt. 1904.
[3] Rpt. 1905.
[4] Rpt. 1904.
[5] Bul. 94.
[6] Rpt. 1907.

and one-sixth more fat than a mixture of equal parts of corn meal and bran. Dried distillers' grains and cotton-seed meal proved equally efficient, but the latter proved more economical. Dried distillers' rye grains made less milk and butter than did the alcohol grains. Armsby and Risser of the Pennsylvania Station[1] found that the substitution of dried distillers' grains for an equal weight of a mixture of 3 lbs. of cotton-seed meal and 2.5 lbs. of corn meal caused a slight increase in the milk yield. The butter from the distillers'-grains ration was not quite as high in quality as that from the cotton-seed meal ration. On the other hand, Billings of the New Jersey Station[2] reports that the butter from cows fed dried distillers' grains was firm, of good flavor and texture, and very marketable. (**317**)

648. Dried brewers' grains.—At the Massachusetts Station[3] Lindsey compared dried brewers' grains with wheat bran for cows. Seven cows, divided into 2 lots, were fed in 2 alternate periods covering 4 weeks each, the ration and daily returns being as follows:

Dried brewers' grains compared with wheat bran.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Dried brewers' grains, 4.3 lbs.	Corn silage, 26.3 lbs.		
Gluten feed, 3.0 lbs.	Blue-grass hay, 12.1 lbs.	21.4	1.1
Lot II			
Wheat bran, 4.4 lbs.	Corn silage, 26.2 lbs.		
Gluten feed, 3.0 lbs.	Blue-grass hay, 12.6 lbs.	20.8	1.1

The results show dried brewers' grains somewhat superior to wheat bran for milk production. Hills of the Vermont Station[4] found dried brewers' grains and wheat bran equal in feeding value to a mixture of cotton-seed meal, linseed meal, and wheat bran. Hayward and Weld of the Pennsylvania Station[5] found dried brewers' grains equal to buckwheat middlings. (**175**)

649. Malt sprouts.—Lindsey of the Massachusetts Station[6] fed malt sprouts against gluten feed to cows getting a basal ration composed of 10 lbs. of Kentucky blue-grass hay, 10.4 lbs. rowen hay, 2 lbs. wheat bran, and 1 lb. corn meal. The additional concentrates fed appear in the table together with the daily yield of milk and fat.

It will be seen that 2 lbs. of malt sprouts were hardly equal to 1.5 lbs. of gluten feed. Hills of the Vermont Station[7] found that

[1] Bul. 73.
[2] Rpt. 1907.
[3] Bul. 94.
[4] Rpt. 1903.
[5] Bul. 41.
[6] Bul. 94.
[7] Rpt. 1907.

malt sprouts were not relished by cows, some refusing them whether dry or soaked. When fed against cotton-seed meal and linseed meal, the cows took less food and their milk fell off one-tenth. When fed against ground oats, the cows ate 9 per ct. less food and their milk fell off 4 per ct. Since malt sprouts are not relished by cows, not over 2 lbs. should be fed at one time. Lindsey states that they may form one-third of the concentrates of the ration, and at prevailing prices to this limited extent they are an economical nutrient. (**176**)

Malt sprouts compared with gluten meal.

Average ration	Average daily yield per cow	
	Milk	Fat
	Lbs.	Lbs.
Lot I		
Malt sprouts, 2.0 lbs.		
Gluten feed, 1.5 lbs. Basal ration	18.1	0.89
Lot II		
Gluten feed, 3.0 lbs. Basal ration	18.2	0.91

650. Cereal by-products v. pure grains.—To determine whether the digestible matter in such by-products as dried brewers' grains, malt sprouts, and gluten feed are as valuable as the digestible matter of the pure grains, Jordan and Jenter of the New York (Geneva) Station[1] fed the following rations:

Ration No. 1	Lbs.
Ground oats	5
Ground peas	6
Timothy hay	5
Corn silage	40

Ration No. 2	Lbs.
Malt sprouts	2
Dried brewers' grains	3
Gluten feed	3
Timothy hay	15
Corn silage	25

Each ration was fed to 5 cows for 9 weeks with the following results:

Comparison of pure grains and cereal by-products for milk production.

	Ration No. 1		Ration No. 2	
	Digestible matter eaten	Milk solids produced	Digestible matter eaten	Milk solids produced
	Lbs.	Lbs.	Lbs.	Lbs.
Total, 5 cows for 63 days	4,807.9	865.0	4,435.8	861.5
Daily average, 1 cow	15.3	2.7	14.1	2.7
Digestible nutrients fed for 1 lb. milk solids	5.6		5.2	

[1] Bul. 141.

The table shows that the ration containing malt sprouts, brewers' grains, and gluten feed was rather more efficient for milk production than one of oats and peas, containing slightly more digestible matter.

651. Flesh meal, fish scrap.—In a trial by Schrodt and Peters,[1] bran and rape cake were gradually replaced by equal quantities of flesh meal until the allowance of the latter reached 2.2 lbs. per head daily. It was found that the customary shrinkage in live weight when in full milk flow did not occur, and there was an increase in the total quantity of milk as well as in the total solids and fat. Flesh meal effected a saving of 2 lbs. of feed per head daily, and the cows learned to relish it highly. (**756**)

According to Kühn,[2] milk and butter of normal quality were produced on a daily allowance of 2.3 lbs. of fat-free fish scrap supplied with a variety of other feed, no deleterious effects resulting. (**306**)

652. Skim milk.—Beach and Clark of the Connecticut (Storrs) Station[3] found that when sweet separator skim milk was offered to the herd of 24 cows, only 4 would drink it, even tho water was withheld as long as 48 hours and grain was mixed with the milk. Skim milk was substituted for half the grain in the ration at the rate of 8 lbs. of milk for 1 of concenerates, and about 1 ton of milk was fed to each of the 4 cows. Feeding the skim milk caused a small increase in milk flow and a saving of grain, which, taken together, gave to the milk so fed a value of 19 cents per cwt., which is less than pigs would have returned. (**302**)

653. Whey.—At the Kiel Dairy Station[4] Schrodt fed cows a ration composed of 11 lbs. clover hay, 5.5 lbs. barley straw, 10 lbs. mangels, 5.5 lbs. wheat bran, and 2.2 lbs. palmnut meal. During one period 11 lbs. of sweet whey was fed, and during another an allowance of 22 lbs. The whey had a favorable influence on the quantity of milk yielded, and no deleterious effect on the quality of the butter. (**304**)

III. Silage; Roots; Soilage.

654. Corn silage v. corn fodder.—Voorhees and Lane of the New Jersey Station[5] planted a 15-acre field to corn in rows 3.5 feet wide. with the stalks 8 inches apart in the row. When the ears were glaz-

[1] Füh. Landw. Ztg., 1892, p. 836.
[2] Jahresber. Agr. Chemie, 1894, p. 482.
[3] Rpt. 1904.
[4] Landw. Wochenbl. Schl. Hol., 1882, p. 237; Jahresber. Agr. Chemie, 1882, p. 441.
[5] Bul. 122.

ing, the crop from 12 acres, averaging 11.25 tons of green forage. was run thru the feed cutter and placed in the silo. The remaining 3 acres was harvested by cutting and shocking. After curing in the field for a month, the unhusked fodder, yielding 4.1 tons per acre, was stored in the barn. The cost of ensiling the crop was $11.22 per acre, while cutting, shocking, storing the unhusked fodder in the barn, and later running it thru the feed cutter cost $10.31 per acre.

The next step was to test the relative merits of the silage and fodder. Two lots of 4 cows each were fed silage and fodder corn, respectively, for 2 twelve-day periods as shown below, the rations being reversed at the close of the first feeding period. The silage was eaten without waste, while a portion of the fodder corn was left uneaten. Both lots of cows gained in weight during the trial.

Corn silage compared with corn fodder.

Average ration		Average daily yield per cow	
		Milk	Fat
Lot I		Lbs.	Lbs.
Corn silage, 44.0 lbs.	Wheat bran, 4.6 lbs. Dried brewers' grains, 3.4 lbs. Corn meal, 1.1 lbs. Linseed meal, 1.1 lbs.	23.7	0.90
Lot II			
Corn fodder, 14.3 lbs.	Concentrates as above	21.0	0.90

The table shows that the silage-fed cows averaged 2.7 lbs., or 12.8 per ct., more milk daily than those on dry fodder corn—a convincing example of the merits of corn silage.

Hills of the Vermont Station[1] found that cows fed green fodder corn early in September shrank 5 per ct. in butter yield, while others fed corn silage pitted the previous year gained 8 per ct. (**350**)

655. Corn silage v. hay.—At the Maine Station[2] Jordan fed cows first with good hay, later with hay and silage, and again with hay, all getting the same amount of concentrates. The yield of 4 cows for 14-day periods, just preceding or following a change in the ration, was as follows:

When fed on hay	1,212 pounds
When changed to silage and hay	1,297 pounds
An increase of 85 lbs., or 7 per ct.	
When fed on silage and hay	1,200 pounds
When changed to hay	1,098 pounds
A decrease of 102 lbs., or 8 per ct.	

[1] Rpt. 1907. [2] Rpt. 1889.

We observe that when the cows were changed from good hay to silage and hay their milk flow increased 7 per ct., and when changed back it decreased 8 per ct. In this trial 440 lbs. of corn silage proved somewhat superior to 100 lbs. of good hay (mostly timothy). Jordan holds that when good timothy hay is worth $10 per ton, average corn silage is worth $2.62 per ton.

In an extended trial with 6 cows Hills of the Vermont Station[1] found that when 3.5 lbs. of corn silage was substituted for 1 lb. of mixed timothy, red top, and clover hay, the milk yield was increased 7 per ct. Rating hay at $10 and silage at $3 per ton, there was a gain of 1.66 cents daily per cow by replacing one-third of the hay with silage. From available data it is fair to conclude that for dairy cows 100 lbs. of good mixed hay is worth as much as 400 to 450 lbs. of average corn silage.

656. Corn silage v. sugar beets.—Haecker of the Nebraska Station[2] compared corn silage and sugar beets with 2 lots of 5 cows each, fed for a period of 5 weeks with the results shown below. The concentrates consisted of equal parts of oats, corn, and wheat bran.

Corn silage compared with sugar beets.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Corn silage, 30 lbs.			
Alfalfa hay, 10 lbs.	Concentrates, 6–10 lbs.	17.4	0.84
Lot II			
Sugar beets, 30 lbs.			
Alfalfa hay, 10 lbs.	Concentrates, 6–10 lbs.	16.1	0.78

It is shown that where 30 lbs. of corn silage was fed against an equal weight of sugar beets, the small difference in yield of milk and fat was in favor of the silage. (**352**, **563**)

657. Apple-pomace silage.—Hills of the Vermont Station[3] fed as much apple-pomace silage as the cows would consume in addition to 8 lbs. of grain and 10 to 12 lbs. of hay. On apple-pomace silage the cows consumed somewhat more dry matter than those getting corn silage, with a corresponding increase in milk flow. The apple-pomace silage had no deleterious influence on the cows or their milk. Lindsey of the Massachusetts (Hatch) Station[4] holds that apple-pomace silage is equal to average corn silage in feeding value. (**360**)

[1] Rpt. 1901. [2] Bul. 76. [3] Rpt. 1903. [4] Rpt. 1905.

658. Mixed silage v. heavy concentrates.—At the Ohio Station[1] Williams fed 2 uniform lots of 4 cows each the rations reported in the table during 4 months, to determine whether a large part of the concentrates usually supplied could not be replaced by silage composed of 2 parts soybeans, 1 part cowpeas, and 7.5 parts of rather watery corn silage. The 2 rations contained practically the same amount of dry matter and crude protein.

Feeding mixed silage in place of part of the concentrates.

Average ration		Average daily yield per cow Milk	Fat
		Lbs.	Lbs.
Lot I			
Silage, 58.0 lbs.	Oil meal, 2.0 lbs.		
Mixed hay, 6.8 lbs.	Bran, 2.0 lbs.	19.6	1.03
Lot II			
Stover, 4.7 lbs.	Oil meal, 2.5 lbs.		
Mixed hay, 6.5 lbs.	Corn meal, 5.0 lbs.		
	Bran, 6.0 lbs.	16.9	0.80

It is seen that the cows fed 58.0 lbs. of mixed silage with 4 lbs. of concentrates yielded more milk and fat than those receiving 13.5 lbs. of rich, expensive concentrates and no silage. Less dry matter was consumed by the silage-fed cows for 1 lb. of fat than by those getting no silage. During the trial the fat yield of the silage-fed cows increased 1.9 per ct., while that of the others shrank 14.2 per ct. These results forcibly illustrate how protein-rich silage may aid the dairyman in reducing the expense of producing milk. (**707, 711**)

659. Other silage studies.—As a result of feeding trials Hills of the Vermont Station[2] found that: Rye silage was dryer and less readily eaten than corn silage, and made 10 per ct. less milk and butter. Cows changed from corn to rye silage shrank 20 per ct. in milk, while on changing back from rye to corn they gained 2 per ct. Good corn silage gives better results than good Hungarian grass hay or silage. Ensiled peas, vetch, and oats keep as well as corn silage, and are as valuable for dairy cows. (**360-1**)

660. Roots.—The Copenhagen Station[3] studied the value of roots for milk production with 636 cows for 3 years on various farms. The addition of 40 lbs. of mangels or 50 lbs. of turnips to an ordinary ration increased the milk flow by as much as 1.8 to 2.9 lbs. daily, the cows gaining somewhat in weight and the consumption of straw being

[1] Bul. 155. [2] Rpt. 1907. [3] Rpt. 1890.

lessened 0.6 to 2.1 lbs. daily. One pound of concentrates in the form of grain, bran, and oil cake proved equal to 10 lbs. of mangels. The water content of the milk was not materially changed by feeding varying quantities of roots. Indeed the cows eating the largest quantity of roots gave the richest milk. These extensive experiments prove, beyond question, that the milk of the cow cannot be watered by feeding roots. (**275-6**)

661. Roots v. concentrates.—Friis of the Copenhagen (Denmark) Station[1] conducted feeding trials on 6 different farms with 4 lots of 10 to 12 cows each in the following manner: All received the same basal ration, consisting of 6.5 lbs. of hay and 10 lbs. of straw. The concentrates consisted of a mixture of barley, oats, and rye with cotton-seed meal. Each cow received at least 4.5 lbs. of dry matter in the form of mangels. Three lbs. of cotton-seed meal was withheld from the ration of Lot III, and in its stead sufficient mangels were supplied to furnish 3 lbs. of dry matter. With Lot IV, 3 lbs. of cereal grains was withheld and 3 lbs. of dry matter supplied in mangels.

Substituting roots in part for grain in the ration for dairy cows.

	Concentrates given			Daily yield of milk per cow
	Cereal grains	Cotton-seed meal	Dry matter in mangels	
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I	7	1.5	4.5	22.4
Lot II	4	4.5	4.5	23.7
Lot III	4	1.5	7.5	22.5
Lot IV	1	4.5	7.5	24.2

It will be seen that when 3 lbs. of grain or cotton-seed meal replaced an equal amount of dry matter in the form of mangels, there was an increase rather than a decrease in the milk flow. From this and other feeding trials the conclusion was drawn that for cows 1 lb. of dry matter in roots is equal in feeding value to 1 lb. of Indian corn, mixed grains—barley, oats, and rye—or 0.75 lb. of cotton-seed meal.

Wing and Savage of the Cornell Station,[2] from carefully conducted experiments with dairy cows, conclude:

That 1 lb. of dry matter in mangels is slightly superior to 1 lb. of dry matter in corn silage.

[1] Expt. Sta. Rec., 14, 1903, p. 801; Landökon. Forsög (Copenhagen), 1902, p. 30.

[2] Bul. 268.

That 1 lb. of dry matter in mangels is equal to 1 lb. of dry matter in grain, and that mangels may replace half the grain ordinarily fed in a ration composed of grain, mixed hay, and silage.

The Cornell studies led to the conclusion that, when concentrates cost $30 per ton, mangels are an economical feed for dairy cows when they can be produced and stored for $4 per ton,—a high price for this easily-grown crop. **(351-3)**

Hills of the Vermont Station,[1] in a trial with 8 cows fed 16 weeks, found that the dry matter in corn silage was equal to the same weight of dry matter in beets or carrots.

In a trial with 6 cows for 12 weeks, Hills found the dry matter of corn silage superior to that in potatoes. The cows ate the potatoes readily, but they made neither more nor better milk. At 15 cents a bushel the potatoes were more costly than corn silage. The butter from the potato-fed cows was unsatisfactory.

662. Soilage v. silage.—For 7 years the New Jersey Station[2] fed soilage from May 1st to November 1st, and silage the other 6 months. The cows freshened quite uniformly thruout the year. The yield of milk and fat by the 23 cows in the herd for each 6-months period is shown below:

	Average yield per cow	
	Milk	Fat
Lot I, Soilage, May 1st–Nov. 1st	3,402 lbs.	146.8 lbs.
Lot II, Silage, Nov. 1st–May 1st	3,024 lbs.	132.4 lbs.

It is shown that the cows getting soilage returned about 13 per ct. more milk than those fed silage. In view of the fact that soilage was fed in summer and silage in winter, we may regard the two means of maintaining cows as practically equal so far as the yield of milk and fat are concerned. Such being the case, the dairyman seeking to maintain his herd economically, while at the same time securing the largest possible returns, has the choice of two practical systems of supplying forage.

663. Soilage v. pasturage.—During several years at the Utah Station[3] Linfield compared pasture with soilage. A tract on which orchard grass, blue grass, and alfalfa were grown was divided so that one portion could be pastured while the other furnished soilage. During one year soilage crops were especially grown, in which case they consisted of alfalfa, vetch, peas, and oats. Both tracts were irrigated so that maximum yields were possible. No other food than the prod-

[1] Rpt. 1907. [2] Rpt. 1903. [3] Bul. 68.

uct of an acre in each case was supplied. The results of the trial are thus summarized by Linfield:

	Returns from 1 acre of— Soilage (Av. 3 yrs.)	Pasturage (Av. 4 yrs.)
Two cows were kept, days	108	102
They produced in milk, lbs.	3,055	4,447
They produced in butter fat, lbs.	142.9	189.8
They gained or lost in weight, lbs.	+105	−66

It is shown that with irrigation under Utah conditions pasturage was more economical than soilage.

IV. The Various Dry Roughages.

664. Cured fodder corn v. timothy hay.—At the Pennsylvania Station[1] Hunt and Caldwell fed cured fodder corn (corn grown for the forage) against timothy hay to 2 lots, each of 4 cows, for 45 days, with the results shown in the table:

Fodder corn compared with timothy hay.

Average ration		Average daily yield per cow		Gain or loss in weight
		Milk	Fat	
		Lbs.	Lbs.	Lbs.
Lot I				
Fodder corn, 22.8 lbs.	Ground oats, 3 lbs. Wheat bran, 3 lbs.	16.2	0.66	−23
Lot II				
Timothy hay, 22.3 lbs.	Ground oats, 3 lbs. Wheat bran, 3 lbs.	17.1	0.64	+84

The cows fed hay gained in weight, while those on fodder corn lost. Taking all the facts into consideration, the fodder corn proved almost as valuable as the same weight of timothy hay. Two tons of timothy hay per acre is a good return, while the yield of fodder corn used in this trial was nearly 4.5 tons per acre, or over twice that of the timothy hay. The high value of fodder corn for the dairy cow is thus apparent. **(217, 224)**

665. Corn stover v. mixed and clover hay.—At the Wisconsin Station[2] the author compared corn stover (husked shocked corn forage) with hay for dairy cows under the following conditions:

A crop of yellow dent corn yielding 4,490 lbs. of cured stalks and 4,941 lbs. of ear corn per acre was cut and shocked in the usual manner. After drying, the corn was husked and the stalks reserved for

[1] Rpt. 1892. [2] Rpt. 1884.

feeding. The hay fed in the first trial consisted of one-third clover and two-thirds timothy, and in the second early-cut medium red clover was used. Two good fresh cows were fed hay, while 2 others were fed the uncut stover mentioned above. After 3 weeks the feeds were reversed and the trial repeated.

In the first trial it was found that when supplemented by 280 lbs. of corn meal and 392 lbs. of wheat bran—

2,374 lbs. of corn stover returned 1,121 lbs. of milk, making 57 lbs. of butter.

755 lbs. of mixed hay returned 1,064 lbs. of milk, making 56 lbs. of butter.

Since the returns are practically equal, we may conclude that 1 ton of mixed timothy and clover hay is worth 3 tons of corn stover, or husked corn fodder, fed uncut as described. (**501**)

In the second trial, when corn stover was compared with clover hay, grain being fed as before, it was found that—

1,867 lbs. of corn stover returned 1,079 lbs. of milk, making 52 lbs. of butter.

643 lbs. of clover hay returned 1,059 lbs. of milk, making 55 lbs. of butter.

In this trial 1 ton of clover hay was found to be somewhat superior to 3 tons of uncut corn stover. Thirty-four per ct. of the coarse uncut stover was left uneaten in these trials. This shows the heavy loss incident to feeding dry corn forage, which if ensiled would be wholly consumed. (**218, 254**)

666. Meadow fox-tail hay.—In a feeding trial at the Mustiala (Finland) Agricultural College,[1] cows were fed from 12 to 18 lbs. of meadow fox-tail *(Alopecurus)* hay or timothy hay daily, together with oat straw without limit, both lots receiving the same amount of concentrates and roots. The meadow fox-tail hay produced 5.5 per ct. more milk than the timothy hay.

667. Upland prairie v. timothy hay.—Haecker of the Minnesota Station[2] compared native upland prairie hay of excellent quality with medium fine, early-cut timothy hay properly cured. Sixteen cows were used during the trial lasting 77 days, the same quantity of grain and hay being supplied in each case. The returns in milk and fat were practically the same from the two kinds of hay. Later this study[3] was repeated with the same results. It is fair, then, to hold that good upland prairie hay, like that of the Minnesota region, is equal to timothy hay with the dairy cow.

[1] Biet. 1893. [2] Bul. 35. [3] Bul. 67.

668. Johnson-grass hay.—Moore of the Mississippi Station[1] found Johnson-grass hay nearly as valuable as cowpea hay when corn silage, cotton-seed meal, and wheat bran were the other feeds given. Had less rich and palatable concentrates been fed, Johnson-grass hay would probably have shown but half to two-thirds of the value of the cowpea hay. (**233**)

669. Bermuda hay.—Lloyd of the Mississippi Station,[2] studying the returns from a herd of 30 to 60 cows during 3 years, concludes that Bermuda hay equals timothy hay for milk and butter production. (**232**)

670. Salt-marsh hay.—Lindsey and Jones of the Massachusetts (Hatch) Station[3] found in trials with 12 cows, covering 7 months, that where 10 lbs. of various kinds of salt-marsh hay was given daily in place of an equal weight of English hay, the milk flow was decreased from 2 to 5 per ct. They state: "When fed directly after milking, no objectionable flavor could be detected in the milk or butter. It is possible that if these hays were cut very soon after being covered by the tide they would then produce a disagreeable flavor."

671. Cotton-seed hulls.—Moore of the Mississippi Station,[4] in feeding trials with dairy cows, found 100 lbs. of well cleaned cottonseed hulls equal to 67 lbs. of prime Johnson-grass hay. Soule of the Texas Station[5] found cotton-seed hulls nearly equal to sorghum hay for cows. Nourse of the Virginia Station[6] considers cotton-seed hulls about equal to oat straw in feeding value. Conner of the South Carolina Station[7] found cotton-seed hulls decidedly inferior to corn stover in feeding value. Cotton-seed hulls furnish a roughage of fair value in carbohydrates, but are very deficient in crude protein (**193**)

672. Alfalfa hay and fodder corn v. alfalfa hay.—During 4 seasons at the Utah Station[8] Linfield fed 2 lots of cows as shown below, the concentrates supplied consisting of half wheat bran and half wheat, barley, or corn meal:

Alfalfa hay and fodder corn compared with alfalfa hay.

Average ration	Average daily yield per cow	
	Milk	Fat
	Lbs.	Lbs.
Lot I		
Alfalfa hay, 11.5 lbs.		
Fodder corn, 8.7 lbs. Concentrates, 6 lbs.	16.9	0.75
Lot II		
Alfalfa hay, 21.5 lbs. Concentrates, 6 lbs.	17.1	0.74

[1] Bul. 70.
[2] Rpt. 1895.
[3] Bul. 50.
[4] Rpt. 1903.
[5] Bul. 47.
[6] Bul. 148.
[7] Bul. 66.
[8] Bul. 68.

It is seen that when fodder corn replaced nearly one-half the alfalfa hay, about as good returns were secured as when alfalfa hay alone constituted the roughage. These trials show that where corn and alfalfa flourish, both should be used rather than alfalfa alone. (**245**)

673. Alfalfa meal v. wheat bran.—Hills of the Vermont Station,[1] on substituting alfalfa meal (ground alfalfa hay) for the same weight of wheat bran, found a loss of from 3 to 6 per ct. in milk flow caused thereby, and Mairs of the Pennsylvania Station[2] found a loss of about 5 per ct. by such substitution. (**248**)

674. Soybean, cowpea, and Japan clover hay.—At the Tennessee Station[3] Price compared soybean straw and ground soybeans, combined in the same proportion as in soybean hay, with alfalfa hay in a trial with 2 lots of 4 cows each. The returns from rations alternately fed during 3 periods of 30 days each are shown below:

Soybean hay v. alfalfa hay.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Soybean straw, 7.1 lbs. Silage, 25.0 lbs.	Ground soybeans, 3.7 lbs. Corn-and-cob meal, 3.7 lbs.	17.2	0.98
Lot II			
Alfalfa hay, 12.3 lbs. Silage, 24.6 lbs.	Corn-and-cob meal, 3.7 lbs.	15.1	0.80

The table shows that the soybean ration proved more effective than the alfalfa-hay ration. Price concludes: "A ton of soybean hay that can be produced (in Tennessee) for $7 has a higher feeding value than a ton of alfalfa hay."

Wing of the Georgia Station[4] found that cowpea hay produced 30 per ct. more milk than cotton-seed hulls, a reasonable result when the composition of the two is considered.

Lloyd of the Mississippi Station[5] reports Japan clover hay preferable to timothy hay. (**201**)

V. Substituting Protein-rich Roughages for All or Part of the Expensive Concentrates of the Ration.

675. Alfalfa hay.—At the New Jersey Station[6] Billings alternately fed 2 lots of 4 cows each for two 30-day periods as follows: One lot received 40 lbs. corn silage, 7 lbs. corn stover, and 11 lbs. of

[1] Rpt. 1906.
[2] Bul. 80.
[3] Bul. 80.
[4] Bul. 49.
[5] Rpt. 1891.
[6] Buls. 190, 204.

protein-rich concentrates, consisting of wheat bran, dried brewers' grains, and cotton-seed meal. The other lot was given 35 lbs. corn silage, no corn stover, and 2.5 lbs. cotton-seed meal, together with 14 lbs. of alfalfa hay in place of the rest of the rich concentrates given to the first lot.

In the second trial 2 lots of 4 cows each were fed for two 60-day periods, one lot getting 40 lbs. corn silage, 6.8 lbs. corn stover, and a little over 9 lbs. of rich concentrates, and the other 35 lbs. corn silage, 17.5 lbs. of alfalfa hay, and no concentrates. In both trials the feeding was reversed so that both lots were on both sides of the test.

Substituting alfalfa hay for part or all of the rich concentrates in the ration.

Average ration		Average daily yield per cow	
		Milk	Fat
	First trial	Lbs.	Lbs.
Lot I Corn stover, 7.0 lbs. Corn silage, 40.0 lbs.	Wheat bran, 4.5 lbs. Dried brewers' grains, 4.5 lbs. Cotton-seed meal, 2.0 lbs.	27.3	1.13
Lot II Alfalfa hay, 14.0 lbs. Corn silage, 35.0 lbs.	Cotton-seed meal, 2.5 lbs.	26.3	1.05
	Second trial		
Lot I Corn stover, 6.8 lbs. Corn silage, 40.0 lbs.	Dried distillers' grains, 4.6 lbs. Wheat bran, 4.2 lbs. Cotton-seed meal, 0.5 lb.	24.6	1.07
Lot II Alfalfa hay, 17.5 lbs. Corn silage, 35.0 lbs.	No concentrates	20.4	0.88

Studying the first trial we note that where alfalfa hay replaced all the corn stover, some of the silage, and nearly all of the rich concentrates, there was a shrinkage of only 1 lb. of milk per cow daily.

The second trial was more severe, since 17.5 lbs. of alfalfa hay replaced 5 lbs. corn silage, 6.8 lbs. corn stover, and over 9 lbs. of rich concentrates. In this trial each cow getting the heavy alfalfa-hay allowance and no concentrates gave 4.2 lbs. less milk per day than those given more corn silage, some corn stover, and over 9 lbs. of rich concentrates. In both trials alfalfa hay shows a surprising feed value.

In a trial lasting 12 weeks with 8 cows at the New Mexico Station[1] Vernon found that 246 lbs. of alfalfa hay alone, or 202 lbs. of alfalfa

[1] Rpt. 1904.

hay and 50 lbs. of wheat bran, produced 100 lbs. of milk. The cows produced more milk on the bran-alfalfa ration, but the increase was dearly purchased. The findings of Soule of the Tennessee Station[1] confirm the above results.

Hansen of the Royal Agricultural Academy, Germany,[2] on feeding 40 cows 140 days, found that 800 to 933 lbs. of green alfalfa equaled 100 lbs. of sunflower seed cake in feeding value, with cows pastured a portion of the day or wholly confined to the stable. (**709**)

676. Crimson clover hay.—At the New Jersey Station[3] Lane fed 2 lots, each of 2 cows, for 2 periods of 12 days each, alternately on the rations shown below:

Crimson clover hay fed against purchased protein.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Crimson clover hay, 16.4 lbs.			
Corn silage, 30.0 lbs.	No concentrates	20.1	0.85
Lot II			
Mixed hay, 5.0 lbs.	Wheat bran, 6 lbs.		
Corn silage, 30.0 lbs.	Dried brewers' grains, 5 lbs.	23.8	1.00

The table shows that the yield of milk was 3.7 lbs. and of fat 0.15 lb. less on the crimson clover ration than on that containing purchased concentrates. Using the home-grown ration, however, effected a saving of 18.3 cents in the cost of producing 100 lbs. of milk. (**257**)

677. Crimson clover hay and cowpea silage.—Lane[4] also compared a ration of crimson clover hay, cowpea silage, and corn-and-cob meal with one in which the crude protein was largely purchased. The following rations were fed alternately for 2 periods of 12 days each to 2 lots of 2 cows each:

Crimson clover hay and cowpea silage compared with purchased protein.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
Lot I			
Crimson clover hay, 10 lbs.			
Cowpea silage, 36 lbs.	Corn-and-cob meal, 6.0 lbs.	24.8	0.94
Lot II			
Mixed hay, 5 lbs.	Dried brewers' grains, 5.0 lbs.		
Corn silage, 36 lbs.	Cotton-seed meal, 2.5 lbs.	24.6	0.99

[1] Bul. Vol. XVII, 4. [2] Expt. Sta. Rec., 20, 572. [3] Bul. 161. [4] Loc. cit.

The amount of milk and fat produced was practically the same for both rations, showing the high value of crimson clover hay and cowpea silage as sources of protein for dairy cows.

678. Cowpea hay.—At the New Jersey Station[1] Lane alternately fed 2 lots of 2 cows each rations containing either cowpea hay or rich purchased concentrates for periods of 15 days, with the results shown in the table:

Cowpea hay compared with purchased protein.

Average ration		Average daily yield per cow: Milk	Average daily yield per cow: Fat
		Lbs.	Lbs.
Lot I			
Cowpea hay, 17 lbs.			
Corn silage, 36 lbs.	No concentrates	23.7	0.92
Lot II			
Corn stover, 5 lbs.	Wheat bran, 4 lbs.		
Corn silage, 36 lbs.	Dried brewers' grains, 3 lbs.		
	Cotton-seed meal, 2 lbs.	25.7	1.05

Tho 2 lbs. more milk and 0.13 lb. more fat were produced by each cow daily on the ration containing purchased concentrates, this increase was not sufficient to offset the greater cost of the purchased feed. (**261**)

679. Cowpea hay v. wheat bran.—At the Alabama Station[2] Duggar fed 2 lots of 3 cows each cotton-seed hulls and a basal ration of 2 parts cotton seed and 1 part each of wheat bran and cotton-seed meal. In addition the cows in Lot I received cowpea hay and those in Lot II wheat bran with the results shown below:

Cowpea hay compared with wheat bran.

Average ration		Average daily yield per cow: Milk	Average daily yield per cow: Fat
		Lbs.	Lbs.
Lot I			
Cowpea hay, 7.8 lbs.			
Basal ration, 9.6 lbs.	Cotton-seed hulls, 9.6 lbs.	17.3	1.13
Lot II			
Wheat bran, 6.1 lbs.			
Basal ration, 9.6 lbs.	Cotton-seed hulls, 9.6 lbs.	16.0	1.02

In this trial the cows getting the cowpea hay averaged 1.3 lbs. more milk daily than those fed wheat bran, showing that where there is a fair supply of rich concentrates it is more economical to com-

[1] Bul. 174. [2] Bul. 123.

plete the ration with some protein-rich roughage, like cowpea hay or silage, than with more expensive concentrates. The great value of cowpea hay to the dairy interests of the South is well set forth in this trial.

680. Hairy vetch hay.—Duggar of the Alabama Station[1] substituted 6.6 lbs. of hairy vetch hay for 7 lbs. of wheat bran for short periods, and found substantially no decrease in milk flow. (**262**)

681. Soybean silage and alfalfa hay.—At the New Jersey Station[2] Lane fed 2 lots of 2 cows each for 2 periods of 15 days alternately upon the rations shown below:

Soybean silage and alfalfa hay compared with purchased protein.

Average ration		Average daily yield per cow	
		Milk	Fat
		Lbs.	Lbs.
First ration			
Soybean silage, 36 lbs.	Corn meal, 6 lbs.		
Alfalfa hay, 8 lbs.		27.2	0.98
Second ration			
Corn silage, 36 lbs.	Wheat bran, 4 lbs.		
Corn stover, 6 lbs.	Dried brewers' grains, 4 lbs.		
	Cotton-seed meal, 2 lbs.	25.7	0.98

The table shows that the yield of fat was the same for these two rations, while the home-grown ration with corn meal produced slightly more milk. There was a saving of 1.1 cents per lb. of butter produced when the ration of soybean silage and alfalfa hay was fed.

682. Summary.—These trials show conclusively that the legumes rich in crude protein and mineral matter are of great importance in reducing the quantity of expensive concentrates ordinarily fed to dairy cows. If the legumes are so used it is most desirable that some succulent roughage such as corn silage or roots form a part of the ration to furnish variety and palatability as well as nourishment. In such cases very little additional roughage such as straw, corn stover, or low-grade hay should be used, for a cow giving a large quantity of milk cannot long do her best and retain her vitality on even the best of roughages when they alone are fed, for their digestion and passage thru the alimentary tract call for an expenditure of energy beyond her powers. The rich legume roughages may be most profitably used in place of about half the concentrates usually fed, provided corn silage or roots form a part of the ration. This means that ordinarily not over 6 lbs. of expensive concentrates need be fed per cow daily. It is not wise to force the cow giving a good flow of milk to subsist wholly on roughages, no matter how good they may be.

[1] Bul. 174. [2] Bul. 123.

CHAPTER XXVI.

PUBLIC TESTS OF PURE-BRED DAIRY COWS—FEED REQUIRED BY COW—COST OF PRODUCING MILK AND FAT.

683. Exposition breed tests.—Tests of pure-bred cows of various breeds for the production of milk and butter fat were conducted at the World's Columbian Exposition held in Chicago in 1893; at the Pan-American Exposition held in Buffalo in 1901; and at the Louisiana-Purchase Exposition held in St. Louis in 1904. In each case the test was supervised by a joint committee composed of delegates representing, on the one hand, the various breed associations interested, and on the other the Association of American Agricultural Colleges and Experiment Stations. The representatives of the several breed associations had direct and full charge of the cows and their feed and care in all particulars. The representatives of the colleges and stations took charge of all weighings of feed as well as of milk and conducted all analyses of the milk.

From the vast accumulation of data gathered during these tests the following condensed table is compiled, giving some of the more striking and helpful findings. The data for the Columbian Exposition test is taken from the *Jersey Bulletin*, 1893, and the *Journal of the British Dairy Farmers' Association*, 1894; for the Pan-American test, from the *Holstein-Friesian Register*, October, 1901; and for the Louisiana-Purchase Exposition, from the *Dairy Cow Demonstration* of the Louisiana-Purchase Exposition, Farrington, published by Hoard's Dairyman.

In these competitive tests the cows were selected and entered by the several breed associations, there being no restrictions as to choice in this matter. The chosen specimens of each breed were managed as to feed, water, and care entirely in accordance with the ideas and wishes of the committee in charge of that particular breed. The feeding and milking of each cow, however, was done in the presence of representatives of the colleges and experiment stations assisting in the test. Before each test was begun a price was established for each and all kinds of feed by the joint committee. The sub-committee in charge of each competing herd was allowed to give as much of any and all kinds of various feeds as it wished to each cow under its care. Full records were kept of everything eaten, of all the milk yielded, the gain or loss in the weight of the cows, etc. A price was further established for milk and fat so that the returns of each cow over the cost of the feed consumed could be credited. The toble which follows shows the results of one test at each exposition condensed and arranged for comparative study.

Summary of principal test of pure-bred dairy cows at the Columbian, Pan-American, and Louisiana-Purchase Expositions.

Breed	Av. daily yield per cow			Per cent fat	Feed cost 100 lbs. milk	Feed cost 1 lb. fat	Gain in live wt.	Daily return over feed cost
	Milk	Fat	Total solids					
Columbian Exposition, Chicago, 1893: best cow in 90-day test								
	Lbs.	Lbs.	Lbs.		Cents	Cents	Lbs.	Cents
Jersey	40.4	2.0	-------	4.9	70.2	14.3	81	81.3
Guernsey	39.0	1.7	-------	4.4	64.6	14.8	−13	64.2
Short-horn	40.9	1.5	-------	3.7	65.5	18.0	115	58.5
Pan-American Exposition, Buffalo, 1901: average of 5 cows, 146 days								
Jersey	31.0	1.3	4.2	4.2	48.8	11.5	------	22.5
Guernsey	31.6	1.4	4.2	4.3	47.9	11.1	------	23.1
Ayrshire	37.6	1.2	4.6	3.1	40.5	12.9	------	26.4
Short-horn	36.7	1.2	4.4	3.3	48.4	14.6	------	22.7
Holstein-Friesian	44.2	1.3	5.1	3.0	40.2	13.2	------	28.6
Polled Jersey	23.4	1.0	3.1	4.4	51.5	11.6	------	15.7
French Canadian	28.5	1.1	3.6	3.8	44.2	11.8	------	20.2
Brown Swiss	35.8	1.2	3.5	3.4	45.7	13.4	------	23.3
Red Poll	33.3	1.3	4.2	3.8	45.8	12.1	------	21.8
Dutch Belted	28.0	0.9	3.3	3.2	51.4	16.1	------	15.7
Louisiana-Purchase Exposition, St. Louis, 1904: best and poorest cow, 120 days								
Jersey								
Best cow	48.4	2.3	6.7	4.8	55.0	9.7	77	42.1
Poorest cow	38.8	1.6	5.1	4.1	65.0	13.2	85	22.3
Holstein-Friesian								
Best cow	67.5	2.4	7.5	3.5	45.0	11.0	54	38.4
Poorest cow	47.1	1.5	5.1	3.2	61.0	16.5	147	15.0
Brown Swiss								
Best cow	51.0	1.8	6.1	3.4	54.5	13.7	74	23.1
Poorest cow	38.5	1.5	5.1	3.8	69.5	15.5	147	16.5
Short-horn								
Best cow	43.4	1.7	5.5	4.0	54.5	11.7	139	27.1
Poorest cow	21.4	0.8	2.7	3.9	107.5	23.5	234	1.6

Since widely different prices were charged for feed and allowed for products at the different expositions, the returns from milk and fat over the cost of feed in the different tests should not be compared with one another.

684. Station breed tests.—Tests of pure-bred dairy cows have been conducted at the Maine,[1] New Jersey,[2] New York (Geneva),[3] and Wisconsin Stations,[4] the findings being condensed in the following table:

Tests of pure-bred cows at four American stations.

Station and breed	No. of cows	No. lactation periods included	Av. annual yield per cow		Av. per cent fat	Feed cost for	
			Milk	Fat		100 lbs. milk	1 lb. fat
			Lbs.	Lbs.		Cents	Cents
New York							
American-Holderness	2	4	5,721	213	3.73	76.0	20.1
Ayrshire	4	12	6,824	245	3.60	74.0	20.2
Devon	3	5	3,984	183	4.60	94.0	20.5
Guernsey	4	6	5,385	286	5.30	86.0	16.1
Holstein-Friesian	4	4	7,918	266	3.36	65.0	19.1
Jersey	4	11	5,045	282	5.60	90.0	16.1
Short-horn	1	2	6,055	269	4.44	78.0	17.2
Maine							
Holstein-Friesian	2	3	8,369	285	3.41	85.5	25.2
Ayrshire	2	4	6,612	233	3.52	94.9	26.8
Jersey	2	4	5,460	297	5.44	113.0	20.4
New Jersey							
Ayrshire	4	4	7,461	275	3.69	76.0	20.6
Guernsey	4	4	7,446	379	5.09	78.1	15.3
Holstein-Friesian	3	3	8,455	300	3.55	79.7	22.4
Jersey	3	3	7,695	376	4.89	87.5	17.9
Short-horn	3	3	10,457	396	3.79	79.0	20.8
Wisconsin							
Guernsey	9	57	6,273	312	4.99	58.4	11.8
Holstein-Friesian	5	33	11,184	382	3.48	37.1	11.4
Jersey	10	69	5,773	303	5.25	62.3	13.2
Short-horn	8	50	6,920	272	3.94	54.3	13.3
Brown Swiss	2	6	6,971	273	3.92	49.5	12.6

The figures given above by each station may be compared with each other for that station. Only in a general way should those from different stations be compared, for the prices charged for feed varied greatly at the different stations. The Wisconsin prices for feeds, for example, were much lower than were charged by the Maine Station. Many interesting comparisons may be made from the table. At the New York Station the Holstein cows gave the most and cheapest milk, while the Jerseys and Guernseys gave the richest milk and produced butter fat at the lowest cost for feed consumed. The Short-horn cows at the New Jersey Station produced more milk than the cows of any other breed at any station and at reasonable cost for the feed consumed. The butter fat, however, was less economically produced.

[1] Rpt. 1890. [2] Rpt. 1890. [3] Rpt. 1894. [4] Rpts. 1905–7, Bul. 102.

685. A herd record.—On taking charge of the Cornell Station[1] Roberts found a herd of cows yielding about 3,000 lbs. of milk per head yearly. After years of careful breeding and selection the records shown in the table below were actually made, the table including the cost of feed, the milk and fat production, and the feed cost of 100 lbs. milk and 1 lb. fat for every cow in the herd.

One year's milk and fat record with a herd of 20 cows.

No. of cow	Age		Cost of feed	Milk produced	Feed cost of 100 lbs. milk	Fat produced	Feed cost of 1 lb. of fat
	Yrs.	Mo.	Dollars	Lbs.	Dollars	Lbs.	Cents
No. 1	7+		44.24	8,029	0.55	391.6	11.5
No. 2	5	4	47.65	9,740	0.49	309.2	15.5
No. 3	3	5	42.00	4,743	0.89	233.6	18.0
No. 4	1	9	49.07	6,009	0.82	219.3	22.5
No. 5	7+		38.74	6,215	0.62	326.7	12.0
No. 6	1	10	41.24	2,830	1.48	159.0	26.0
No. 7	6	4	52.06	11,165	0.47	418.0	12.5
No. 8	4		39.96	5,671	0.70	285.1	14.0
No. 9	3		36.24	3,388	1.07	197.3	18.5
No. 10	4	8	46.51	6,324	0.74	224.7	21.0
No. 11	1	9	43.80	5,136	0.85	160.8	27.0
No. 12	3	5	43.66	5,786	0.75	294.3	15.0
No. 13	10	4	44.34	5,459	0.81	195.3	22.5
No. 14	2	4	45.98	7,757	0.59	260.3	17.5
No. 15	3	4	47.44	9,003	0.53	299.1	16.0
No. 16	6	4	43.12	9,777	0.44	330.6	18.0
No. 17	7	3	47.87	10,417	0.46	302.9	16.0
No. 18	3	4	48.63	7,955	0.61	282.4	17.0
No. 19	7+		53.38	8,656	0.62	382.8	14.0
No. 20	7+		49.08	10,754	0.46	439.4	11.0

We observe a considerable range in the cost of feed for the several cows, a wide one in the yield of milk, and a marked difference in the cost of producing milk and fat. While in 1875 the average milk yield of the cows in the herd was only 3,000 lbs., in 1892 the descendants of the same cows averaged more than 7,000 lbs. This table teaches that even with good, well-fed herds it is of the highest importance to study the feed consumption and milk and fat production of each individual, in order that only the best cows and their progeny may be retained.

686. Dairy v. beef type.—Haecker of the Minnesota Station[2] separated the Station herd into 4 groups, the first including cows of the beef type; the second, those showing less tendency to beef; the third, spare cows lacking in depth; and the fourth, spare cows with deep

[1] Bul. 52. [2] Bul. 35.

bodies and of distinctly dairy type. The returns of cows of the different types are shown in the following table:

Beef and dairy types of cows.

Type	No. of animals	Av. live weight	Dry matter consumed			Feed cost of 1 lb. fat
			Daily	Daily per 1,000 lbs. live wt.	Per lb. fat	
		Lbs.	Lbs.	Lbs.	Lbs.	Cents
Beef type	3	1,240	20.8	16.7	31.3	17.5
Less of beef type	4	945	20.4	21.0	26.4	15.1
Lacking depth of body	3	875	20.0	23.0	25.5	14.6
Dairy type	12	951	21.9	23.6	21.2	12.1

The great difference in the cost of producing butter fat, due to the type of animal used, is here shown. (**593**)

687. Good and poor producers.—Carlyle and Woll, at the Wisconsin Station,[1] studied the food consumed by and the returns from 33 cows, covering 88 milking periods extending thru the entire winter. The herd was divided into the following classes according to their production capacity.

Feed eaten and returns by cows of different quality.

Character of cows	Wt. of cows	Dry matter eaten daily	Daily production		Dry matter eaten per—		
			Milk	Fat	1,000 lbs. live wt.	100 lbs. milk	1 lb. fat
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
High producers	956	25.3	26.6	1.2	27.0	102	22
Medium producers	1,133	24.7	21.5	0.9	21.4	119	27
Low producers	1,012	21.1	14.6	0.7	21.1	149	32

The high-grade producers ate much more feed for their weight than the others, yet they required only 102 lbs. of dry matter for 100 lbs. of milk, while the low-grade cows, which ate less feed, required 149 lbs., or almost 50 per cent, more feed for 100 lbs. of milk.

688. Profitable v. unprofitable cows.—Beach of the Connecticut (Storrs) Station[2] found the cost of feed and the returns from the 5 best and the 5 poorest cows in the Station herd for 5 years to be as shown in the table on the next page.

The table shows that the good cows ate more feed and gave better returns over cost of keep than the small producers. During the first 2 years the 5 poorest cows did not pay for their feed. By gradual

[1] Bul. 102. [2] Bul. 29.

elimination the net loss of about $4 for each of the poorest cows the first year was changed to a gain of $17 per head for the 5 poorest animals in the herd during the fifth year.

Comparative returns from profitable and unprofitable cows.

	Cost of feed	Yield of fat	Margin over cost of feed	Feed cost of 1 lb. of fat
	Dollars	Pounds	Dollars	Cents
First year				
5 most profitable cows	56.54	304	26.91	18.6
5 least profitable cows	52.02	189	4.09*	27.5
Second year				
5 most profitable cows	60.30	377	43.27	16.0
5 least profitable cows	45.38	164	5.75*	27.7
Third year				
5 most profitable cows	53.24	375	44.25	14.2
5 least profitable cows	43.38	217	15.68	20.0
Fourth year				
5 most profitable cows	59.52	376	43.71	15.8
5 least profitable cows	51.45	237	13.71	21.7
Fifth year				
5 most profitable cows	59.46	366	40.23	16.2
5 least profitable cows	56.11	269	17.67	20.9

* Loss.

Fraser of the Illinois Station[1] reports a cow in the Station herd that in 12 years gave 87,102 lbs. of milk, containing fat sufficient to make 4,318 lbs. of butter. During 3 years one cow gave 11,390 lbs. of milk annually, containing 405 lbs. of fat, and returned $42.60 per year over cost of feed. Another with the same feed and care gave in the same time only 3,830 lbs. of milk annually, containing 138 lbs. of fat, and failed by $5.62 per year of paying for her feed.

689. Unreliability of short tests.—Glover of the Illinois Station[2] found 2 cows in an Illinois dairyman's herd whose best weekly records and actual annual returns during 3 years were as follows:

Best weekly and annual returns of two cows.

	Days in milk	Best week's record		Av. yearly returns	
		Milk	Fat	Milk	Fat
		Lbs.	Lbs.	Lbs.	Lbs.
Cow No. 1	266	309	10.5	5,355	184
Cow No. 2	315	197	10.2	7,190	367

[1] Cir. 106. [2] Cir. 84.

Measured by a single week's performance, cow No. 1 was the better animal, for in that time she gave 36 per ct. more milk and slightly more fat than cow No. 2. By the yearly record, however, it was found that cow No. 2 gave nearly 2,000 lbs. more milk and nearly 100 per ct. more fat than cow No. 1. Time, the scales, the Babcock fat test, combined with good judgment, are all essential in determining the true value of dairy cows.

690. A cow census.—Many years ago Hoard's Dairyman, by means of trained representatives, began studying the returns from cows on dairy farms in many states and under varying conditions. From the great accumulation of data, the following summary by Kingsley[1] covers the yearly returns from 100 herds containing 1,935 cows, whose milk went to 8 creameries in 3 counties in northwestern Illinois:

Summary of the Hoard's Dairyman cow census in northwestern Illinois.

	Fat delivered to creamery	Cost of keep	Gross returns	Returns over cost of keep	Rec'd for $1 invested in feed	Feed cost of 1 lb. butter fat
	Lbs.	Dols.	Dols.	Dols.	Dols.	Cts.
Average for 1 cow in—						
73 dual-purpose herds	133	33.27	36.77	3.50	1.10	27.0
27 dairy-type herds	178	31.73	48.96	17.23	1.56	18.5
25 best herds	204	33.07	55.75	22.68	1.73	16.0
25 poorest herds	97	33.11	26.66	−6.45	0.81	34.2
7 silage-fed herds	197	29.00	54.18	25.18	1.89	16.1
Average for—						
61 herds whose owners read dairy papers	168	33.05	45.96	12.91	1.40	21.0
39 herds whose owners did not read dairy papers	110	32.31	30.15	−2.16	0.94	30.0

Nearly all data heretofore presented concerning cows have come from the experiment stations. This table shows the conditions as they exist on dairy farms in a great Western state.

691. Annual feed requirement.—The next table condenses studies covering from 1 to 6 years at 9 widely separated American stations, showing the yearly feed requirement of cows and their returns in milk and fat.

We learn that the pasture period ranged from 131 days in Minnesota to 191 in Missouri. At the Wisconsin Station, only 1,200 lbs. of hay and less than 1 ton of concentrates were fed per cow, the soilage and silage exceeding 9,000 lbs. per cow. In New Jersey the

[1] Hoard's Dairyman, 39, p. 537.

cows were maintained in summer almost wholly on soilage and silage, over 16,000 lbs. being fed. The great value of alfalfa hay in reducing the amount of the concentrates fed and the cost of keep is shown by the Utah and Montana reports. The yearly feed cost per cow ranged from $21.43 in Utah to $53.46 in Connecticut, a difference of over 150 per ct. between the West with its low-priced alfalfa hay and concentrates and the East where feeds are high. The milk returns varied from 5,498 lbs. per cow in Connecticut to 8,783 lbs. in Nebraska, and the fat from 237 lbs. in Utah to 339 lbs. in Nebraska.

Annual feed requirement of the dairy cow as found by nine stations.

Station	No. of years	Feed eaten				Av. cost of feed per cow	Returns	
		Pasture	Concentrates	Soilage, roots, silage	Hay		Milk	Fat
		Days	Lbs.	Lbs.	Lbs.	Dols.	Lbs.	Lbs.
Connecticut [1]	5	152	2,029	8,694	1,830	53.46	5,498	279
New Jersey [2]	6	168	2,624	16,753	1,825	44.68	6,165	277
Michigan [3]	1	139	2,774	3,638	3,986	35.96	7,009	260
Wisconsin [4]	3	180	1,914	9,448	1,200	37.68	7,061	299
Minnesota [5]	1	131	3,435	5,306	2,029	37.82	6,408	301
Missouri [6]	1	191	3,027	--------	3,480	35.30	5,927	248
Utah [7]	1	187	1,976	3,692	2,347	31.61	8,783	339
Montana [8]	2	150	1,169	--------	6,468	32.45	5,993	250
Nebraska [9]	5	153	1,305	--------	4,518	21.43	5,601	237

[1] Bul. 29. [2] Rpts. 1897-1904. [3] Bul. 166. [4] Rpts. 1905-7. [5] Bul. 35.
[6] Bul. 26. [7] Bul. 68. [8] Rpt. 1905. [9] Bul. 101.

From this table the intelligent, experienced dairyman can closely estimate the quantity and cost of the concentrates and roughages required to maintain his herd of cows during the year, and the returns in milk and fat he may reasonably expect therefrom.

692. Monthly feed cost of milk.—In 1897 the author compiled the data from 4 widely separated stations presented in the following table showing the feed cost of 100 lbs. of milk for the different months of the year according to the prices then prevailing for pasture, concentrates, and roughages.

Since the data were gathered by the stations the cost of feeding stuffs has greatly advanced, so that the figures are only relatively valuable. They show that the feed necessary to produce 100 lbs. of milk in March cost 76 cents, while when the cows were on pasture in June it fell to 26 cents. Winter prices were again reached in November. The average feed cost for the year at the 4 stations was 55 cents for 100 lbs. of milk and 13.3 cents for a pound of fat. To get the present feed cost of milk and fat in the United States the figures of the table should be increased by from 40 to 75 per ct.

Feed cost of 100 lbs. of milk and 1 lb. of fat by months.

	New York[1]		Minnesota[2]		Missouri[3]		Utah[4]		Average	
Number of cows	20		23		12		15			
Average weight of cows	1,123 lbs.		976 lbs.		990 lbs.		970 lbs.			
Average fat per cow	286 lbs.		301 lbs.		248 lbs.		222 lbs.			
Month	100 lbs. milk	1 lb. fat	100 lbs. milk	1 lb. fat	100 lbs. milk	1 lb. fat	100 lbs. milk	1 lb. fat	Milk	Fat
January	$ .64	$ .17	$ .65	$ .149	$ .94	$ .240	$ .56	$ .138	$ .68	$ .168
February	.68	.18	.67	.151	1.01	.253	.62	.160	.72	.179
March	.71	.18	.67	.165	1.21	.299	.59	.142	.76	.187
April	.71	.18	.71	.162	1.01	.234	.49	.121	.71	.171
May	.58	.145	.59	.132	.43	.096	.48	.113	.54	.125
June	.28	.075	.32	.076	.24	.053	.15	.038	.26	.064
July	.38	.095	.37	.078	.23	.053	.19	.049	.31	.072
August	.65	.155	.51	.114	.14	.033	.21	.051	.42	.098
September	.51	.125	.51	.106	.21	.052	.26	.066	.41	.094
October	.41	.105	.60	.140	.42	.098	.38	.091	.47	.112
November	.65	.175	.68	.159	.65	.153	.59	.135	.65	.157
December	.63	.155	.65	.164	1.03	.265	.63	.143	.71	.174
Average	$ .57	$ .145	$ .58	$ .133	$ .63	$ .152	$ .43	$ .104	$ .55	$ .133

[1] Bul. 52. [2] Bul. 35. [3] Bul. 26. [4] Bul. 43.

693. Sample rations in forced feeding.—Farrington[1] gives the following to show the actual rations fed on a certain day to cows of the several breeds in the Louisiana-Purchase Exposition dairy contest.

Rations fed on the same day at the Louisiana-Purchase Exposition.

	Brown Swiss	Holstein-Friesian	Jersey	Short-horn
Roughage	Lbs.	Lbs.	Lbs.	Lbs.
Long alfalfa hay	7	------	18.0	9
Cut alfalfa hay	------	15	6.0	------
Corn silage	------	------	16.0	24
Green cut corn	40	15	------	------
Green cowpeas	------	35	------	------
Total roughage (green and dry)	47	65	40.0	33
Concentrates				
Wheat bran	------	2	3.0	4
Linseed oil meal	------	------	2.0	2
Ground oats	------	------	2.5	2
Hominy feed	8	5	2.5	3
Gluten feed	------	------	5.0	2
Corn meal	------	------	1.5	------
Corn hearts	------	------	2.5	2
Cotton-seed meal	1	1	------	2
Distillers' grains	15	14	------	4
Total concentrates	24	22	19.0	21

[1] Dairy Cow Demonstration, La.-Pur. Expo.

While the roughage supply for the cows under test was not large, a heavy concentrate allowance of from 19 to 24 lbs. was fed daily, the Brown Swiss cows getting the largest and the Jerseys the least.

694. Records of great cows.—The Guernsey cow Yeksa Sunbeam,[1] during a semi-official test beginning September 1904, produced milk and fat from feeds as reported below. The concentrates consisted of a mixture of bran, gluten feed, and oil meal.

Ration and production of the Guernsey cow Yeksa Sunbeam.

Month	Ration	Monthly yield of milk	Per ct. of fat	Monthly yield of fat
		Lbs.		Lbs.
1	Silage, hay, concentrates 15 lbs.	1,428.2	5.69	81.26
2	Silage, hay, concentrates 15 lbs.	1,322.5	5.62	74.32
3	Silage, hay, concentrates 15 lbs.	1,294.4	6.08	78.70
4	Silage, alfalfa hay, rutabagas 10 lbs., concentrates 15 lbs.	1,217.0	6.04	73.51
5	Silage, alfalfa hay, rutabagas 10 lbs., concentrates 14 lbs.	1,060.8	5.75	61.00
6	Silage, alfalfa hay, rutabagas 10 lbs., concentrates 14 lbs.	1,185.1	6.05	71.70
7	Silage, alfalfa hay, rutabagas 10 lbs., concentrates 14 lbs.	1,089.6	5.79	63.09
8	Pasture, mixed clover hay, concentrates 12 lbs.	1,127.5	5.75	64.83
9	Pasture, mixed clover hay, concentrates 8 lbs.	1,158.4	5.25	60.82
10	Pasture, concentrates 10 lbs.	1,266.0	5.88	74.44
11	Pasture, green clover 8 lbs., concentrates 10 lbs.	1,463.8	5.42	79.34
12	Pasture, clover hay, concentrates 14 lbs.	1,307.5	5.67	74.14
	Totals and average	14,920.8	5.74	857.15

During the year ending January 25, 1909, the pure-bred Jersey cow Jacoba Irene[2] produced 17,253 lbs. of 5.53 per ct. milk, containing 954.2 lbs. fat. Besides pasture for 6 hours daily during 5 months, she consumed feed as follows:

Concentrates		Roughages	
Bran	1,694 pounds	Corn silage	7,400 pounds
Corn	661 pounds	Chaffed hay	1,074 pounds
Oil meal	489 pounds	Long hay	3,000 pounds
Gluten	1,615 pounds		
Ground oats	364 pounds		

In a semi-official test ending December 22, 1907, the Holstein Friesian cow Colantha 4th's Johanna[3] produced 27,432.5 lbs. of 3.64 per ct. milk, containing 998.26 lbs. of fat, or an average yield of 2.73

[1] Wis. Sta., Bul. 131. [2] Jersey Bul. 28, p. 274. [3] Wis. Sta., Bul. 160.

lbs. of fat daily for the entire year. Her concentrate allowance, consisting of equal parts of oats, bran, and gluten feed together with 2 or 3 lbs. of oil meal, began with 12 lbs. daily, which was gradually increased to 22 lbs., the maximum except that for one week she was fed 24 lbs. daily. During the first 65 days the roughage consisted of 30 lbs. corn silage, 35 lbs. roots, and clover hay without limit. After this, 10 lbs. of silage was fed in place of the roots. While on pasture she was fed 12.5 to 15 lbs. of grain daily with clover hay and corn silage, of which she ate very little. During a 7-day test she produced an average of 4.03 lbs. of fat daily, requiring for each lb. of fat 10.6 lbs. of dry matter, of which 1.4 lbs. was digestible crude protein.

CHAPTER XXVII.

FEED AND CARE OF THE DAIRY COW.

I. Care and Management.

Monrad,[1] a most reliable dairy authority, tells us that in the mountain districts of Norway, in the dawn of dairying, cows on small farms were fed in winter on straw, birch leaves, reindeer moss, and horse dung, cooked and given as a mash mixed with chaff and leaves, while on large ones the mixture was fed uncooked. As late as the close of the last century, herring hauled inland and stored in snow banks were boiled with horse dung and shavings of mountain ash and birch bark for feeding goats, sheep, and young cattle. Along the coast even now herring, fish offal, seaweed, and ocean algæ are fed in spring time when the hay gives out. The butter yield on the summer mountain pastures in the early times was from 24 to 48 lbs. per cow for the season, and the annual yield of milk from a good cow ranged from 1,600 to 1,800 lbs. While the changes from such primitive times have been great, the cow has generously responded to every advancement in feed and care.

695. Dairying and maternity.—When a steer is fattening, the process goes on rapidly at first, but after a time it is accomplished only at a high cost for the feed consumed. How different is the dairy cow, which takes her food, not for storing what she makes from it for her own use, but for nurturing her young. Food given to her at night is converted into milk by morning, and soon drawn from her, makes easy way for more. So strong is the maternal impulse that, if food fails, the cow will for a considerable time draw from her flesh and bones the substances necessary to maintain the milk flow and preserve its normal composition, in order that her young may be properly nourished. (**604**) The basis of dairying is the maternity of the cow, and success in this art depends upon rationally recognizing this great basic fact. W. D. Hoard of Wisconsin[2] first brought this form of the subject prominently to the attention of dairymen. Whoever will study dairying from this standpoint will come to regard the cow in a new light and become a better dairyman.

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[1] Hoard's Dairyman, April 16, 1909.
[2] Bul. No. 1, Wis. Farmers' Inst., and elsewhere.

696. Shelter.—The steer, gorged with feed and every day adding to the heat-holding fat layer just beneath the skin, prefers the yard or open shed to the stable. **(495)** The dairy cow stands in strong contrast, her system being relaxed thru the annual drain of maternity and the daily loss of milk, the combination severely taxing her digestive and assimilative powers and drawing heavily on her vitality. In winter the cow should be comfortably housed in a well-lighted, well-ventilated stable, the temperature of which should range from 40° to 50° F.

697. Exercise.—Confinement is advisable with the fattening steer soon to be slaughtered, since it prevents waste of tissues and conserves feed. With the dairy cow a high standard of bodily health and vigor can only be maintained thru proper stable conditions, supplemented by a reasonable amount of outdoor air and exercise even during winter. Whenever possible, the cow should be out of doors 2 or 3 hours each day, enjoying the sunshine and exercising muscles which cannot be called into action while she is in stanchions. At the Cornell Station[1] Roberts devised a system whereby the cows stood in stanchions while feeding and being milked. Afterward they were turned into a large covered enclosure where they were free to stand or lie at will. In other words, they were milked and fed in one room and spent most of their time unconfined in another. The accumulation from the horse stable was spread on the floor of the covered shed, and this in turn was overlaid with straw and sprinkled with land plaster to suppress odors. A modified plan, and a most excellent one, is to have a small sanitary room in which are admitted 2 or more cows at a time for milking and eating their concentrates. At other times they are confined in a covered enclosure provided with a roomy rack for holding the roughage they need. The special milking room can be kept scrupulously clean and properly aired, making possible the cleanest of milk.

698. Regularity and kindness.—To skilful feeding and wholesome quarters the successful dairyman adds regularity and kindness. On this point Babcock of the Wisconsin Station[2] writes: "I would recommend, therefore, in order to obtain the best results from any cow, that first of all she be treated kindly, all sources of excitement being avoided so far as possible. She should also be fed and milked at regular intervals by the same person, and all conditions should be maintained as nearly uniform as possible at all times. It is my opinion that kind treatment and pleasant surroundings will have a

[1] Bul. 13; The Fertility of the Land, p. 20. [2] Rpt. 1889.

greater influence upon the quality of milk than the kind of food, provided the ration given contains sufficient nutriment for the maintenance of the animal.''

699. Fall-fresh cows.—Spring-fresh cows yield most of their milk when low prices prevail for dairy products and the dairyman is busiest with the crops. In winter such cows yield only a small flow of milk at most. On the other hand, a fall-fresh cow gives a large supply of milk during the winter, and flushes again with the stimulus of pasture in springtime. Fall-fresh cows should annually yield from 10 to 15 per ct. more milk than those calving in the spring.

700. Calving.—Good dairy cows usually show a strong tendency to lay on fat when not giving milk. Dry cows should be put in good condition before calving, fleshing up on grass alone if possible, for having been heavily fed with rich concentrates while giving milk this is the only opportunity for a marked change in the ration, which should prove both beneficial and recuperative. Before calving time let the feed be cooling and slightly laxative. Silage, roots, clover hay, and fodder corn are desirable for roughage, while wheat bran, oats, and linseed oil meal are particularly satisfactory for concentrates. Immediately after calving let the feed supply be small. To allay thirst give tepid water carrying a little ground oats. A clinical thermometer rightly used a few days before and after calving may announce coming trouble before it would otherwise be observed.

701. Frequency of feeding.—The ample paunch and the considerable time needed for rumination teach that the common practice of feeding cows twice daily, morning and evening, with possibly a little roughage additional at midday, is a reasonable one. Those who give their cows first a little of this and then a little of that, busying themselves all day in the stable, usually ascribe success to their irksome system of feeding, when in truth it is due to good care generally and not to the particular system of feeding. Habit is strong with the cow, and a simple system of feeding and stable management once established should be rigorously continued. (**615**)

702. Order of feeding.—In the roomy paunch hay and grain eaten separately are rapidly and thoroly commingled by the churning action of that organ and gradually softened in the warm, abundant liquid it contains. This true, the particular order of feeding roughages and concentrates is not important. The cow seems best satisfied when the concentrates are given first, and these out of the way, she contentedly proceeds to dispose of the roughage before her. Turning to water should follow a few hours after feeding.

703. Preparation of feed.—The cow giving a large flow of milk is working as hard as the horse ever does, and, this true, any grain given her should be ground or crushed if not otherwise easy of mastication and digestion. Corn and oats should generally, and wheat, rye, barley, kafir, and milo always, be ground or "chopped," and roots should be sliced or pulped. Because the cow takes kindly to dry feed and everything which enters the paunch is quickly soaked and softened, there seems no occasion for feeding slops, nor is there any advantage from cooking ordinary feeding stuffs. (**332**)

704. Generous feed and care.—Since it requires something like 73 per ct. of all the well-fed cow eats to support her body and manufacture the milk she produces, how short-sighted is that dairyman who would withhold any part of the remaining 27 per ct. of feed that the cow can possibly eat! (**592**) Having reached the point of liberal feeding, the wise dairyman will next study the capacity and needs of each individual cow in order that all may receive the largest profitable allowance.

During the heated periods of summer, cows are more comfortable in darkened stables away from blood-sucking flies than in pastures. In such cases soilage should be fed by day, and the herd turned into the yard or pasture at night. Knowing the difficulties of bringing cows back to their normal milk flow after a shrinkage caused by scant feeding, the prudent dairyman provides at all times not only abundant feed but also all possible comforts. (**602**)

705. Water, salt.—Cows require a large amount of water for their bodily needs and for the milk. Creatures of habit, they are well content if once each day they have ample opportunity to easily secure all the water they can then drink. Some devices for stall watering are actually dangerous, for while the drinking basin may be kept clean, the supply pipe coming into it from below retains any saliva which may drop into it from the basin. Such material quickly putrefies and steadily contaminates the water which rises thru the pipe into the basin. The dairyman who boasts of a spring or creek to which his cows must daily journey, often in inclement weather, will usually find a conveniently located well with windmill or gasoline lift far superior. (**87, 452, 612**)

The studies of Babcock and Carlyle show that dairy cows must have salt to thrive. (**91**) Near the sea, salt in addition to that contained in the feeding stuffs may not be essential, but elsewhere it should be liberally supplied, the allowance increasing with the amount of rich concentrates fed. From 0.75 to 1 ounce of salt per day per cow is a reasonable allowance, and should be supplied in any convenient manner as frequently as once each week.

II. Feed for the Dairy Cow.

706. Concentrates and roughage.—The wise dairyman holds in mind that a good dairy cow in full flow of milk is expending as much energy as a horse at hard labor, and this without cessation for many months. (**590-2**) We have learned that the harder the horse works the more grain and the less roughage must he have, and the same is true for the cow. Except when pasture is good a portion of the cow's provender should consist of grain or rich concentrates, and if she is yielding a large amount of milk, i. e. working extra hard, all grain should be ground or crushed. The dry cow doing little work can subsist on less carefully prepared food, and all or most may be in the form of roughage. In feeding, the aim should be to supply as much roughage as the cow will readily consume, and to this add sufficient concentrates to keep the digestible matter up to the standard set by the scientists. (**611**)

Our American experiment stations have now so well solved the problem that we know if good roughage, such as alfalfa or clover hay with corn silage, is supplied in abundance, from 4 to 8 lbs. of such concentrates as corn, oats, barley, or milling and other rich by-products will usually furnish ample concentrates. This is a material reduction from earlier recommendations and tends to the more economical production of dairy products. However, such small allowance of concentrates is only profitable when the roughages fed are of high quality, palatable, and abundant. The dairyman who persists in feeding his cows wholly on such low-grade roughages as timothy hay, corn stover, etc., must pay the penalty by feeding from 10 to 12 lbs. of expensive concentrates daily if his cows are to maintain a reasonable flow of milk.

707. The burden of dairying.—So large are the feed and labor bills on many dairy farms, especially in the earlier settled portions of our country, that when they have been met little remains for the proprietor. Analysis will show that in nearly every case it is the feed bills and not those for labor that are the real burden. Whoever would improve his condition must cut the monthly feed bills to the minimum, not thru parsimonious feeding, but by growing great crops of the best feeding stuffs. With rare exceptions the dairy farm should produce all the roughage and all or nearly all the concentrates the herd consumes. Growing the needed feeding stuffs will increase labor and fertilizer bills, but such shifting of expenditure should prove highly economical in the end. Indian corn flourishes over a large portion of the United States, and one or more kinds of legumes can be successfully grown on every farm. By the judicious and generous use of these two best allies of the dairyman, the great burden of the feed bills can be lessened.

708. The corn plant.—Wherever it flourishes the dairyman should make the largest possible use of the corn plant. The manure from the stable, wisely fortified with commercial fertilizers, will so enrich the fields that each acre will produce from 12 to 20 tons of green forage bearing a great wealth of ears rich in grain. Most of the crop, still green, should go directly into the silo, which should hold sufficient silage for 6 months winter and 2 months midsummer feeding, allowing 40 lbs. for each cow daily. A portion of the crop, cured in the shock, will provide corn meal and some stover. (**Ch. IX**)

709. Legume hay.—Almost everywhere in America the Indian-corn plant provides the cheapest, most abundant, and most palatable carbohydrates the farmer can produce, but it falls short in furnishing protein, so vital in milk production. Happily at least one of the legumes—alfalfa, clover, cowpeas, or vetch—can be grown on every American farm to supply the deficiency. The dairyman who grows great crops of corn for silage must also have broad fields of clover, alfalfa, or some other legume to help round out the ration. With corn silage, the daily legume hay provision should be not less than 15 lbs. per cow for 6 months. With rich corn silage and all the palatable legume hay the cow will eat, not over 4 or 5 lbs. of expensive concentrates are needed to complete a well-balanced liberal ration. The findings of Hart and McCollum of the Wisconsin Station, that a cow yielding 30 lbs. of milk daily requires a minimum of not less than 2 ounces of lime a day, gives a new value to legume hay, which is rich in lime. (**89, Ch. XII**)

710. Roots.—Since roots may successfully replace half the grain usually fed to cows even when corn silage is fed, (**661**) the dairyman who can produce a great tonnage of mangels or rutabagas may still further reduce the concentrates required by his herd. When bran, corn, etc., sold for low prices, the dairyman with a silo could hardly afford to grow roots, but with the advancing prices of good concentrates many farmers can now profitably grow and feed roots.

To build up the fertility of the fields so that they will economically produce great crops of corn, legumes, and roots will call for much labor, and the judicious use of commercial fertilizers in many cases, but it is far better to spend money for these purposes than to pay it in the dragging-down process of forever buying feed that under a wiser system could be profitably produced at home. (**275-6**)

711. Protein-rich silage.—There is great need for some protein-rich legume which can be satisfactorily ensiled. The soybean and cowpea are the most promising candidates, and if these can be profitably grown and successfully ensiled along with the green corn crop, the mixture will furnish a ration almost rich enough in protein and sufficiently digestible to nearly do away with the necessity for supplying any concentrates. (**360, 658**)

712. Soilage, summer silage.—The dairyman who feeds silage knows that not for a single day in winter will his cows suffer for food. Let him next plan that there shall be equal provision for them in summer. It is practically impossible to have pastures that will provide an abundance of grass for the herd at all times with little or no waste. Pasturage supplemented by partial soilage or silage solves the problem of summer feeding as economically and completely as does silage feeding solve the problem of winter feeding. The wise dairyman will provide sufficient soilage or silage to make good all possible shortage of the pastures in summer. Soilage and silage enable the dairyman to maintain the maximum flow of milk at the minimum cost for production, regardless of the season. (**Ch. XIV, Part I**)

713. Trashy feeds and timothy hay.—The prevailing high prices for concentrates have brought out a great many new feeds and feed combinations, ranging from worthless to excellent. Feeling the pinch of poverty, the dairyman is tempted to buy the poorer grades, vainly hoping that his cows will thrive on them, while he saves a little money by their use. Almost without exception, low-grade concentrates are extravagantly expensive feeding stuffs. (**Ch. XIV, Part IV**)

Next to the folly of buying trashy feeds is the practice of many dairymen, especially in the Eastern states, of using timothy hay for roughage, supplemented with large quantities of expensive purchased concentrates. (**224, 664**) Timothy hay has its uses, but it is not suitable or economical for feeding dairy cows. The dairyman who relies on this roughage for nourishing his dairy herd often gets no return for his invested money and less wages for himself than the hired man who helps him milk the cows.

714. Compounding rations.—Chapter VIII, which teaches how to formulate rations, and Table III of the Appendix, giving the digestible nutrients in feeding stuffs, should be studied by dairymen desirous of knowing the composition of feeding stuffs and how to compound rations that will furnish all the nutrients required by cows without supplying any in excess. There is no gain in attempting to apply these teachings with extreme exactness to every-day feeding operations. No two cows in the herd have exactly the same wants, and the various feeds at hand are not identical in chemical composition with the averages given in the tables of composition. Such tables and standards are invaluable in giving sound and helpful fundamental knowledge so that one has a clear, broad conception of what he is doing and can move forward along the right lines with confidence. Having well in hand the basic facts concerning feeding stuffs and rations, it is enough if the weight of concentrates each cow consumes daily is known, while the quantity of roughage may be estimated from weighings made occasionally.

To aid in efforts at economical feeding, the following groupings of commonly available feeding stuffs are presented, based on their digestible nutrients, fiber, and palatability:

Roughages

Class I	*Class II*	*Class III*
Poor in diges. crude protein, poor in digestible carbohy., high in fiber	Fair in diges. crude protein, fair in digestible carbohy., considerable fiber	Rich in diges. crude protein, fair in digestible carbohy., considerable fiber
Wheat straw	Timothy hay	Alfalfa hay
Barley straw	Red top hay	Red clover hay
Oat straw	Bermuda hay	Cowpea hay
Marsh hay	Johnson-grass hay	Vetch hay
Salt marsh hay	Sorghum fodder	Soybean hay
Rye hay	Kafir fodder	Velvet bean hay
Cotton-seed hulls	Milo fodder	Beggar-weed hay
Corn stover	Corn fodder	
	Corn silage	
	Roots	

Concentrates

Class IV	*Class V*	*Class VI*
Fair in diges. crude protein, rich in digestible carbohy., little fiber	Rich in diges. crude protein, fair in digestible carbohy., some fiber	Highest in diges. cr. protein, fair in digestible carbohy., little fiber
Ground corn	Low-grade flour	Gluten meal
Corn-and-cob meal	Wheat bran	Gluten feed
Hominy feed	Wheat middlings	Buckwheat middlings
Oats	Rye bran	Field-pea meal
Barley meal	Rye middlings	Cowpea meal
Emmer meal		Soybean meal
Rye meal		Linseed meal
Buckwheat meal		Cotton-seed meal
Buckwheat bran		Soybean cake meal
Rice meal		Dried brewers' grains
Kafir		Dried distillers' grains
Milo		
Dried beet pulp		

It will be observed that both the roughages and concentrates are divided into three classes on the basis of digestible nutrients, palatability, and general usefulness. When the crude-protein-poor roughages of Class I are fed, then as an offset the protein-rich concentrates from Class VI should as a rule be taken. When Class III, which furnishes roughage of the highest quality, is fed, the concentrates of Class IV, which are only fair in crude protein and rich in carbohydrates, should largely furnish the concentrates. In general, crude-protein-rich concentrates in large quantity must be fed with roughages which are poor in crude protein, while crude-protein-rich roughages should be supplemented with concentrates rich in carbohydrates rather than rich in crude protein. The several divisions of the table are more or less arbitrary. The last roughages listed in Class I might go with Class II, and roots and corn silage might form a separate class because of their succulence and great palatability. This classification is sufficiently complete, however, to give the intelligent student a general conception of how to properly combine nitrogenous and carbohydrate-rich feeding stuffs into rations that will fully and economically nourish the dairy cow.

The provident dairyman will grow an abundance of the low-priced useful roughages of Class II, especially corn for forage and silage, as well as for grain. He will also grow one or more of the invaluable legumes in Class III in such abundance that he will need but the minimum of expensive concentrates to complete the balanced ration. To illustrate the use of the preceding classification table, three rations are given in the table on the next page.

In the first ration where timothy hay from Class II supplies the roughage, 11 lbs. of expensive concentrates from Classes IV and VI are necessary to furnish the additional nutrients required. Even then this expensive ration is not satisfactory, for timothy hay is a poor cow feed at best and a large amount of concentrates is used.

The second ration with clover hay from Class III and ground corn from Class IV is better and less expensive than the first. Such a ration is theoretically ample, but there should be a larger variety of feeding stuffs to make it entirely satisfactory.

The last ration may be called ideal. Drawing legume hay from Class III and corn silage from Class II, the combination of roughage is most palatable and acceptable to the cow, while there is further required only 4 lbs. of concentrates from IV and VI to balance the ration. This last ration is less expensive and more desirable than the second one, and far less expensive and much more desirable than the first. Altho all are "balanced" from the theoretical standpoint, the last one is not only the lowest in cost, but if put to the test will probably produce from 20 to 30 per ct. more milk than the first and somewhat more than the second.

Sample rations for dairy cows based on the previous table and Tables III and IV of the Appendix.

	Dry matter	Digestible nutrients		
		Crude protein	Carbo-hydrates	Fat
	Lbs.	Lbs.	Lbs.	Lbs.
A poor ration, roughage from Class II				
Timothy hay, 20 lbs.	17.4	0.56	8.48	0.26
Ground corn, 4 lbs.	3.6	0.31	2.67	0.17
Dried brewers' grains, 7 lbs.	6.4	1.40	2.25	0.42
	27.4	2.27	13.40	0.85
A fair ration, roughage from Class II				
Clover hay, 22 lbs.	18.6	1.56	8.32	0.40
Ground corn, 8 lbs.	7.2	0.62	5.34	0.34
	25.8	2.18	13.66	0.74
An ideal ration, roughage from II and III				
Corn silage, 40 lbs.	10.6	0.56	5.68	0.28
Clover hay, 15 lbs.	12.7	1.07	5.67	0.27
Ground corn, 3 lbs.	2.7	0.23	2.00	0.13
Cotton-seed meal, 1 lb.	0.9	0.38	0.21	0.10
	26 .9	2.24	13.56	0.78

In compounding desirable and economical rations for the dairy cow there should first be provided at least two varieties of palatable roughage, one of which is leguminous, such as alfalfa, clover, or cowpea hay, in order to furnish a considerable amount of crude protein and mineral matter. The other, richer in carbohydrates, should if possible be succulent in character. Corn silage and roots serve advantageously, or in their absence dry corn forage, sorghum forage, or similar roughage may be fed. The two classes of roughages combined should furnish fully three-fourths of the necessary carbohydrates and half or more of the crude protein. The ration should then be completed by adding from 6 to 8 lbs. of concentrates, of two kinds if possible, for variety and palatability. If the ration contains corn silage well loaded with ears, or if roots are fed, then the concentrates may be cut to 4 or 5 lbs. It is never well to entirely eliminate the concentrates from the ration of cows giving a good flow of milk, for a ration composed wholly of roughage will carry so much inert matter that the work of digesting it taxes the animal severely.

When there is an ample supply of suitable roughage, a safe and simple rule as to the proper supply of concentrates is that in practice at the Wisconsin Agricultural College, which is: Give to each cow as many pounds of concentrates daily as she yields pounds of butter fat weekly. Or give 1 pound of concentrates daily for each 3 or 4 lbs. of milk yielded daily, according to its richness. If the roughages are meager in quantity or of low palatability, more concentrates must be given than is here recommended.

The dairyman seeking further light on the proper amount of concentrates and roughages of the various kinds for his dairy herd will find the information amply and helpfully set forth in the numerous feeding trials, conducted at the various experiment stations with many kinds of feed, reported in Chapters XXIV and XXV. (**611**)

CHAPTER XXVIII.

GENERAL INVESTIGATIONS IN CARE AND MANAGEMENT OF SHEEP.

715. Period of gestation.—Below are given the findings of Tessier[1] of France, and Carlyle, Humphrey, and Kleinheinz of the Wisconsin Station,[2] showing the gestation period of ewes. The Wisconsin data cover 17 years of the records kept by Kleinheinz, the station flock master.

The gestation period of ewes.

Authority	Number of ewes	Shortest period	Longest period	Average period	Range of period	Over 75 per ct. between
		Days	Days	Days	Days	Days
Tessier of France	912	146	161	152	15	150–154
Wisconsin Station	764	140	156	147	16	145–149

The Wisconsin ewes, mostly grades of the English breeds, carried their lambs for an average of 147 days, while the French ewes, doubtless of the Merino breed, yeaned in 152 days. At the Wisconsin Station the grade Merinos and Cheviots carried their lambs longer than those of the English breeds under observation.

716. Breeding studies.—Studies of the Wisconsin Station flock, covering 5 years, by Humphrey and Kleinheinz show:[3] The length of the gestation period does not influence the birth size of the lamb. The average weight of ram lambs at birth is about 0.5 lb. greater, and the gestation period somewhat longer, than in the case of ewe lambs. The per cent of male lambs is practically the same as females. The age of the ram appears to have no effect on the sex of his offspring, but as the age of the ewe increases, the per cent of ram lambs she bears increases. The size of the lamb is determined by the size of the ewe and not of the ram. Six-year-old ewes produced the largest per cent of increase, while young ewes have more singles. The size of the ram appears to have no effect on the number of lambs yeaned by the ewes. The larger the ewe of a given breed the greater is the per cent of her increase.

[1] Coleman, Sheep of Great Britain.
[2] Rpt. 1907, Bul. 95.
[3] Wis. Sta., Rpt. 1907.

717. Weight of lambs at birth.—Below is given the average weight of lambs of several breeds at yeaning, as reported by Humphrey and Kleinheinz from records covering 5 years of the Wisconsin Station[1] flock:

Average weight of lambs at birth.

Breed	Singles	Twins	Triplets	Av. of all
	Lbs.	Lbs.	Lbs.	Lbs.
Shropshire	8.9	7.4	5.8	7.7
Dorset	10.7	8.5	....	9.3
Shrop-Merino	10.4	8.3	7.8	8.6
Southdown	8.5	7.4	....	7.9
Oxford	10.4	8.2	7.1	8.3
Hampshire	10.3	8.4	....	9.0
Cheviot	8.8	8.2	....	8.4
Montana range	8.0	7.3	6.5	7.2

718. Ewe's milk.—In America sheep are not generally used for producing milk for man, but in many districts abroad, especially the mountain regions of Continental Europe, their milk is extensively employed, partly for direct consumption and to a larger extent for the manufacture of cheese. Ewe's milk has a peculiar, somewhat unpleasant odor and taste, and differs from cow's milk mainly in its greater proportion of fat and protein. It is also thicker and sours more slowly. The fat content of ewe's milk is extremely variable, ranging from 2 to 12 per cent.[2] The butter is pale yellow, less firm than cow's butter, and becomes rancid much quicker.

The yield of milk by sheep will vary greatly according to breed and feed. Sieglin[3] states that the East Friesian milk sheep in Germany yield at 2 to 3 years of age from 3 to 4 quarts of milk daily for 2 months after weaning their lambs, and keep up an excellent flow of milk during the autumn months. These sheep are prolific, dropping 2, 3, and even 4 lambs, individuals lambing twice a year. Three sheep are estimated to consume as much feed as 1 cow. Ordinary sheep yield from 100 to 150 lbs. of milk per year, while the milk breeds produce from 300 to 1,400 lbs.

719. Composition of ewe's milk.—Below is given the composition of ewe's milk as determined by Sartori and Fleischmann.[4] For com-

[1] Rpt. 1907.

[2] See Staz. Sper. Ag. Ital. 23, p. 572; Analyst, 1893, p. 248; Fleischmann, Milchwirtschaft, 1901, p. 64; Jensen, Milchkunde und Milchhygiene, 1903, p. 17.

[3] Schäfer-Sieglin Lehrbuch der Milchwirtschaft, 1908, p. 17.

[4] Milchkunde und Milchhygiene, Jensen, p. 18.

parison the table gives the average composition of cow's milk, according to König.[1]

Composition of ewe's milk, with that of cow's milk for comparison.

Authority	Water	Casein and albumin	Fat	Sugar	Ash
	Per cent	Per cent	Per cent	Per cent	Per cent
Sartori—Av. of analyses of milk from 2,700 ewes	78.70	6.30	8.94	5.06	1.02
Fleischmann—Av. of analyses of milk from 250 ewes	75.54	7.16	11.90	3.43	1.05
König—Av. of analyses of milk from 705 cows	87.27	3.39	3.68	4.94	0.72

It is here shown that, as a rule, ewe's milk is markedly richer in all constituents than that of the cow. (**595**)

720. Milking qualities of ewes.—At the Wisconsin Station[2] Carlyle, Fuller, and Kleinheinz kept lambs from their dams except at regular intervals when they were allowed to suckle. The milk yielded by the ewes was determined by weighing their lambs immediately before and after placing them with their dams.

Daily milk yield of ewes of different breeds.

Breed	Number of ewes	Av. daily milk yield	Composition			Specific gravity
			Fat	Solids not fat	Total solids	
		Lbs.	Per cent	Per cent	Per cent	Per cent
Oxford	2	3.1	7.7	11.0	18.6	1.038
Southdown	2	1.9	8.4	11.1	19.5	1.038
Dorset	2	4.3	7.2	10.9	18.1	1.038
Shropshire	3	2.5	5.9	10.8	16.7	1.039
Merino	3	2.3	6.0	10.8	16.8	1.038
Range	2	2.7	7.2	11.1	18.3	1.039
Average, 14 ewes		2.8	7.1	10.9	18.2	1.038

In this trial the Dorsets gave the most and the Southdowns the richest milk. On the average the milk of these ewes contained over 7 per ct. fat and nearly 11 per ct. of solids not fat, its specific gravity exceeding that of cow's milk.

721. Feed for 100 lbs. of ewe's milk.—At the Wisconsin Station[3] Shepperd recorded the milk yielded by ewes receiving a mixture of

[1] Chem. Nahrungs-und Genuss-mittel, II, 1904, p. 602.
[2] Rpt. 1904.
[3] Agri. Science, VI, p. 397.

3 parts of wheat bran and 1 of linseed meal, with fair-quality clover hay and sliced potatoes for roughage.

Feed and water consumed by ewes for each 100 lbs. of milk produced.

	Concentrates	Clover hay	Potatoes	Water drank
	Lbs.	Lbs.	Lbs.	Lbs.
Single ewe	51	61.6	38	293
Group of 2 ewes	59	55.5	29	417
Group of 2 ewes	72	63.0	36	404

It is shown that the single ewe under trial produced 100 lbs. of milk while consuming 51 lbs. of concentrates, 61.6 lbs. of clover hay, and 38 lbs. of potatoes. The figures show that the ewe ranks with the cow in ability to convert hay and grain economically into milk, tho she is at the same time growing a fleece. (**686, 687**)

722. Value of ewe's milk for lambs.—Shepperd[1] further noted the amount of milk consumed by lambs and the gains made by them. The lambs, kept from the ewes except when sucking, were weighed before and after sucking to ascertain the amount of milk they received.

Daily gain of young lambs and gain per lb. of ewe's milk consumed.

	Age	Gain per day	Gain per lb. of milk
	Days	Lbs.	Lbs.
Lamb No. 1	25	0.62	0.156
Lamb No. 2	28	0.47	0.166
Lamb No. 3	36	0.44	0.145
Lamb No. 4	34	0.40	0.159
Average	31	0.48	0.156

In this trial the lambs made an average daily gain of nearly 0.5 lb., each lb. of milk consumed producing about 0.15 lb. increase in live weight. Shepperd concludes that the gain of lambs, during the first month of their lives at least, is largely controlled by the quantity of milk they receive, and consequently that ewes should be carefully selected for their milking qualities. (**473, 814**)

723. Feeding milk to lambs.—At the Wisconsin Station[2] the author reared 4 vigorous cross-bred Shrop-Merino lambs on cow's milk and other appropriate feeding stuffs. They were 10 days old and averaged 10 lbs. each in weight when the trial began. For the first 21 days cow's milk at blood heat constituted their sole food, and

[1] Loc. cit., pp. 397, 405. [2] Rpt. 1890.

after that skim milk, ground oats, and green clover were supplied. During the last 21 days hay was fed in place of the milk.

Rearing lambs on cow's milk and other feeds.

Period	Feed for 100 pounds gain				
	Whole milk	Skim milk	Oats	Green clover	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1st period, 21 days	579				
2d period, 115 days		830	119	262	
3d period, 21 days			291	1,197	176

At the close of the last period, when 167 days old, the lambs averaged 79 lbs. each, showing a daily gain, including birth weight, of nearly 0.5 lb. each. The heavy gains which followed the use of cow's milk suggest its profitable use in forcing lambs to meet the requirements of special markets, e. g. "Christmas lambs." (**301-2, 474, 881-5**)

724. Relative economy of lambs and pigs.—From the figures for the second period of the preceding article and those in Article 816 the following data are deduced:

Feed required for 100 lbs. of increase by young pigs and lambs.

Feed	Pigs	Lambs
	Lbs.	Lbs.
Meal	237	119
Skim milk	475	830
Green clover		262
Meal equivalent	316	284

Estimating that 6 lbs. of skim milk equals 1 lb. of meal in feeding value, according to the Danish formula, (**883**) we have 316 lbs. of meal or its equivalent as the feed required for 100 lbs. of gain with unweaned pigs. Using the same ratio for the skim milk fed to the lambs and estimating that 10 lbs. of green clover is equal to 1 lb. of meal, we have 284 lbs. of grain, or its equivalent, as the feed required for 100 lbs. of gain with young lambs, or 32 lbs. less than that required by the pigs. From this it is apparent that lambs make at least as economical gains for feed consumed as do pigs of the same age. (**472**)

725. Iowa Station breed test.—The most extensive breed test conducted with sheep in this country was made by Wilson and Curtiss at the Iowa Station.[1] In the first trial there were 10 wethers in each

[1] Buls. 33, 35.

lot, averaging 12 months in age, and in the second 9 wethers in each lot, averaging 9 months in age. The Merinos in the first trial were of the National Delaine strain and in the second trial were Rambouillets. The first trial lasted 90 and the second 105 days, the rations for all the lots being alike. The leading results of the 2 trials are arranged in the following table:

Comparison of breeds for mutton and wool production.

	Av. wt.	Av. daily gain	Av. total gain	Feed for 100 lbs. gain			Per cent dressed carcass	Av. wt. of fleece	Value of fleece
				Grain	Hay	Roots			
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
Southdown	78	0.40	39.2	483	451	279	55.3	5.7	0.70
Shropshire	95	0.41	40.6	500	476	306	54.6	8.3	1.04
Dorset	92	0.45	44.8	485	494	286	53.4	6.4	0.80
Suffolk	105	0.47	46.3	492	493	280	53.1	6.4	0.81
Oxford	107	0.46	45.2	499	500	311	52.6	9.5	1.30
Leicester	109	0.48	47.2	465	462	293	54.8	10.3	1.54
Cotswold	102	0.55	54.5	418	411	249	54.2	11.3	1.56
Lincoln	108	0.50	49.7	457	451	270	53.4	11.7	1.67
Merino	78	0.32	32.4	573	509	345	50.7	8.2	0.87

The large breeds such as the Leicester, Cotswold, and Lincoln made somewhat the largest daily gains, while the Merinos ranked lowest in daily gains and consumed the most feed for 100 lbs. of gain. The Cotswolds consumed the least feed for a given gain, tho it is not reasonable to hold that they are in a class by themselves in this particular. (**769**)

726. Daily gain for various breeds.—The best daily gains made by fat wethers exhibited at the American Fat-Stock Show, Chicago,[1] between the years 1879 and 1882, inclusive, were as follows:

Weight and average daily gain from birth of wethers making the best gains.

Breed and age	Age	Weight	Av. daily gain from birth
	Days	Lbs.	Lbs.
Wethers 2 and under 3 years			
Leicester	969	300	0.31
Cotswold	933	281	0.30
Wethers 1 and under 2 years			
Cotswold	535	220	0.41
Grade Oxford	612	232	0.38
Leicester	600	295	0.49
Wethers under 1 year			
Cotswold	170	152	0.89
Southdown	213	193	0.90
Leicester	235	178	0.75

[1] Trans. Dept. Agr., III, 1884, p. 228.

727. Soiling ewes and lambs.—Because of their daintiness and the large variety of plants they crop if opportunity offers, it is usually impracticable to soil sheep. Desiring to ascertain, regardless of cost, the amount of food required by sheep for growth in summer, the author conducted the trial reported below.[1] Ten large Merino ewes were chosen, each with a vigorous lamb at foot 1 month old when the trial began, June 3. With patience and laborious attention to details the shepherd fed the lot successfully, obtaining the results given in the table:

Feed required for 100 lbs. gain when soiling ewes and lambs.

	Green clover	Green corn fodder	Hay	Oats
Ewes and lambs, before weaning	Lbs.	Lbs.	Lbs.	Lbs.
1st period, June 3–July 29 (57 days)	2,882	478	-------	45
2d period, July 29–Sept. 16 (49 days)	555	2,400	-------	45
Lambs only, after weaning				
3d period, Sept. 16–Oct. 14 (28 days)	-------	915	292	413

Placing a fair price on the substances consumed, we find that 100 lbs. of increase was made at a reasonable cost. When we remember that the ewes would have preferred to do their own foraging and would have eaten weeds and weed seeds as well as better forage, we must conclude that evidence points to the sheep as one of the most economical meat producers on the farm.

728. Feeding grain to lambs before and after weaning.—At the Wisconsin Station[2] Craig gave some lambs grain before weaning, others grain after weaning, and still others grain during fattening only. Among the conclusions reached are the following:

"The continuous grain feeding from birth until the lambs were about 10 months old did not produce any noticeable difference in the carcasses in respect to the mixture of fat and lean, but materially influenced the early maturity of the lambs. The lambs so fed attained a given weight from 4 to 7 weeks sooner than those fed no grain before weaning and required about the same amount of grain for the same increase in weight.

"When lambs are fed grain continuously from birth they are fit for the market at any time, so that advantage may be taken of any favorable fluctuation that may occur in market prices.

"When the lambs are to be sold at weaning time in July at the age of 3 or 4 months, or in November when about 7 months old, it will pay to feed them grain."

[1] Rpt. Wis. Expt. Sta., 1890. [2] Rpt. 1896.

The unlimited feeding of grain after weaning led the lambs to eat less pasture. One-half pound of grain per head daily is the greatest amount that was found profitable to feed at this time.

729. Grain-feeding lambs before weaning.—At the Wisconsin Station[1] Craig fed various grains to unweaned high-grade Shropshire lambs for periods averaging 10 weeks. The lambs were induced to eat grain as early as possible and were given all they could consume in a trough accessible at all times thru a "creep," which shut out the dams. A summary of 4 trials is here shown.

Feeding various grains to lambs before weaning.

Grain fed	Average daily grain consumption	Average weight at beginning	Average daily gain	Average total gain	Grain fed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn meal*	0.4	39	0.51	35.8	74
Whole oats	0.4	44	0.53	37.0	78
Wheat bran	0.3	43	0.48	33.6	71
Cracked peas	0.4	37	0.53	37.0	81

* Average of 5 trials.

Corn meal gave good returns in these trials, especially when cost is considered. This feed is one of the best for unweaned lambs designed for the butcher, since it puts on much fat. For unweaned lambs which are to go into the breeding flock, at least one-half of the concentrates should be such as were fed to the other lots in these trials. Oats and peas are rich in crude protein and one or both can be grown on almost any farm in America. Where not available, bran can take their place. The large daily gains made by these unweaned lambs and the small amount of grain required in addition to the dams' milk for a given gain forcefully illustrate the principle that young animals give the best returns for feed consumed. (**95**)

730. Fattening shorn lambs.—At the Michigan Station[2] Mumford fed 2 lots of 10 lambs each for 13 weeks with the results given in the table. One lot was shorn in November at the beginning of the trial, and the other left unshorn, both receiving good clover hay and a grain mixture of equal parts of corn and wheat. Both lots were kept in a barn, the window in the pen containing the unshorn lambs being kept open, while that in the pen of the shorn lambs was kept closed. In spite of this care the shorn lambs suffered from the cold. Had it

[1] Rpt. 1903. [2] Bul. 128.

been possible to give the shorn lambs still warmer quarters they would undoubtedly have given better returns.

Feeding shorn and unshorn lambs confined in a barn.

	Average ration		Av. wt. at beginning	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Grain	Hay				Grain	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Unshorn	1.3	1.3	85	0.25	23.0	506	510
Shorn	1.4	1.5	84	0.18	16.1	786	830

The shorn lambs ate more food, drank less water, and made 30 per ct. less gain than the unshorn lambs.

At the Wisconsin Station[1] Craig, after studying the subject for four years, concludes:

"1. Fall shearing is a beneficial practice to prepare lambs that are six months old for early winter market.

"2. To secure the benefits of fall shearing, it should be done early in the season, at least not later than October.

"3. When done under such circumstances, the removal of the fleece hastens the fattening, and the gain is made at a slightly cheaper rate.

"4. The results show that by shearing in the fall and again in the spring more wool is obtained than from a single spring shearing, but the market value of the two clippings is not any greater than that of the single clipping in which the fibers of the fleece are longer.

"5. When the lambs are to be fattened during three or four of the winter months, there appears to be no practical advantage in fall shearing."

731. "Self-feeders" for fattening lambs.—To save time and labor some feeders follow the practice of placing quantities of grain sufficient to last a week or more in a box arranged so that the grain passes down into the feed trough as rapidly as the sheep consume the supply below. Mumford[2] concludes from trials covering 3 years, "Fattening lambs by means of a self-feed is an expensive practice, and economy of production requires more attention to the variation in the appetites of the animals than can be given by this method." Wing[3] writes, "Not only is the death rate much heavier where self-feeders are used, but the cost of gain is also much greater." Trials with self-feeders are reported from the Michigan Station[4] with ten

[1] Rpt. 1904.
[2] Mich. Expt. Sta., Bul. 128.
[3] Sheep Farming in America.
[4] Bul. 113.

80-lb. lambs in each lot, fed for 105 days, and from the Minnesota Station[1] with eight 80-lb. lambs in each lot fed for 117 days.

Trials with "self-feeders" for fattening lambs.

Method of feeding	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Grain	Hay			Grain	Hay
Michigan		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Self-feed	Corn, 1.4 lbs.	0.9	0.23	24.8	607	387
Ordinary	Corn, 1.5 lbs.	1.0	0.31	32.8	481	334
Self-feed	Corn and bran, 1.8 lbs.	0.9	0.22	23.7	776	405
Ordinary	Corn and bran, 1.6 lbs.	1.0	0.25	26.7	638	421
Minnesota						
Self-feed	Wheat screenings, 3.2 lbs.	0.5	0.35	41.6	908	130
Ordinary	Wheat screenings, 2.4 lbs.	0.8	0.32	37.5	742	251

In each trial the use of a self-feeder increased the amount of feed required for 100 lbs. of gain. (**497**)

Carlyle and Morton of the Colorado Station[2] report favorably on self-feed hay racks for Colorado conditions. Racks, costing $1 per running foot and accommodating four lambs per foot, two on a side, save sufficient feed to pay for themselves in two seasons.

732. Fattening sheep of different ages.—At the Montana Station[3] Shaw compared the fattening qualities of average western range lambs, 1- and 2-year-old wethers, and aged ewes. Each lot of about 50 was fed whole barley and clover hay for 88 days with the following results:

Fattening range sheep of different ages.

Age when fed	Average ration		Av. wt. at beginning	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Barley	Clover hay				Barley	Clover hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lambs	0.7	2.1	63	0.27	23.7	253	763
One-year-old wethers	0.7	3.8	95	0.27	23.5	256	1,413
Two-year-old wethers	0.7	4.1	116	0.28	24.3	248	1,469
Aged ewes	0.7	2.3	92	0.18	15.6	387	1,320

It will be observed that all lots, except the aged ewes, made practically the same daily and total gains. The lambs, however, consumed but little over half the hay eaten by the others. About the same amount of grain was required by all but the aged ewes. Other trials at the same Station[4] showed that lambs make more rapid and

[1] Bul. 44. [2] Bul. 151. [3] Bul. 35. [4] Buls. 47, 59.

economical gains than do yearling wethers. Owing to their tendency to grow, lambs require a longer period to fatten than do mature wethers, and their ration should contain more fat-producing material. (**95, 815**)

733. Exercise v. confinement.—At the Wisconsin Station[1] Humphrey and Kleinheinz tested the influence of exercise and close confinement on fattening wether lambs during 3 consecutive winters. In each trial 2 lots of 12 lambs each were fed the same rations. One lot was closely confined and the other received exercise daily when the weather permitted. The results of the 3 trials are averaged below:

Exercise v. confinement for fattening wether lambs.

	Average ration			Av. daily gain	Feed for 100 lbs. gain		
	Grain	Hay	Roots		Grain	Hay	Roots
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Exercised	1.1	1.9	1.4	0.15	708	1,297	1,068
Not exercised	1.1	1.9	1.4	0.17	618	1,113	899

These lambs made neither large nor economical gains, as they were not fed to produce the largest gains, and all were in better condition at the beginning than average feeding lambs. These results indicate that, in fattening growing wethers, close confinement in dry, airy, well-lighted pens is better than allowing much exercise. (**495, 771**)

734. Exposure v. confinement.—Next to feed, the feeding place and the method of confinement are of importance in fattening sheep. At the Minnesota Station[2] Shaw fed 4 lots, each of 8 lambs averaging 78 lbs., for 117 days under various conditions as to confinement. Lot I was kept out of doors continuously in a yard sheltered from the wind by a low building at one side. Lot II was confined in a yard with an open shed for shelter. Lot III was kept in a compartment of the barn having one large window facing the east for ventilation. All lots were fed the same ration with the following results:

Effect of various methods of confinement on fattening lambs.

Where fed	Average daily gain	Feed for 100 lbs. gain		
		Wheat screenings	Oil meal	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, out of doors	0.28	804	90	316
Lot II, in yard with shed	0.32	668	74	251
Lot III, in stable	0.28	722	80	283

[1] Rpts. 1904-5. [2] Bul. 44.

It will be seen that Lot II, kept in a yard with an open shed, made the largest and the most economical gain, while Lot I, kept out of doors, made as good gains as those confined in the barn, but required slightly more feed for 100 lbs. of gain. (**771, 828**)

735. Water.—The following table presents data gathered at the Michigan[1] and Colorado[2] Stations on the consumption of water by fattening lambs weighing about 80 lbs. at the beginning of the experiment:

Water drank by lambs on various rations during fattening.

Rations	Water drank daily	Av. daily gain	Feed and water for 100 lbs. gain				No. of trials
			Grain	Hay	Roots	Water	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Michigan							
Grain and clover hay, open-yard feeding	1.4	0.22	583	530	-------	599	1
Grain and clover hay	2.8	0.28	520	423	-------	979	8
Grain, roots, and clover hay	1.9	0.36	422	279	591	540	3
Clover hay and sugar beets	0.3	0.13	-------	1,018	4,901	314	1
Colorado							
Grain and alfalfa hay, cold water given	5.1	0.36	365	489	-------	1,423	2
Grain and alfalfa hay, warm water given	5.3	0.36	374	500	-------	1,514	2

It will be noticed that the addition of roots to the ration greatly decreased the amount of water required per lamb daily, lambs fed clover hay and unlimited sugar beets drinking only 0.3 lb. each daily. Lambs fed in an open yard required less water than those kept in confinement. At the Colorado Station, supplying lambs fattening on alfalfa hay and grain with warm instead of cold water made no difference either in the quantity of water drank or in the rate and economy of the gains produced. (**87, 612**)

Grey and Ridgeway of the Alabama Station[3] found that in late summer ewes in confinement drank 2.5 lbs. of water each while living on green sorghum forage, and 6.1 lbs. when on cotton-seed meal and hulls.

736. Salt.—In a feeding experiment in France[4] in which 3 lots of sheep were fed the same ration of hay, straw, potatoes, and beans, those receiving 0.5 oz. of salt per head daily gained 4.5 lbs. per head more than those fed no salt, and 1.25 lbs. more than those fed 0.75 oz. of salt per head daily. This indicates that sheep can be given too much as well as too little salt. The fleeces of the salt-fed sheep were better and heavier than of those fed no salt.

[1] Buls. 113, 128, 136.
[2] Bul. 75.
[3] Bul. 148.
[4] Abs. in Agr. Jour. and Min. Rec. 5 (1902), p. 361.

Grey and Ridgeway of the Alabama Station[1] found that a flock of 100 ewes would in 1 year consume from 1,500 to 2,000 lbs. of salt, which is a larger amount, certainly, than they require in many sections, tho the sheep is to a marked extent a salt-craving animal. (**91**)

737. Weight of fattened sheep.—The weight of fat sheep of the several breeds competing for prizes at the American Fat-Stock Show, Chicago, during the years 1878 to 1884, inclusive,[2] are shown below:

Weight of fat sheep of various breeds—American Fat-Stock Show.

Breed	Wethers			Ewes		
	Under 1 year	1 year and under 2 years	2 years old or over	Under 1 year	1 year and under 2 years	2 years or over
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cotswold	142	199	258	127	235	273
Other long wools	151	239	263	112	204	238
Southdown	119	172	205	97	130	169
Other middle wools	117	181	223	87	208	211
American Merino	79	112	137	52	73	101
Grades or crosses	118	188	221	122	165	213

738. Weight of fattened wethers.—Below are given the average weights and daily gains of fat wethers of the different breeds winning prizes at the Smithfield Club Show, London, England, from 1894 to 1908, inclusive:[3]

Weight of prize-winning wethers at Smithfield.

Breed	Wether lambs				Yearling wethers			
	Number	Av. age	Av. wt.	Av. daily gain	Number	Av. age	Av. wt.	Av. daily gain
		Days	Lbs.	Lbs.		Days	Lbs.	Lbs.
Middle-wool								
Southdown	96	285	149	0.52	97	637	202	0.32
Mountain	30	231	132	0.57	65	600	192	0.32
Ryeland	----	----	----	----	14	609	201	0.33
Cheviot	28	243	139	0.59	51	612	220	0.36
Shropshire	56	272	158	0.58	56	636	251	0.39
Suffolk	70	285	201	0.70	49	647	304	0.45
Dorset	39	336	203	0.59	28	669	255	0.39
Hampshire	91	199	208	0.67	72	659	281	0.42
Oxford	55	280	195	0.65	48	647	279	0.43
Long-wool								
Leicester	59	272	158	0.58	63	606	266	0.44
Kentish or Romney Marsh	63	249	159	0.64	61	615	268	0.47
Devon	43	276	184	0.67	27	624	267	0.43
Cotswold	28	284	195	0.61	17	625	293	0.47
Lincoln	45	288	207	0.72	52	641	334	0.52

[1] Bul. 148.
[2] Trans. Dept. Agr., Ill., p. 228, 1884.
[3] Lond. Live Stock Jour., Vols. 40–66.

739. Weight of carcass.—At the American Fat-Stock Show in 1884[1] animals competing for prizes were slaughtered with the results shown in the following table:

Slaughter tests with sheep at the American Fat-Stock Show, Chicago.

Age of animals	Number	Live weight at slaughter	Weight of dressed carcass	Per cent
		Lbs.	Lbs.	
Under one year	2	99	57	57
One year, under two	4	171	105	61
Two years or over	2	248	156	62

740. Smithfield slaughter tests.—At the Smithfield Club Show, London, England, animals of different breeds competing for prizes in the carcass class during the years 1898-1908, both inclusive,[2] on slaughtering showed the following results:

Smithfield slaughter tests.

Breed and age	Av. live wt. at slaughter	Av. wt. of dressed carcass	Av. per cent of dressed carcass	Av. wt. of fat	Av. wt. of pluck	Av. wt. of skin
	Lbs.	Lbs.		Lbs.	Lbs.	Lbs.
Suffolk, lambs	152	96	63	9.7	5.1	13.5
Suffolk, 1-2 years	178	118	69	11.8	5.4	14.0
Southdown, lambs	120	76	63	6.7	3.8	10.6
Southdown, 1-2 years	143	95	67	8.7	4.2	11.9
Cross-bred, lambs	126	78	62	7.1	4.2	13.2
Cross-bred, 1-2 years	165	107	65	11.0	5.0	14.7
Cheviot, lambs	113	79	63	6.7	3.5	12.3
Cheviot, 1-2 years	149	98	65	9.1	4.3	15.1
Hampshire, lambs	155	100	64	9.9	4.9	15.2
Hampshire, 1-2 years	185	119	64	12.8	5.9	14.4
Blackfaced, lambs	121	75	62	8.5	3.3	15.3
Blackfaced, 1-2 years	167	105	63	16.0	4.6	18.9
Welsh, 1-2 years	121	78	64	9.0	3.5	11.5
Kent, lambs	137	103	61	7.0	5.1	19.0

741. Shrinkage in shipping.—Linfield of the Montana Station[3] during 4 winters fattened average range lambs and 2-year-old wethers on clover hay and grain and shipped them from Bozeman, Montana, to Chicago, where they were slaughtered. The per cent of shrinkage and the dressed weight of the carcasses is shown in the next table.

It is shown that average range lambs shrank 0.8 per ct. more than 2-year-old wethers and yielded 2.2 per ct. more dressed carcass to the Chicago weight. The shrinkage in these trials ranged from

[1] Breeder's Gazette, 1884, p. 824.
[2] Lond. Live Stock Jour., Vols. 40–66.
[3] Buls. 47, 59.

4.6 to 8.7 per ct. At the Oklahoma Station[1] it was observed that, on account of the laxative nature of alfalfa hay, sheep fed thereon shrank more in shipping than others fed prairie hay. (**587**)

Data on shrinkage and weight of dressed carcass of lambs and wethers.

	Av. wt. at Bozeman	Av. wt. at Chicago stockyards	Range of shrinkage	Mean shrinkage	Av. per cent dressed carcass to Chicago wt.*
	Lbs.	Lbs.	Per cent	Per cent	
Lambs	87.5	80.7	4.6–8.7	7.6	54.5
2-year-old wethers	138.0	128.6	5.1–8.6	6.8	52.3

*Average of 3 trials.

742. Wool production.—Soil and climate produce marked effects on the characteristics of sheep, as shown by Brown[2] in his study of the evolution of various English breeds. The rich lowlands of England with their abundant nutritious grasses produced the heavy-bodied, plethoric Long-wools, the next higher lands with less abundant herbage furnished the Downs and Middle-wools, while the mountains with scanty herbage produced the active, still lighter breeds. Coleman[3] states that the peculiar luster of the Lincoln wool diminishes when these sheep pass to a less congenial soil, and that wool in certain districts of Yorkshire brings a higher price than that of other localities, due to the favorable influence of soil and climate. He further states that limestone soils, while for many reasons peculiarly suited to sheep, tend to produce a harshness in wool which renders it less valuable than that from sheep living on clays or gravels.

Aside from the moisture and dirt, wool is made up of yolk or suint, fat, and pure wool-fiber.[4] The yolk or "fat," chiefly a compound of potassium with an organic acid, comprises from 15 to over 50 per ct. of the unwashed fleece, being low in sheep exposed to the weather and especially high in Merinos. As the yolk is soluble in water, most of it is removed by washing the sheep or fleece. The "fat" in a washed fleece may range from 8 to over 30 per ct.

Warington[5] states that the production of wool-hair and wool-fat is practically no greater when a full-grown sheep receives a liberal fattening diet than when it is given only a maintenance ration. Feeding lambs liberally produces a larger body and consequently a heavier fleece. At the Wisconsin Station[6] Craig found that lambs

[1] Bul. 78.
[2] British Sheep Farming.
[3] Cattle, Sheep, and Pigs of Great Britain.
[4] Warington, Chemistry of the Farm.
[5] The Chemistry of the Farm.
[6] Rpt. 1896.

fed grain from an early age sheared about 1 lb. more of unwashed but practically the same amount of washed wool as those getting no grain until after they were weaned. The early feeding had produced more yolk but not more wool-fiber. With starvation the yield of wool is considerably diminished. The strength of the wool-fiber is dependent on the breed, the quality of the sheep, and the conditions under which they are reared. Badly bred and poorly nourished sheep produce wool of uneven fiber, lacking strength. As wool-hair is formed from the nitrogenous part of the food, the amount of protein supplied sheep must not fall too low.

743. Frequency of shearing.—Weiske and Dehmel[1] studied the influence of frequent shearing on the yield of wool. Two Rambouillet sheep were shorn every other month for a year, and 2 others at the beginning and the end of the experiment, with the results given in the following table:

Influence of frequent shearing on growth of wool.

	Av. weight unwashed wool	Av. weight pure wool fiber	Av. per cent yolk
	Lbs.	Lbs.	
Shorn 6 times	12.4	5.3	57.7
Shorn once	12.8	4.3	65.8

The sheep shorn 6 times produced less unwashed wool, but nearly 25 per ct. more pure wool fiber than those shorn once.

[1] Futterungslehre, 1872, p. 511.

CHAPTER XXIX.

EXPERIMENTS IN FATTENING SHEEP.

I. Feeding and Fattening.

Nearly all the feeding trials here reported are with lambs, for the sufficient reason that these animals make better use of their feed than do mature sheep, and also because their flesh is more in demand. Two classes, western range lambs and those from the farms of the East, appear in the trials.

In what follows, when no mention is made in detailing a feeding experiment, it may be assumed that eastern lambs weighed about 80 lbs. when feeding began and western lambs 67 lbs. and that the feeding period covered from 12 to 15 weeks. Western clover hay has a feeding value equal to that of alfalfa hay, a fact to be remembered in studying the trials in which it was used.

744. Indian corn.—This grain is extensively used for fattening sheep and lambs over the United States as far west as Colorado, beyond which wheat and barley are more commonly used. The table below gives the results of 4 trials with corn for fattening lambs at eastern experiment stations and 4 similar trials at western stations:

Fattening lambs on whole corn and hay.

Experiment station	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Corn	Hay			Corn	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Eastern states						
Michigan*	1.5	1.0	0.31	32.8	481	334
Michigan*	1.4	0.9	0.24	24.8	607	387
Wisconsin†	1.5	1.0	0.37	20.8	411	277
Minnesota‡	1.3	1.0	0.25	21.1	523	402
Av. of 4 trials	1.4	1.0	0.29	24.9	506	350
Western states						
South Dakota**	1.5	1.3	0.28	30.5	561	485
South Dakota ††	1.6	1.5	0.35	39.0	466	431
Wyoming‡‡	1.1	1.7	0.29	28.6	381	584
Nebraska§	1.0	1.4	0.33	31.9	308	412
Av. of 4 trials	1.3	1.5	0.31	32.5	429	478

*Bul. 113. †Rept. 1895. ‡Bul. 31. **Bul. 86. ††Bul. 80. ‡‡Bul. 73. §Bul. 66.

From this table we learn that eastern lambs gained 0.3 lb. per head daily, and required about 500 lbs. of corn and 350 lbs. of clover hay for each 100 lbs. of increase while fattening. Western range lambs gained slightly more than 0.3 lb. per head daily, and required about 425 lbs. of corn and 500 lbs. of alfalfa hay for 100 lbs. increase. This is about 75 lbs. less corn and 150 lbs. more hay for 100 lbs. of gain than eastern lambs required. (**521-3**)

745. Corn alone and in combination.—At the Wisconsin Station[1] Craig fed 3 lots, each of 5 high grade, 58-lb. Shropshire lambs, the grain allowances shown below before and after weaning. The lambs were fed all the grain they would eat morning and evening, and during the day were with their dams on blue-grass pasture.

Corn meal compared with grain mixtures.

Grain fed	8 weeks before weaning				8 weeks after weaning			
	Av. grain allowance	Av. daily gain	Av. gain in 8 weeks	Grain for 100 lbs. gain	Av. grain allowance	Av. daily gain	Av. gain in 8 weeks	Grain for 100 lbs. gain
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Corn meal only	0.13	0.50	28	26	0.5	0.34	19.0	137
Lot II, Corn meal and oats	0.15	0.50	28	31	0.5	0.33	18.5	141
Lot III, Corn meal and peas	0.21	0.50	28	42	0.5	0.35	19.6	136

It is shown that corn meal alone proved more economical before weaning than corn and oats or corn and peas, and of equal value to these combinations after weaning. It is probable that corn will force the largest and most economical gains with lambs both before and after weaning, the protein required coming from the dam's milk and pasture grass. It is not prudent, however, to use corn alone for ewe lambs designed for the flock, since this grain builds fat rather than bone and muscle.

In feeding ground corn alone there is likely to be more sickness among the lambs than if they have a mixed grain allowance. The lambs that were fed grain continuously from birth sheared a heavier fleece of unwashed wool than either those receiving no grain previous to fattening or those not allowed grain until after weaning This increased weight of fleece was due to the excess of yolk or grease in the wool of the lambs fed grain from birth, as all fleeces showed about the same weight of washed wool.

[1] Rpt. 1897.

746. Wheat.—In the following table are summarized the results of 5 trials at 4 stations with whole wheat and hay for fattening lambs:

Fattening lambs on whole wheat and hay.

Experiment station	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Whole wheat	Hay			Wheat	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Michigan*	1.3	1.3	0.24	21.7	553	552
Montana†	0.8	2.0	0.27	25.3	302	767
Utah‡	0.9	1.2	0.19	17.0	454	657
South Dakota§	1.5	1.3	0.28	31.5	532	469
South Dakota§	1.5	1.3	0.28	31.5	536	470
Average of 5 trials	1.2	1.4	0.25	25.4	475	583

*Bul. 128. †Bul. 47. ‡Bul. 78. §Bul. 86.

In round numbers the Michigan lambs required 550 lbs. each of wheat and red clover hay for 100 lbs. of gain. The Montana range lambs, in excellent condition when the trial began, consumed only 300 lbs. of good wheat and nearly 800 lbs. of clover hay for 100 lbs. gain. The South Dakota lambs were fed mixed brome and prairie hay with bread wheat in the first, and good durum or macaroni wheat in the second trial. Since both lots required practically the same feed for 100 lbs. gain, we may conclude that these 2 varieties of wheat have the same feeding value. Compared with the corn-fed range lambs previously reported, the wheat-fed range lambs required from 50 to 75 lbs. more grain and 100 lbs. more of alfalfa hay for 100 lbs. gain. This shows that wheat is less valuable than corn for fattening lambs. (**161**)

747. Oats.—The results of 3 trials at western stations with whole oats and hay for fattening lambs are presented in the following table:

Fattening lambs on whole oats and hay.

Experiment station	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Whole oats	Hay			Whole oats	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Montana*	0.8	2.1	0.22	20.9	366	959
Montana†	0.6	1.8	0.25	23.9	253	738
South Dakota‡	1.6	1.3	0.25	27.7	649	535
Average of 3 trials	1.0	1.7	0.24	24.2	423	744

*Bul. 47. †Bul. 59. ‡Bul. 86.

For each 100 lbs. of gain the Montana lambs consumed on the average about 310 lbs. of oats and 850 lbs. of clover hay. The South Dakota lambs ate 350 lbs. more oats and 300 lbs. less prairie hay for the same increase. Since on the average these lambs consumed about as much oats and nearly 250 lbs. more hay for 100 lbs. of gain than those fed corn as reported in Article 744, we may conclude that oats have somewhat less value than corn for fattening lambs. The great importance of a legume hay is emphasized by the high feed cost of the Dakota lambs getting prairie hay. (**169**)

748. Barley.—Thruout the western range district barley is used for fattening sheep and lambs. Below are given the results of 5 trials at western experiment stations with barley and hay for fattening range lambs.

Fattening range lambs on whole barley and hay.

Experiment station	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Barley	Hay			Barley	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Montana*	0.7	2.1	0.27	23.7	253	763
Montana†	0.8	2.1	0.26	24.3	316	819
South Dakota‡	1.8	1.0	0.36	37.9	509	263
South Dakota§	1.6	1.3	0.26	28.5	617	518
Wyoming‖	0.8	2.8	0.33	29.6	257	834
Average of 5 trials	1.1	1.9	0.30	28.8	390	639

*Bul. 35. †Bul. 47. ‡Bul. 71. §Bul. 86. ‖Bul. 81.

In round numbers the Montana lambs consumed less than 300 lbs. of barley and 800 lbs. of clover hay for 100 lbs. of gain, while the South Dakota lambs required from 500 to 600 lbs. of barley and only 400 lbs. of prairie hay. It is shown that the lambs fattened on barley required about the same amount of grain and 100 lbs. more hay than corn-fed lambs for 100 lbs. of gain. Whole barley was satisfactorily masticated and digested by the lambs, and the beards, with rare exceptions, caused no injury to their mouths. Whole barley is only slightly less valuable than corn for fattening lambs. In these trials prairie hay again gives poor returns with fattening animals in comparison with legume hay. (**171**)

749. Emmer.—Owing to the greatly increased production of emmer (speltz) in the western states, this grain has assumed importance as a food for sheep and lambs. In the table on the next page are given the results of four trials at western experiment stations with emmer for fattening range lambs.

In the first Dakota trial brome hay was fed for roughage, and in the second mixed prairie and brome hay. Over 700 lbs. of emmer and 500 lbs. of hay were required on the average for 100 lbs. of gain. The Colorado lambs fed emmer and good alfalfa hay gained 0.32 lb. daily and consumed only 300 lbs. of emmer and 625 of hay for 100 lbs. gain—an unusually economical gain. We learn that with brome and prairie hay for roughage emmer is much less valuable than corn, while with a legume hay it has a satisfactory feeding value. (**178**)

Fattening lambs on whole emmer and hay.

Experiment station	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Emmer	Hay			Emmer	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
South Dakota*	1.8	1.0	0.24	25.0	747	399
South Dakota†	1.7	1.3	0.22	24.9	738	596
Colorado‡	1.0	2.0	0.32	28.4	303	626
Wyoming‖	0.8	2.7	0.23	20.6	359	1,141
Average of 3 trials	1.3	1.8	0.25	24.7	537	691

*Bul. 71. †Bul. 86. ‡Bul. 75. ‖Bul. 81.

750. Various grains compared.—At the Wisconsin Station[1] Humphrey and Kleinheinz fed 4 lots, each of 4 thrifty 140-lb. yearling wethers, the following grain allowances during each of two winters. Each wether was given a daily average of 1.0 lb. of native hay and 2.1 lbs. of roots or cabbage. The results of the trials, which lasted 98 and 105 days, are averaged below:

Various grains for fattening wethers.

Daily grain allowance	Av. daily gain	Av. total gain	Feed for 100 lbs. gain		
			Grain	Hay	Roots or cabbage
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Cracked corn and oats, 1.7 lbs.	0.36	36.9	453	290	573
Lot II, Cracked peas and oats, 1.7 lbs.	0.34	34.9	479	309	604
Lot III, Cracked barley and oats, 1.6 lbs.	0.35	35.7	453	301	592
Lot IV, Whole oats, 1.5 lbs.	0.32	33.8	468	338	663

The wethers getting whole oats made the poorest gains, but their allowance of concentrates was also the smallest. As the returns were so nearly alike in all cases, we may conclude that corn, peas, barley, and oats, when fed with the roughages named, have practically the same value for fattening mature sheep. The daily gains made by these yearlings were no greater than those which lambs make, and,

[1] Rpt. 1905.

considering the excellence of the combination of grain, hay, and roots or cabbage, they were hardly as economical.

751. Millet, low-grade wheat, weed seeds.—Below are given the results of trials at several stations with cull wheat and weed seeds compared with cracked corn for fattening lambs:

Millet, cull wheat, and weed seeds compared with cracked corn for fattening lambs.

Station and average ration	Av. daily gain	Feed for 100 lbs. gain	
		Grain	Hay
*Minnesota**	Lbs.	Lbs.	Lbs.
Lot I Cracked corn, 1.3 lbs. Timothy hay, 1.0 lb.	0.25	523	402
Lot II Small wheat, 1.8 lbs. Timothy hay, 0.9 lb.	0.24	745	367
Lot III Pigeon grass, 2.4 lbs. Timothy hay, 0.5 lb.	0.27	874	189
Lot IV Wild buckwheat, 2.3 lbs. Timothy hay, 0.7 lb.	0.28	816	249
South Dakota†			
Millet, 1.6 lbs. Mixed hay, 1.3 lbs.	0.28	581	474
Utah‡			
Frosted wheat, 0.9 lb. Alfalfa hay, 1.4 lbs.	0.21	419	650

*Rpt. 1893. †Bul. 86. ‡Bul. 78.

Apparently no advantage was gained from cracking corn for the lambs, since it gave only normal returns. Small wheat, pigeon-grass seed, and wild buckwheat, about 90 per ct. pure, fed with hay produced satisfactory gains in each case, tho larger amounts were required than of cracked corn for a given gain. If clean and free from poorer stuff, these elevator by-products may be considered to have about three-fourths the value of corn for fattening lambs. (**185**) In a previous trial at the South Dakota Station it was found that lambs fed whole millet voided a large percentage of the seed unbroken and undigested. Accordingly in this trial the millet was coarsely ground, and thus prepared it proved nearly as valuable for fattening lambs as cracked corn. Frosted wheat produced nearly as large gain as good wheat, 419 lbs. of wheat and 650 lbs. of alfalfa hay putting on 100 lbs. of gain.

752. Wheat screenings.—Below are summarized the results of four trials at western stations with wheat screenings for fattening range lambs:

Fattening lambs on unground wheat screenings and hay.

Experiment station	Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
	Unground wheat screenings	Hay			Unground wheat screenings	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Minnesota*	2.4	0.8	0.32	37.5	742	251
Montana†	0.8	2.0	0.29	27.2	282	773
Utah‡	1.1	1.3	0.20	18.3	532	623
Utah‡	0.9	1.5	0.24	21.4	396	622
Average of 4 trials	1.3	1.4	0.26	26.1	488	567

*Bul. 44. †Bul. 47. ‡Bul. 78.

In round numbers the Minnesota lambs required 740 lbs. of wheat screenings and 250 lbs. of mixed clover and timothy hay for 100 lbs. gain, while the Montana lambs required 300 lbs. of wheat screenings and nearly 800 lbs. of clover hay. In the first Utah trial lambs fed chaffy screenings and alfalfa hay required more screenings and 100 lbs. less hay for 100 lbs. of gain than the Montana lambs. The last lot consumed only 400 lbs. of heavier screenings and 625 lbs. of alfalfa hay for 100 lbs. of gain. Comparing these returns with those in the previous articles, it is shown that good wheat screenings have about the same value for fattening lambs as wheat. Like wheat, screenings give the best returns when fed with alfalfa or clover hay. **(167)**

753. Soybeans.—At the Wisconsin Station[1] Richards and Kleinheinz compared soybeans with oats as a supplement to corn for feeding ewe lambs averaging 103 lbs. per head. The results of the trial, which lasted 84 days, are shown in the table:

Soybeans compared with oats for ewe lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
			Grain	Roughage
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Soybeans and corn, 1.2 lbs. Hay, 0.8 lb. Corn stover, 0.6 lb.	0.19	16.3	611	711
Lot II Oats and corn, 1.2 lbs. Hay, 0.8 lb. Corn stover, 0.6 lb.	0.16	13.7	728	862

[1] Rpt. 1904.

As these lambs were intended for breeding stock they were rather lightly fed. The lambs fed soybeans and corn made larger gains, consumed less grain and roughage for 100 lbs. gain, and were thriftier than those fed oats and corn. Soybeans are evidently a most excellent supplement to corn for lambs. **(201)**

754. Oil cakes.—At the Edinburgh and East of Scotland College of Agriculture[1] Bruce tested the relative value of various concentrates with 4 lots, each of 30 yearling wethers averaging 93 lbs. All lots were fed the concentrates given below with unlimited hay and sliced turnips for roughage. The results of the trial, which lasted 85 days, were as follows:

Various concentrates for fattening yearling wethers.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain		
			Concentrates	Hay	Turnips
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Cotton cake, 0.8 lb. Hay, 0.3 lb. Turnips, 14.2 lbs.	0.30	25.1	282	95	4,797
Lot II Cotton cake and linseed cake, 0.8 lb. Hay, 0.4 lb. Turnips, 13.7 lbs.	0.34	28.6	247	112	4,075
Lot III Linseed cake, 0.8 lb. Hay, 0.4 lb. Turnips, 13.5 lbs.	0.36	30.9	227	115	3,728
Lot IV Dried distillers' grains, 0.8 lb. Hay, 0.3 lb. Turnips, 13.6 lbs.	0.31	26.5	267	92	4,376

The wethers fed linseed cake produced the largest gains and required the smallest amount of concentrates and roughage for 100 lbs. of gain. Cotton-seed cake proved the least valuable. Mixed cottonseed cake and linseed cake produced nearly as large and as economical gains as linseed cake alone. Lot IV, fed dried distillers' grains, made satisfactory gains, requiring 40 lbs. more concentrates and about 650 lbs. more turnips for 100 lbs. gain than Lot III. The large amount of turnips consumed shows how freely British farmers use roots in sheep feeding. **(188, 200, 317)**

755. Dried beet pulp and molasses-beet pulp.—At the Michigan Station[2] Shaw fed 4 lots, each of 18 western lambs averaging 67 lbs.,

[1] Bul. 10. [2] Bul. 220.

on dried beet pulp or molasses-beet pulp with other concentrates and clover hay, as shown below, in trials which lasted 85 days:

Dried beet pulp and molasses-beet pulp for fattening range lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
			Concentrates	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Corn, 0.7 lb. Linseed meal, 0.2 lb. Bran, 0.4 lb. Clover hay, 1.5 lbs.	0.33	28.1	385	465
Lot II Dried beet pulp, 0.7 lb. Linseed meal, 0.2 lb. Bran, 0.4 lb. Clover hay, 1.5 lbs.	0.33	28.0	387	456
Lot III Molasses-beet pulp, 0.9 lb. Linseed meal, 0.3 lb. Clover hay, 1.3 lbs.	0.34	29.2	372	378
Lot IV Dried beet pulp, 0.9 lb. Linseed meal, 0.3 lb. Clover hay, 1.3 lbs.	0.33	28.3	383	421

The table shows that the several lots made substantially the same daily and total gains, all consuming practically the same amount of concentrates and roughage for 100 lbs. of gain. This being true, we may conclude that for fattening lambs dried beet pulp is equal to the same amount of corn, and that molasses-beet pulp is no more valuable than dried beet pulp. (**311-12, 645-6**)

756. Meat meal, dried blood.—Schenke[1] states that, when mixed with better liked feed, sheep will readily consume a ration containing from 5 to 10 per ct. of meat meal. Meat meal produced larger but less economical gains than grain alone, and evidently increased the wool production.

Regnard[2] obtained excellent results when feeding dried blood to lambs in place of milk, supplying about 0.5 lb. daily for each 100 lbs. live weight. (**306, 651**)

757. Corn silage v. roots.—At the Michigan Station[3] Mumford compared corn silage with roots for fattening lambs. In the first trial, lasting 84 days, sugar beets and corn silage were fed, and in the second, lasting 119 days, rutabagas and corn silage. The concen-

[1] Landw. Vers. Stat., 58, 1903, pp. 26, 27.
[2] Pott, Landw. Futtermittel, p. 656.
[3] Buls. 84, 107.

trates consisted of 2 parts of oats and 1 part of bran in the first trial, and equal parts of oats and bran in the second.

Corn silage compared with roots.

Average ration	Av. daily gain	Feed for 100 lbs. gain		
		Grain	Hay	Roots or silage
First trial	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Sugar beets, 4.7 lbs. Hay, 1.0 lb. Grain, 1.0 lb.	0.43	233	233	1,101
Lot II Silage, 4.5 lbs. Hay, 0.8 lb. Grain, 1.0 lb.	0.36	282	225	1,266
Second trial				
Lot I Rutabagas, 5.6 lbs. Hay, 1.6 lbs. Grain, 1.0 lb.	0.25	398	413	2,277
Lot II Silage, 3.4 lbs. Hay, 0.8 lb. Grain, 1.0 lb.	0.25	400	337	1,383

In the first trial sugar beets gave somewhat better results than corn silage, while in the second rutabagas did not quite equal corn silage. **(352)**

758. Corn silage v. mangels.—At the Iowa Agricultural College[1] Kennedy, Robbins, and Kildee fed 79-lb. lambs for 112 days on corn silage or mangels in combination with alfalfa hay with the results shown in the table:

Corn silage compared with mangels for fattening lambs.

Average ration	Av. daily gain	Feed for 100 lbs. gain			Cost for 100 lbs. gain
		Grain	Roots or silage	Hay	
	Lbs.	Lbs.	Lbs.	Lbs.	Dollars
Lot I Mixed grain, 2.0 lbs. Corn silage, 1.4 lbs. Alfalfa hay, 1.6 lbs.	0.42	463	327	367	5.90
Lot II Mixed grain, 2.0 lbs. Mangels, 4.3 lbs. Alfalfa hay, 1.6 lbs.	0.44	450	986	357	6.82
Lot III Mixed grain, 1.9 lbs. Alfalfa hay, 1.7 lbs.	0.37	511	------	464	6.33

In this trial the lambs were all heavily fed on grain and made correspondingly large gains. The lot fed corn silage made almost as

[1] Bul. 110.

good gains as that fed mangels and at considerably lower cost for feed consumed. (**352**)

759. Wet beet pulp.—The value of wet beet pulp with and without grain for fattening range lambs was tested at the Utah Station[1] during 2 consecutive winters. The results of the 2 trials, the first with 2 lots of 17 lambs each fed 78 days, and the second with 2 lots of 16 lambs each fed 107 days, are given below. Each lot was fed an unlimited allowance of alfalfa hay and wet beet pulp. In addition Lot II received mixed wheat screenings and bran, and Lots III and IV mixed wheat shorts and bran.

Wet beet pulp with and without grain for fattening lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain		
			Concentrates	Beet pulp	Alfalfa hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Wet beet pulp, 3.7 lbs. Alfalfa hay, 1.6 lbs.	0.21	16.2	....	1,786	797
Lot II Wet beet pulp, 3.3 lbs. Alfalfa hay, 1.4 lbs. Screenings and bran, 0.5 lb.	0.33	25.7	156	1,014	423
Lot III Wet beet pulp, 2.3 lbs. Alfalfa hay, 1.0 lb. Shorts and bran, 0.9 lb.	0.21	22.0	470	1,120	530
Lot IV Wet beet pulp, 2.2 lbs. Alfalfa hay, 1.1 lbs. Shorts and bran, 0.4 lb.	0.19	20.6	254	1,180	590

Lot I required about 1,800 lbs. of wet beet pulp and 800 of alfalfa hay for 100 lbs. of gain. By feeding 156 lbs. of grain, about 800 lbs. less wet beet pulp and nearly 300 lbs. less alfalfa hay were required for 100 lbs. of gain. As a rule it is best to feed about 0.5 lb. of grain per head daily when the rest of the ration consists of wet beet pulp and alfalfa hay. (**309-10**)

760. Rape.—At the Ontario Agricultural College[2] Shaw pastured on rape 3 lots, each of 15 lambs averaging 71 lbs. in weight. Each lot was confined to a measured acre by hurdles. Lot I was given no additional feed; Lot II was fed 0.5 lb. of oats each daily; and Lot III had the run of an adjoining grass pasture in addition to the rape. The acre of rape lasted each lot 58 days, during which time the lambs made the gains shown in the table on the next page.

[1] Buls. 78, 90.

[2] Rpt. 1891.

The addition of oats to the rape ration did not prove economical. The value and importance of grass pasture in supplementing rape for sheep feeding is strongly brought out by the larger daily and total gains made by Lot III. It is shown that an acre of rape will put from 300 to 400 lbs. of gain on lambs grazed thereon.

Returns from one acre of rape.

How fed	Av. daily gain	Av. total gain	Gain in wt. from 1 acre
	Lbs.	Lbs.	Lbs.
Lot I, Rape only	0.39	22.9	344
Lot II, Rape and 0.5 lb. oats	0.40	23.7	348
Lot III, Rape and grass pasture	0.47	28.0	420

At the Ontario College[1] 54 acres of rape pastured 17 steers and 537 sheep, 1 acre lasting 12 lambs for 2 months. An acre of rape was estimated to be worth $16.80. At the Michigan Station 15 acres of rape pastured 128 lambs for 7.5 weeks, during which time they gained 2,890 lbs. in weight. It was estimated that 1 acre of rape pastured 9 lambs 7 weeks, producing in that time 203 lbs. of increase. (**282, 895, 899**)

761. Rape v. blue grass.—Craig of the Wisconsin Station[2] grazed 2 lots of 48 lambs each, one lot on a blue-grass pasture and the other on rape. During the grazing period of 4 weeks each lamb was fed an average of 0.7 lb. daily of a mixture of equal parts of peas and corn. During this period Lot I consumed the rape on 0.64 of an acre. At the close of the 4-week period both lots were placed in pens, and the grain allowance was increased to 1 lb. daily per lamb, together with an unlimited allowance of hay, which amounted to 0.6 lb. daily for each rape-fed and 0.7 for each grass-fed lamb. The following table summarizes the results of the trial:

Relative value of rape and blue-grass pasture for lambs.

	Pasture period of 4 weeks		Pen period of 12 weeks			
	Av. daily gain	Av. total gain	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
					Grain	Hay
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, On rape	0.37	10.4	0.24	19.8	429	261
Lot II, On blue grass	0.24	6.8	0.22	17.9	476	315

The table shows that the lambs pastured on rape did much better than those pastured on blue grass, both while on pasture and also

[1] U. S. Dept. Agr., Farmers' Bul. 49. [2] Rpt. 1897.

later when confined to feeding pens. This trial tends to establish a secondary value for rape in sheep feeding.

762. Field peas.—At the Wyoming Station[1] Morton tested the value of field peas for fattening lambs in a 98-day trial with 2 lots, each of 100 lambs averaging 58 lbs. Lot I was grazed upon field peas and Lot II fed shelled corn and alfalfa hay, with the results given below:

Field peas for fattening lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I Field peas, 0.2 square rod	0.20	20.0	0.6 acre field peas
Lot II Shelled corn, 0.9 lb. Alfalfa hay, 2.2 lbs.	0.32	31.2	292 lbs. corn 682 lbs. hay

Altho the lambs fed alfalfa and corn gained about one-half more than those grazed upon field peas, yet owing to the lower cost of producing the peas the net returns from the 2 lots were nearly the same. In a previous trial at this Station[2] lambs grazed on field peas made larger gains and went to the market in better condition than others fed alfalfa and corn. (**205, 805**)

763. Alfalfa hay v. prairie hay.—At the Nebraska Station[3] Burnett fed 52-lb. lambs alfalfa hay in opposition to prairie hay, giving them in addition all the shelled corn they would eat. The results of the trial which lasted 98 days are as follows:

Alfalfa hay compared with prairie hay for fattening lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
			Corn	Hay
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I Alfalfa hay, 1.4 lbs. Shelled corn, 1.0 lb.	0.33	31.9	306	411
Lot II Prairie hay, 0.9 lb. Shelled corn, 0.9 lb.	0.20	19.8	429	424

As shown above, the lambs in Lot I, fed alfalfa hay, ate more hay and grain, made heavier gains, and yet consumed 123 lbs. less corn for each 100 lbs. of gain. They were more thrifty, had better appetites, and so were able to convert more feed into mutton. (**245**)

764. Common fodders.—At the Michigan Station[4] Mumford fed 6 lots, each of ten 75-lb. lambs, for 98 days to test the value of vari-

[1] Bul. 73. [2] Bul. 64. [3] Bul. 66. [4] Bul. 136.

ous roughages. Each lamb received 1.4 lbs. shelled corn and 1.2 lbs. rutabagas daily, together with the dry fodder shown below:

Comparison of various roughages for fattening lambs.

Daily allowance of dry roughage	Av. daily gain	Av. total gain	Feed given for 100 lbs. gain		
			Corn	Dry fodder	Roots
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Clover hay, 1.2 lbs.	0.33	32.4	423	362	365
Lot II, Alfalfa hay, 1.3 lbs.	0.35	34.4	395	373	340
Lot III, Millet hay, 1.0 lbs.	0.26	25.8	523	372	453
Lot IV, Corn stover, 1.4 lbs.	0.31	30.2	451	462	387
Lot V, Oat straw, 1.4 lbs.	0.29	28.5	478	489	411
Lot VI, Bean straw, 1.5 lbs.	0.30	29.6	463	488	395

In this trial alfalfa hay proved slightly superior to clover hay. (**254**) Concerning millet hay, which gave the poorest returns, Mumford writes: "More care is necessary in feeding millet hay to fattening lambs than any other coarse fodder. Unless fed in small quantities it induces scouring." (**229**) Lot IV, given corn stover cut into 1.5 to 3 inch pieces with a silage cutter, made nearly as large daily and total gains as Lot I, fed clover hay, and consumed only a little more feed for 100 lbs. of gain. This shows the high value of good stover for lambs. (**218**) Oat straw proved inferior to clover or alfalfa hay, yet Lot V, receiving this fodder, made large and economical gains. (**242**) Experienced feeders will agree that the fair returns from the millet hay and the good returns from the corn stover and oat straw were made possible in this trial because roots were fed with them. Bean straw proved a good substitute for clover hay.

765. Sorghum hay.—At the Nebraska Station[1] Burnett fed 3 lots, each of 12 lambs averaging about 60 lbs., for 98 days on the rations given below:

Sorghum hay compared with alfalfa hay for fattening lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
			Concentrates	Hay
Lot I	Lbs.	Lbs.	Lbs.	Lbs.
Alfalfa hay, 1.7 lbs. Shelled corn, 1.4 lbs.	0.32	31.3	424	519
Lot II				
Sorghum hay, 1.7 lbs. Shelled corn, 1.3 lbs.	0.21	20.2	612	818
Lot III				
Sorghum hay, 1.7 lbs. Shelled corn, 1.1 lbs. Linseed meal, 0.2 lb.	0.27	26.8	502	617

[1] Bul. 71.

The lambs fed sorghum hay and shelled corn made only two-thirds as large gains as those fed alfalfa hay and corn, and required nearly 200 lbs. more grain and 300 lbs. more roughage for 100 lbs. of gain. The lambs fed 0.2 lb. of linseed meal in addition to sorghum hay and shelled corn made heavier and more economical gains than those getting no linseed meal. The report states that during the last 2 weeks of the trial the lambs fed sorghum hay and corn tired of the ration and ate poorly, while those getting linseed meal in addition to the sorghum hay and corn ate well and made good gains thruout the trial. (**222**)

766. Various roughages for fattening lambs.—At the Oklahoma Station[1] McDonald and Malone fed 4 lots, each of 10 lambs averaging about 75 lbs., the following rations for 140 days. Each lot was given all the grain and roughage it would consume.

Alfalfa, cowpea, and prairie hay, and corn stover for fattening range lambs.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain		
			Grain	Hay	Corn stover
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I					
Alfalfa hay, 1.5 lbs.					
Corn meal, 1.6 lbs.	0.36	50.3	454	411	----------
Lot II					
Cowpea hay, 1.5 lbs.					
Corn meal, 1.6 lbs.	0.37	52.1	433	391	----------
Lot III					
Prairie hay, 1.0 lb.					
Corn meal, 1.2 lbs.					
Cotton-seed meal, 0.4 lb.	0.28	39.9	581	366	----------
Lot IV					
Corn stover, 0.8 lb.					
Alfalfa hay, 0.7 lb.					
Corn meal, 1.2 lbs.					
Cotton-seed meal, 0.4 lb.	0.34	47.7	479	206	220

These lambs were fed for the longest period coming under our observation, and made the largest total gains as well as large daily gains. They also consumed but a small amount of grain and roughage for 100 lbs. of gain. Cowpea hay proved fully equal to alfalfa hay. (**261**) Prairie hay with corn meal and cotton-seed meal produced fairly large total and daily gains, but at a greater consumption of concentrates for 100 lbs. of gain. The ration fed Lot IV, consisting of alfalfa hay, corn stover, corn meal, and cotton-seed meal, proved nearly as good as that supplied either of the first two lots.

[1] Bul. 78.

767. Grazing sheep on annual pastures.—Keeping sheep chiefly on pastures specially sown for them was first practiced in America at the Minnesota Station[1] in 1895 by Shaw, who writes thus of this system: "It enables the flockmaster to maintain a much larger number of animals than he otherwise could. It makes it possible for him to give them more or less of succulent pasture from spring till fall, which is favorable to their development. It enables him to destroy cheaply and effectively nearly all kinds of weeds and to fertilize his land so that it will be in a good condition to grow other crops."

In one trial Shaw grazed 2 lots, each of ten 80-lb. yearling wethers, for 112 days by means of hurdles on the following succession of pastures: Winter rye, peas and oats, barley and oats, rape, kale, peas and oats. Lot II received 0.5 lb. of oats per head daily in addition to pasture. The results of the trial are given below:

Grazing yearling wethers on special crops with and without grain.

Average ration	Av. daily gain	Av. total gain
	Lbs.	Lbs.
Lot I, Pasture	0.15	16.8
Lot II, Pasture and 0.5 lb. oats	0.24	26.9

While the gains were not remarkably large with either lot, they were all that could be expected during warm weather. Lot II gained 60 per ct. more than Lot I, which received no grain, and was in better condition at the close of the trial. The increase in gain was worth more than the cost of the grain fed.

768. Sheep fattening in Great Britain.—Ingle[2] has collated all published sheep-feeding trials reported in Britain between the years 1844 and 1905, numbering 194. From his extended report the following typical examples are drawn to show the rations used by British farmers in fattening sheep and lambs.

In his review of these feeding trials Ingle observes that: Clover hay proved extremely useful not only because of the nitrogenous matter but also of its high content of lime compared with phosphoric acid. Linseed cake produced a given increase with less than the average amount of feed, and the carcasses dressed above the average. Cotton-cake gave average results. Oats, on the whole, were unsatisfactory. Barley was satisfactory unless used in large quantity, when it seemed to have an injurious effect on the animals. Whole barley

[1] Bul. 78.

[2] Trans. Highl. and Agr. Soc. Scotland, 1910.

was better relished than barley meal. (**171**) Wheat gave good results. Malt showed little or no superiority over barley. (**173**) Dried brewers' grains and dried distillers' grains proved very satisfactory. (**175, 317**) Mangels gave better results than swedes, and stored swedes proved better than frosted swedes. The best results followed feeding from 95 to 100 lbs. of roots weekly per 100 lbs. of live sheep. (**275**)

Rations used by British farmers in fattening sheep and lambs.

No. of animals	Length of feeding period	Breed	Average ration	Av. weight	Av. daily gain	Av. total gain
	Days			Lbs.	Lbs.	Lbs.
20	102	Oxford	Linseed cake, 0.3 lb. Barley, 0.3 lb. Hay, 0.4 lb. Swedes, 22.9 lbs.	128	0.43	42
10	108	Oxford—Hampshire	Linseed cake, 0.7 lb. Molasses, 0.1 lb. Clover hay, 2.1 lbs. Wheat straw, 0.3 lb.	130	0.24	27
8	121	Cotswold	Cotton-seed cake, 1.6 lbs. Hay, 1.0 lb. Roots, 15 lbs.	132	0.33	41
10	60	......	Corn, 0.6 lb. Oats, 0.5 lb. Swedes, 14.8 lbs.	108	0.23	14
10	35	......	Decort. cotton-cake, 0.6 lb. Dried distillers' grains, 0.4 lb. Turnips, 15 lbs.	109	0.29	10
19	105	Leicester—Blackfaced	Corn, 0.7 lbs. Hay, 0.5 lb. Swedes, 11.5 lbs.	97	0.33	35
18	105	......	Linseed cake, 0.7 lb. Swedes, 12.8 lbs.	99	0.36	37
15	72	Mountain	Decort. cotton-cake, 0.3 lb. Corn, 0.3 lb. Clover hay, 0.8 lb. Swedes, 13 lbs.	61	0.19	14
38	93	Half-bred	Bombay cotton-cake, 0.3 lb. Dried distillers' grains, 0.3 lb. Hay, 0.4 lb. Swedes, 16.3 lbs.	119	0.40	36
19	105	Cross Bor. Leices.—Blackfaced	Hay, 0.7 lb. Swedes, 15.3 lbs.	91	0.21	22

The almost universal feeding of oil cake and roots in great quantity to fattening sheep by the British farmer is shown in these examples.

CHAPTER XXX.

GENERAL CARE OF SHEEP AND LAMBS—FATTENING—HOTHOUSE LAMBS.

I. Shepherd and Flock.

The sheep is the plant-scavenger of the farm. Because of its dainty manner of nibbling herbage we might suppose that its likes were few and dislikes many, yet nearly every plant at some period of its growth seems palatable and is freely eaten. No domestic or wild animal is capable of subsisting on more kinds of food. Grasses, shrubs, roots, the cereal grains, leaves, bark, and in times of scarcity fish and meat, all furnish subsistence to this wonderfully adaptive animal. In the great pine forests of Norway and Sweden[1] they will exist thru a hard winter by eating the pungent resinous evergreens. Among the Laplanders, when other foods fail, they eat dried fish, the half-rotten flesh of the walrus, or even the very wool off each others' backs. Low[2] reports that the sheep of the Shetland Islands feed upon the salty seaweed during the winter months, knowing by instinct the first ebbing of the tide, and that they are fed dried fish when normal foods are scarce.

McDonald[3] writes of the Iceland sheep: "The only kindness which these animals receive from their keepers in the winter is being fed on fish-bones and frozen offal, when their natural food is buried too deep even for their ingenuity and patience."

While sheep may subsist upon such articles, the organs of mastication and digestion plainly indicate that plants in some form constitute their natural food. The cutting teeth in the lower jaw of the sheep fit against the cartilaginous pad above in such manner that, when feeding, the herbage is torn off rather than cut. The feces of the sheep show the finest grinding of any of the farm animals, all minute weed seeds being generally crushed and destroyed. If sufficient numbers of sheep are confined to one field for a sufficient time, every green thing is consumed, many species of plants being entirely destroyed. When closely pastured upon brush land they will derive much nourishment from the leaves, bark, and twigs.

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[1] Sheep Husbandry, Killebrew, p. 6.
[2] Domestic Animals of the British Islands.
[3] Cattle, Sheep and Deer.

This system of feeding cannot, however, be considered desirable for mutton sheep.

769. Mutton breeds and the Merinos compared.—The Merino sheep is peculiarly a wool-bearer, and nearly all lines descended from the Spanish stock have been selected for that single purpose. The story of the Spanish Merino in its home country forms one of the most interesting chapters in the history of live stock.[1] In their pilgrimage from South to Central Spain each spring and their return in the fall the Spanish flocks make annual journeys covering over a thousand miles. Only the strongest and most rugged animals survived the long, fatiguing, perilous marches. The ability to exist in enormous flocks, to range over a vast territory, and to subsist upon scant food are the leading of the many remarkable qualities wrought by stern Fate into the very constitution of the Merino sheep. (**725**)

Almost opposite in several characteristics are the English mutton breeds of sheep, which have been reared in small flocks confined to limited pastures, the best specimens being saved and nurtured each year with intelligent attention to all their wants. They have been sheltered from storms and liberally fed with rich roughage and grain from barn and stack whenever the fields were scant of herbage or the weather severe. In general the life of the English mutton sheep has been one of quiet contentment and of plenty almost to surfeit. In this country we cannot hope to attain the wonderful success reached by British sheep-owners unless we closely follow or improve upon their methods.

770. Size of the flock.—The sheep is distinctively a gregarious animal. The improved American Merino of today still shows in a marked manner the result of inheritance by its ability to exist in great flocks and thrive under the most ordinary conditions of care and keep. With reasonable oversight thousands of Merino sheep can be held in single bands where the range is ample, and for the brief period of fattening tens of thousands can be successfully fed together, as is now commonly done with range sheep, carrying Merino blood, which are brought to feeding points in the trans-Missouri corn-belt states.

Two hundred sheep of the mutton breeds are as many as can be successfully managed in one flock, and to secure the best returns from even this number one should have had previous experience in their management. The novice would better begin with a flock of 25, increasing the number as experience grows.

[1] Low, Domestic Animals of the British Islands, Vol. II.

771. Winter quarters.—Above every other animal on the farm the sheep should be kept dry as to coat and feet. Inattention to either of these essentials will result disastrously. With dry winter quarters sheep will stand a great degree of cold without inconvenience. Indeed, their quarters in winter should not be warm, compared with those of other farm animals. One thickness of matched boards will make the barn or shed where sheep are confined sufficiently warm in the northern states except for winter lambs. Ample ventilation is of great importance, and drafts should be avoided. Sunshine, good drainage, and conveniences for feeding are the other requisites of a good sheep barn. The amount of shed space per sheep will vary with the size of the animal. A ewe weighing 100 lbs. will require about 10 sq. ft. of ground space, while one weighing 150 lbs. should have 15 sq. ft. A space 40x40 ft. sq., for example, will accommodate about 160 sheep weighing 100 lbs. each, or 100 weighing 160 lbs., not allowing for feed racks. A provision of 15 inches running length of feed rack should be made for each sheep weighing 100 lbs., and 2 ft. for those weighing 200 lbs. Breeding sheep housed in winter should have access to a dry yard having a sunny exposure and well protected from winds and storms, in which to obtain the exercise so essential to thrift and health. (**733-4**)

772. Winter care.—The flock should be so divided into groups that all the members of each group are of the same age, sex, strength, and general characteristics. To give the highest returns a division of mutton sheep should not contain over 50 members. Aged breeding ewes should constitute one band, shearling ewes another, the ewe lambs a third, and the wether lambs a fourth. These bands should be again divided if there is a marked difference between their strongest and weakest members. The wise flockmaster will group his flock so that each member may have an equal chance with its fellows at the feed trough and in enjoying comforts and attentions from his hand. Ewe lambs intended for the breeding flock should receive liberal rations during the winter months in order that they may grow steadily during the first year of their lives. Craig[1] writes: "The growth and development of the lamb the first year of its life determines very largely the size and weight of the fleece and the vigor and power it will attain." Ram lambs should receive liberal rations of muscle-building foods, but never much fat-forming food.

773. Feed for breeding ewes.—In wintering breeding ewes there should be ample provision of good bulky feed, such as clover, alfalfa,

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[1] Wis Expt. Sta., Rpt. 1897.

cowpea, or vetch hay, along with corn fodder or corn stover cut in the fall when the leaves are still green, good prairie hay, roots, pea straw, oat straw, barley straw, etc. At the Wisconsin Station[1] corn silage proved a satisfactory and economical roughage for breeding ewes when fed in combination with hay or corn stover. Ewes that are heavily fed on such nitrogenous feeds as wheat bran, clover, alfalfa hay, etc., are in danger of producing lambs that are too large at birth with excessive development of bone.[2] In addition to a liberal supply of roughage, each ewe should receive 0.25 to 0.5 lb. daily of such concentrates as oats, bran, peas, or a mixture thereof. At the Wisconsin Station[3] dried brewers' grains produced better results than bran, oats, or corn when the milk flow was considered. Ewes fed clover or alfalfa hay will not require as much grain as those given straw or corn stover. Oil meal or linseed meal is acceptable, and 1 or 2 tablespoonfuls may be given to each ewe daily. Corn, if fed at all, should form but a small part of the grain allowance of breeding ewes in winter, as it is too fattening. Breeding ewes should have abundant exercise, and should always be kept in good condition, carrying more flesh than most American farmers think proper. To winter them on straw, or straw and hay with no grain, is to perpetuate a flock that will gradually but surely degenerate.

774. The ram.—The ram is half the flock, and money invested in a vigorous, first-class, pure-bred specimen will be soon repaid. He should be strong, well built, full of vim, and a good getter. A ram of such character will care for 40 or 50 ewes. At the Wisconsin Station[4] yearling rams proved less prolific than 2- or 3-year-old rams. During the breeding season it is best to turn the rams with the ewes for but a short time daily, or only at night. Rams should be kept in a good thrifty condition on muscle-forming feeds, but should never be made fat. All rams that have won prizes at exhibitions should be studiously avoided, as should all that have for any reason been made really fat, for such high living quite generally renders them impotent, or at least greatly lessens their procreative powers.

775. Date of lambing.—The lamb dropped in late winter or early spring is far more valuable than one coming later. Under good management the early-yeaned lamb comes into the world with comfortable surroundings and a kind master in attendance to give attentions conducive to comfort and growth. With the coming of spring the young thing is of sufficient size and vigor to pass out with its dam

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[1] Rpts. 1900, 1901.
[2] Wing, Sheep Farming in America, p. 106.
[3] Rpts. 1902, 1904.
[4] Rpt. 1907.

and make the most of the fresh grass and genial sunshine. The early lamb is much less susceptible to stomach worms and many of the evils which attack the later-dropped lambs. Early farm-raised lambs may be fattened and sold before the market is flooded with western range lambs from the feed lots. Where there are poor accommodations or cold quarters lambs should not be dropped in northern latitudes earlier than May, and not until the dams are on pasture.

776. Flushing the ewes.—With the mutton breeds twin lambs are desirable, and to secure as many of them as possible English flockmasters ''flush'' the ewes at breeding time. They are given an extra allowance of nutritious, highly palatable food for two or three weeks before the desired date of breeding in order that they may be rapidly gaining in flesh at that time. Flushed ewes not only produce more twins, but are also more sure to breed. Craig[1] found that ewes suckling twins do not lose any more flesh than those with one lamb only, and that twins make as rapid gains as singles. Under western range conditions, where less attention can be given to the individual ewes, one lamb to each ewe has given the best results.

777. At lambing time.—As lambing time approaches, the shepherd should take quarters in the sheep barn or close by, and remain in attendance until the season is over. Lambs of the mutton breeds are often in need of quick, intelligent attention from the shepherd as they enter the world. A chilled new-born lamb is best warmed by immersion in water as hot as the hand can bear. When well warmed it should be wiped dry, taken to its mother, and held until supplied with her milk.[2] If the young lamb is unable to draw milk within a few minutes after birth, it should have patient, intelligent help at this time. To this end the ewe must sometimes be held, and the lamb aided, the whole being accomplished by that patient skill so characteristic of the good shepherd, but so impossible of description. One twin is usually weaker than the other, and frequently the mother cares only for the stronger one. Here the shepherd's tact serves well in promptly helping the weaker member to its full share of food. Lambs can be successfully reared on cow's milk, tho close attention is necessary during the first month. Warm cow's milk with some cream added can be fed from a teapot over the spout of which a rubber ''cot'' with an opening in the end has been placed, or a nursing bottle may be used. At first the lamb should be fed 15 to 18 times a day, and later half a dozen times. When a ewe refuses to own her

[1] Wis. Rpt. 1899.

[2] Wing, Sheep Farming in America.

lamb, she will usually own it upon putting them together in a small pen out of sight of the other sheep and helping the lamb to suckle for a few times. In stubborn cases the ewe may be confined in stanchions so that she cannot prevent the lamb sucking.

In case a ewe loses her lamb she may often be induced to adopt a twin lamb by first sprinkling some of her own milk over it. Still more effective is the practice of removing the skin from the dead lamb and tying it upon the back of the lamb to be adopted.

The shepherd, rooming close by the lying-in quarters, should be in attendance every two or three hours in the night when the lambing season is on, in order to help the weak ones and see that all are prospering. With the first fill of milk from the dam the new-born lamb becomes comfortable, and is usually able thereafter to take care of itself. Lambs of the mutton breeds are often weak at birth, but under good management gain rapidly in strength. For two or three days after parturition the ewe should be supplied sparingly with dry food of the same character as that given before lambing. Succulent feed should be added with the demand for more milk by the young.

778. Teaching the young lamb to eat.—When about two weeks old the lusty young lamb will be found nibbling forage at the feed trough beside its dam, and the shepherd should provide specially for its wants to early accustom it to take additional food. This is best accomplished by having an enclosure or room adjoining the ewe-pen, into which the lambs find their way, while the mothers are prevented from entering because of the limited size of the openings, called the "lamb-creep." In this space, accessible to the lambs only, should be placed a low, flat-bottomed trough, with an obstruction lengthwise across the top to prevent the lambs from jumping into it. In the trough should be sprinkled a little meal especially palatable to the lamb, such as ground oats, bran, corn meal or cracked corn, oil meal, soybean meal—one or all,—varying the mixture to suit the changing tastes of the young things. At first they will take but little, but soon will become regular attendants at the trough thru habit impelled by appetite. There should not be more feed in the trough at any time than will be quickly consumed, and any left over should be removed and the trough thoroly cleaned before the next allowance is given. All feed should be fresh and have no smell of the stable—that which is left over can be given to the pigs. Lambs will drink a good deal of water, and this should be supplied fresh and clean.

779. Turning to pasture.—With the springing of the grass, ewes and lambs should be turned to pasture for a short time during the warm part of the day. It is best to accomplish the change gradually and while the grass is short. After a few hours spent in the sunshine, nibbling at the grass, the ewes and lambs should be returned to shelter, where a full feed awaits them. When the grass has become ample and nutritious, stable feeding may be dropped for ewes, or both ewes and lambs, according to the plan followed. With good pasture, breeding ewes need no grain. Indeed, we may look forward to the pasture season as marking the time to "draw the grain from their systems," as it is termed by feeders. In some instances pastures so stimulate the milk flow of ewes that the over-supply of rich milk causes digestive derangement and sudden death with young lambs. The shepherd should forestall such trouble by removing the ewes from the pasture after a few hours grazing each day, and by giving hay or other dry feeds, thereby reducing the milk flow.

It is usually best to feed the lambs concentrates in addition to what they get from dams and pasture. To this end, at some convenient point in the pasture let there be a "lamb-creep," and in a space accessible by way of the creep a trough for feeding grain. Whenever the lamb passes thru the creep it should find something in this trough tempting the appetite,—oats, bran, pea meal, and corn meal constituting the leading articles. Grain never gives such large returns as when fed to thrifty young animals, and the growing lamb is no exception.

780. At weaning time.—Lambs of the mutton breeds, more or less helpless at birth, are lusty at four months of age, and will be found grazing regularly beside their dams in pasture when not at rest or eating grain beyond the lamb-creep. At this age, for their own good as well as that of the ewes, weaning time is at hand. If possible, advantage should be taken of a cool spell in summer to wean the lambs. Lambs weaned during excessively hot weather may receive a serious setback because of the heat and the fretting for their mothers. The lambs should be so far separated from their dams that neither can hear the bleating of the other. For a few days the ewes should be held on short pasture or kept on dry feed in the yard. The udders should be examined, and if necessary, as is often the case with the best mothers, they should be drained of milk a few times lest inflammation arise. The lambs should be put on the best pasture and given a liberal supply of grain in addition. New clover seeding is especially relished, while young second-crop clover is also satisfactory. An especially choice bite may always be provided for the lambs at this important time by a little forethought on the part of the stockman.

Wing writes:[1] "As a rule it is not necessary to wean lambs before they go to market. If they are fed right they will, while sucking their mothers, reach a weight of 75 to 85 lbs., if of mutton breeds." Lambs which are to remain on the farm should be weaned at 10 to 12 weeks. By separating them from their dams before the advent of warm weather, and putting them on clean pasture free from contamination, they may escape stomach worms and other parasites.

781. Maintenance ration for breeding ewes in winter.—At the Wisconsin Station[2] Carlyle and Kleinheinz recorded the amount of feed eaten in winter by well-fed, pregnant Shropshire, Dorset, Southdown, Merino, and Shropshire-Merino ewes ranging in weight from 138 to 157 lbs. each at the beginning of the trial. The ewes were divided evenly as regards size and breed into lots of 12 each. The mixed grains fed consisted of equal parts of corn, oats, and bran. The corn forage consisted of corn fodder and corn stover. The table shows the average amount of feed consumed daily by each ewe during the winter and the average daily gain of each lot:

Feed required to maintain a breeding ewe for 1 day in winter.

Single trial	Av. daily gain	Average of 2 other trials	Av. daily gain
	Lbs.		Lbs.
Lot I		*Lot I*	
Shelled corn, 0.5 lb.		Mixed grain, 0.5 lb.	
Mixed hay, 2 lbs.		Corn forage, 3.3 lbs.	0.19
Corn silage, 2.5 lbs.	0.23	*Lot II*	
Lot II		Mixed grain, 0.5 lb.	
Whole oats, 0.5 lb.		Corn silage, 3 lbs.	
Mixed hay, 2 lbs.		Corn forage, 1.8 lbs.	0.09
Corn silage, 2.5 lbs.	0.23	*Lot III*	
Lot III		Mixed grain, 0.5 lb.	
Wheat bran, 0.5 lb.		Corn silage, 2.9 lbs.	
Mixed hay, 2 lbs.		Mixed hay, 2.1 lbs.	0.16
Corn silage, 2.5 lbs.	0.20	*Lot IV*	
Lot IV		Mixed grain, 0.5 lb.	
Dried brewers' grains, 0.5 lb.		Roots, 2.9 lbs.	
Mixed hay, 2 lbs.		Mixed hay, 2.6 lbs.	0.18
Corn silage, 2.5 lbs.	0.24		
Lot V			
Mixed bran, corn, and oats, 0.7 lb.			
Mixed hay, 2.3 lbs.			
Corn silage, 2.7 lbs.	0.20		

[1] Sheep Farming in America. [2] Rpts. 1900–1903.

We learn from the table that breeding ewes weighing about 145 lbs. each can be so maintained when carrying their lambs in winter as to gain steadily in weight on a daily allowance of 2 lbs. of mixed hay, 2 to 3 lbs. of corn silage, corn forage, or roots, and 0.5 lb. of grain or other concentrates. All of the rations tested were highly satisfactory. The daily cost of maintaining these large ewes was 2 cents per head or less according to the value of the feeds used.

In previous trials at the Wisconsin Station[1] Craig considers alsike clover hay one of the best dry roughages, as it was eaten with relish and comparatively small waste. Corn fodder and oat hay also proved satisfactory. Cut (chaffed) oat hay gave poor results, as the pieces gathered in the wool about the necks of the sheep and it was not well eaten. Of succulent fodders corn silage gave the best results. It should not contain too much corn, however, which is injurious to breeding ewes.

782. Cost of keep at the South.—Grey and Ridgeway of the Alabama Station,[2] in studying the cost of maintaining pregnant ewes during the winter, report the following:

Cotton-seed meal compared with soybean hay for wintering pregnant ewes.

Average ration	Total gain	Cost of feed per month
	Lbs.	Cents
Lot I, Cotton-seed meal 0.5 lb., cotton-seed hulls 1.3 lbs.	1.8	30
Lot II, Soybean hay 1.9 lbs.	1.6	35

It is shown that on the given feeds ewes can be maintained at the South for from 30 to 35 cents per month. After lambing it required 75 per ct. more cotton-seed meal and 81 per ct. more hulls to maintain the ewe and her lamb than before.

783. Water and salt.—Opinions as to the amount of water necessary for sheep vary more than with any other domestic animal. In countries with heavy dews and ample succulent feed in summer, and where root crops are largely used in winter, water may possibly be denied sheep, but under most conditions it is a necessity and should never be withheld. A sheep needs from 1 to 6 quarts of water daily, according to feed and weather. The best results are secured when they have free access to fresh, pure water. On the arid ranges of the Southwest when grazing on certain succulent plants, like singed cacti, sheep sometimes go 60 days without water.[3] (**87**)

[1] Rpt. 1893.
[2] Bul. 148.
[3] Wilcox and Smith, Farmer's Cyclopedia of Live Stock, p. 590.

Sheep require salt, and it should be supplied them at regular intervals. In winter it may be given in a trough used only for this purpose. In summer salt may be rendered doubly useful by scattering it on the sprouts growing about the stumps, on brush patches, or over noxious weeds. Some western sheep raisers never salt their sheep but allow them to eat alkali, which is safe for them when it contains 80 per ct. of salt.[1] It is believed that salted sheep are less liable to become locoed. (**91**)

784. The stomach worm.—In the territory east of the Mississippi river the stomach worm, *Strongylus contortus,* is a serious menace to sheep raising, lambs being especially susceptible to attack. The eggs of the parasite pass in the droppings of the sheep and are scattered about the pastures, where they soon hatch. Sheep become infested only by swallowing the worms while grazing. Fields on which no sheep, cattle, or goats have grazed for a year, and those that have been freshly plowed and cultivated since sheep grazed thereon, are practically free from infection. Old blue-grass pastures are especially to be avoided. During warm weather, otherwise clean pastures may become infested in from 3 to 14 days by grazing sheep thereon.

To remove the worms from the intestinal tract of sheep, various drenches are recommended by breeders, such as 1 tablespoonful of turpentine, benzine, or gasoline, thoroly mixed with 5 to 6 ounces of fresh cow's milk, with a tablespoonful of raw linseed oil added. The above dose, suitable for a lamb of average size, should be increased for older sheep. Creosote has been highly recommended, 8 ounces of a 1 per cent solution in water being a dose for young lambs. Wing[2] advocates feeding dried tobacco, either alone or mixed with salt, to lambs and ewes as a preventive and remedy, but breeders disagree on the value of this treatment.

Tho these remedies are of value, prevention of infection has proved more successful. Kleinheinz, the shepherd of the Wisconsin Station, recommends the following system of handling sheep and lambs: In the northern United States worm-free and infested sheep may graze together in a clean field at any time from the last of September until May with little danger. From June to September change to fresh, clean pasture every 2 or 3 weeks. Annual pastures, as rape, clover seeding, etc., are well adapted to this system. This effective method requires several separate, clean pasture lots. In the warmer sections the sheep should be changed to clean pasture

[1] Wilcox and Smith, Farmer's Cyclopedia of Live Stock, p. 590.
[2] Sheep Farming in America.

earlier in the spring and more frequently during the summer. Thoroly treating the ewes with some vermifuge will remove most of the worms, and aid in preventing infection. Farmers often make the serious mistake of allowing the lambs to remain with their dams after weaning. Instead, they should at once be placed on fresh, clean pasture on which no sheep have previously grazed that season. Nothing is better than turning the lambs into a field of well-matured rape connecting with a fresh grass pasture. Well-fed thrifty sheep and lambs can much better resist parasites than those getting poor feed and care.

II. Fattening Sheep and Lambs.

785. Mature sheep.—It is generally conceded unwise to feed yearlings for the block, since they are shedding teeth and therefore are not in condition to give good returns for feed and care. Unless prices for wool rule high the stockman cannot afford to carry wethers past the period when they may be fed off as lambs. (**732**) Culls from the flock can be prepared for the butcher at any time by the use of a little extra grain. In the vicinity of cities profitable sales can be made of fat culls at times when regular feeders have failed to supply the market.

786. Fattening lambs.—The demand for well-fattened lambs steadily increases, the tender, juicy, high-flavored meat finding favor among Americans. Not only do prices for fat lambs rule high as compared with mature sheep and farm animals generally, but there are other advantages in feeding off lambs before they reach maturity. A given weight of feed goes further with lambs than with mature sheep, the money invested is sooner turned, and there is less risk from death and accident. Thus everything tends toward marketing the lambs as rapidly as they can be disposed of to secure the highest prices. If they are not sufficiently fat in late summer or early fall to meet the reasonable demands of the market, it shows that there has been a lack of feed and care or that parasites have destroyed profits.

787. Quarters for winter fattening.—Fattening sheep should be protected from wet coats and feet at all times. Ideal quarters in the Northern states are a dry, littered yard, with a sunny exposure, provided with a well-bedded, comfortable shed opening to the east or south and extending along the windward side to break the cold winds and driving storms. In such quarters the air is bracing, the sunshine invigorating. Here the animals, covered with a heavy coat and filled with rich grain and roughage, are warm and comfortable, and comfort is essential to the highest gains. When succulent feeds such as beet pulp are fed, the quarters must be especially well drained and the shed well bedded. If confined in quarters sufficiently warm for dairy cows, sheep sweat badly in winter. Stone basements are unsatisfactory, and if used ample ventilation must be provided. Damp walls are a sure indication of lack of ventilation and impending trouble. (**733-4**)

788. Feed racks.—Grain and roughage should be fed separately, and there should be racks in the yards sufficiently large to hold roughage for several days. If sheep are fed in close quarters the hay should be supplied daily, since they dislike feed that has been "blown on," as shepherds say. Grain troughs should have a wide, flat bottom, forcing the sheep to consume the grain slowly. Fifteen inches of linear trough space should be provided for each animal. Tho sheep can be successfully fattened when the grain is supplied by a self-feeder, they make smaller and less economical gains than where the feed is given at each meal time.

789. The various grains for fattening.—Corn is the best single grain for fattening sheep, causing them to put on fat rapidly and not forcing the growth of lambs, as is the case with some other concentrates. For eastern lambs 500 lbs. of corn and 400 lbs. of clover hay, and for western lambs 450 lbs. of corn and 500 lbs. of alfalfa hay, should produce 100 lbs. of gain where the conditions are reasonably favorable and the fattening period not too extended. (**744**) From these data the feeder can readily calculate the cost and possible profits of fattening lambs.

Thruout the western range district, where corn is not raised in large quantities, barley is extensively used for fattening sheep and lambs. This grain produces nearly as large and economical gains as corn. (**748**)

Wheat is worth about 10 per ct. less than corn for sheep, tending to produce growth rather than fat. It should not be fed to sheep except when off grade or low in price. Durum or macaroni wheat has proved equal to bread wheat for fattening lambs. In tests at the Utah Station, frosted wheat produced as large and more economical gains than marketable wheat. (**746**) The value of wheat screenings from the elevators and mills depends entirely on their quality, the light, chaffy grades having little value. Good wheat screenings produce as large gains, pound for pound, as corn, when fed with clover or alfalfa hay. They should be fed close to the mills or elevators where they can be obtained without the payment of heavy freight bills. If possible, corn should be mixed with screenings or wheat for lamb-fattening, since they tend to growth as well as to fattening. (**752**)

Where oats are low in price they may be used for sheep feeding and will produce excellent mutton. Like wheat, oats conduce to growth, and hence it is best to mix corn with them for fattening lambs. (**747**)

Lamb-feeding trials in the Western states show that emmer (speltz) has nearly as great feeding value, pound for pound, as corn when fed with alfalfa hay. At the South Dakota Station[1] when fed with mixed brome and prairie hay emmer was worth about two-thirds as much as barley for lambs. (**749**)

Experiments at the Kansas Station[2] show that kafir has about the same feeding value as corn for sheep. Where extensively grown it is a valuable and economical substitute for that grain. (**183**)

790. Feeds rich in protein.—Linseed meal, cotton-seed meal, and gluten feed are concentrates rich in crude protein, which may sometimes be profitably mixed with corn or other grains for fattening lambs. Lambs should never receive more than half a pound of linseed or cotton-seed meal per head daily, and one-eighth or one-fourth lb., in combination with other concentrates, would prove much more satisfactory. (**754**)

Field peas and soybeans, also rich in crude protein, are usually too expensive to form the entire concentrate allowance for fattening lambs. Excellent results have been obtained by mixing either of these feeds with corn or other grains. (**750, 753**)

Experiments show that bran is not especially suitable for fattening sheep, a large quantity being required for a given gain. Like wheat and oats, bran induces growth rather than fattening, and its bulky character is also against it, tho a limited quantity may be useful, as it is greatly relished by sheep.

791. Grinding grain.—Of all the farm animals the sheep is best able to do its own grinding, and with few exceptions whole grain only should be furnished. The common saying of feeders, "a sheep which cannot grind its own grain is not worth feeding," is a truthful one. Valuable breeding sheep with poor teeth may be continued in usefulness by being fed ground grain. In certain cases grinding may prove beneficial. At the Colorado Station[3] Cooke, when feeding western sheep on wheat, observed that much of the grain passed thru the animals unbroken. At the South Dakota Station[4] Wilson

[1] Buls. 71, 86.
[2] Breeder's Gazette, Vol. 51.
[3] Bul. 32.
[4] Bul. 86.

and Skinner, on feeding millet seeds, which are small and have a hard covering, to lambs, found that a large percentage was voided undigested. On grinding the millet it proved highly satisfactory. (**342**)

792. Roughage.—The legumes are the prime source of roughage for sheep—clover and alfalfa in the East, alfalfa in the irrigated regions of the West, and the cowpea, beggar weed, and other plants in the South. Clover, one of the best of roughages for sheep, should be cut early in order to secure the leaves and heads, which are the parts desired. Alfalfa hay is superior even to red clover in palatability and in the nutriment it carries. When of good quality it not only answers for roughage, but because of its abundant nutriment it serves as a partial substitute for grain, thus materially reducing the cost of feeding and fattening. At the Oklahoma Station[1] cowpea hay proved equal to alfalfa hay for fattening lambs. So long as there is an ample supply of good legume hay of any kind, sheep show little desire for other varieties of forage.

Next in value to hay from the legumes come the dry leaves of the corn plant. For sheep feeding, corn should be cut early and cured in well-made shocks. The sheep will eat a little more of the stalks if shredded, but cutting will not induce them to eat any of the coarser parts.

793. Succulent feeds.—One of the advantages of feeding silage or roots to sheep is the tonic and regulating effect. Both corn silage and roots are greatly relished, and feeding trials show them to be about equal in nutritive value. The low cost of producing silage should lead to its more common use. Roots are universally fed to sheep in Great Britain, and no other farmer compares with the British farmer in producing high-quality mutton. Wet beet pulp has proved a valuable feed for lambs, especially when combined with alfalfa hay.

794. Dipping.—In all cases before sheep are admitted to the fattening pens they should be examined by an experienced shepherd, and if any evidence of skin disease or vermin is found the flock should be dipped in the most thoro manner. At the West scab, and in the East lice and ticks, are common troubles. To attempt to fatten sheep afflicted with any of these pests is to court disaster. Sheep having any ticks show increased irritability and restlessness as soon as fattening begins.

795. Length of feeding period.—The feeding period with sheep and lambs which have never received grain while on pasture should

[1] Bul. 78.

last from 12 to 14 weeks, according to their condition in the beginning and the rapidity with which they gain. The tables in the preceding chapter show that lambs increase in weight at least a quarter of a pound per day when gaining normally. For a feeding period of 100 days the gains should run from 25 to 30 lbs. per head. This weight, mostly fat, added to the carcass of a lamb weighing originally 60 to 90 lbs., brings it to the size desired by the market. Formerly the market called for a large lamb, but now the demand is for plump ones weighing from 80 to 90 lbs., or even less if they are from the western ranges. As soon as lambs are ripe, or when the backs and the region about the tail seem well covered with fat, they should be sold, for further gains cannot be made at a profit. Ripe lambs fed a heavy grain ration at the North Dakota Station[1] gained only 0.8 lb. each in 4 weeks, returning a heavy loss instead of profit.

796. Feed consumed.—As shown in Chapter XXIX, fattening lambs weighing from 60 to 80 lbs. each will consume from 0.7 to 2.0 lbs. of grain and 0.9 to 2.0 lbs. of hay, the entire ration containing from 1.5 to 3.5 lbs. of dry matter. The addition of silage, roots, or beet pulp will somewhat increase the weight of dry matter consumed, on account of the increased palatability of the ration.

797. Rate of increase.—The experiments reported in the preceding chapter show that well-fed lambs gain from 2 to 3.25 per ct. each week upon their initial weight. From 8 to 10 lbs. of dry matter is required to produce each pound of increase in live weight. The quantity of feed required to produce 100 lbs. of gain with various rations is shown in the numerous trials reported in the previous chapter.

798. Cost of gain.—The data given in the last chapter will enable the feeder to calculate the feed cost of producing 100 lbs. of gain with lambs fattened on nearly any available feed combination. For example, if it requires 500 lbs. of corn and 400 lbs. of clover hay for 100 lbs. of gain, and corn is worth 56 cents a bushel, or $1 per 100 lbs., and hay $10 a ton, or 50 cents per 100 lbs., then the feed cost of 100 lbs. of gain will be:

500 lbs. of corn at $1 per 100	$5.00
400 lbs. of hay at 50 cents per 100	2.00
Cost of 100 lbs. gain	$7.00

The above is a fair estimate of the cost of feed required to produce 100 lbs. of gain with eastern lambs fed in small lots on corn

[1] Bul. 28.

and clover hay at the prices given. The feed required for a given gain will, for various reasons, often exceed the amount here stated, and it may fall somewhat below under skillful management. The cost of gain with other combinations of feed may easily be worked out in the same manner from data in the tables. Comparing the cost of gains, it will be found that lambs give better returns for the feed supplied than do steers. Mature sheep will cost from 25 to 30 per ct. more for a given gain than lambs.

799. Hints on sheep feeding.—Sheep feeders do not begin operations at an early hour in winter, preferring not to disturb the animals until after daybreak. Usually grain is first given, followed by hay and water. The trough in which grain is fed should be kept clean at all times, and there should be ample space, so that each animal may get its share of grain. Nowhere does the skill of the feeder show more plainly than in getting sheep to full grain feed without getting a single one "off feed." Western sheep may not be able at first to take over 0.1 lb. of grain per day. If so, 2 months or 10 weeks may be required in getting the flock to full feed. English mutton sheep take grain more readily, and in some cases no more than 3 or 4 weeks need intervene between placing the lambs on feed and full feeding. In no case should this operation be hurried, for it means waste of feed and injury to, if not loss of, some of the animals.

While regularity and quiet are of importance at all times in the management of all farm animals, they are paramount with fattening sheep. The flock should always be cared for by the same attendant, who should move among them quietly, giving notice of his approach by speaking in a low voice and closing doors and gates gently. Dogs and strangers should be kept from the feeding pens at all times. **(93)**

III. Fattening Plains Sheep.

800. The Colorado system.—Fattening range sheep and lambs on grain and alfalfa is a vast industry in Colorado, where in 1907 about 2,000,000[1] were fed. Some locally grown barley or wheat is fed when low enough in price, but shelled corn from further eastward and locally grown alfalfa hay form 95 per ct. of the feed used. The whole western range is drawn on for feeders, and the small fine-wool type of earlier times has been largely replaced by the cross-

[1] Breeder's Gazette, 51, p. 348.

bred lamb of better mutton quality. Formerly many mature wethers were fed, but now mostly lambs are fattened.

In feeding plants the corral or enclosure is divided into two rows of lots with a lane between, each lot accommodating from 400 to 500 lambs. No shelter is provided, but windbreaks are desirable. The hay is fed in the lanes, 12 to 14 feet wide, extending between the lots. The low fences bordering the lanes have a 7-inch space between the first and second boards, thru which the lambs feed on the hay. About 1 running foot of lane fencing and feed trough is allowed each sheep. The hay from the stacks is hauled down the lanes, and is piled along the fences, being pushed up to them 2 or 3 times a day as it is eaten away.

All lots are provided with flat-bottomed troughs for feeding grain. There is an extra or vacant lot at one end of each row of lots, likewise provided with troughs. At feeding time grain is placed in the troughs of this extra lot and the lambs from the adjoining lot are turned in. As soon as a lot is vacated, grain is put in the troughs of this lot, and the lambs enter from the next lot, and so on. At the next meal feeding begins by using the vacant lot at the other end of the row, reversing the process. After a week or more of preliminary hay feeding, corn feeding is begun. At first only a very little corn is sprinkled in the troughs, but as the lambs get used to it the amount is gradually increased until after about 2 months the lambs are on full feed, which is from 2 to 3 bushels of corn per 100 head daily. The feeding yards are usually located on streams or ditches which supply running water. Those on high ground have watering troughs into which the water is pumped. Salt is liberally furnished in troughs.

Most of the Colorado lambs are marketed unshorn. If feeding continues until late in the spring the lambs are usually shorn 6 weeks before shipping. They will then gain enough more to make up the weight of the wool removed, will pack more closely in the car, and will shrink less in shipping. Gains of from 15 to 30 lbs. per head are secured by this method of fattening. With favorable markets and low-priced feed enormous profits are made, but sometimes heavy losses occur.

801. Fattening on beet pulp.—In the vicinity of beet sugar factories, especially near Fort Collins, Colorado, and Logan, Utah, wet beet pulp has proved a valuable addition to the ration of alfalfa hay and corn. The pulp is most valuable when fed with a moderate allowance of grain, and the corn-alfalfa-beet pulp ration has proved ideal, producing high quality mutton. The Colorado Station[1] found 1 ton of beet pulp equal to 200 lbs. of corn in fattening lambs, tho when fed in large quantities it produced soft flesh. Griffin of that station concludes that, owing to the excessive shrinkage of pulp-fed lambs, they should be finished off on grain and hay without pulp. There is little bone-forming material in beet pulp, and lambs long fed on it are said to be weak-boned. It would seem that alfalfa hay should make good this deficiency.[2] (**89, 759**)

802. Fattening on wheat screenings.—During the last decade hundreds of thousands of Montana sheep and lambs were annually fed on wheat screenings in Minnesota near St. Paul. The screenings were fed in sheds, usually from self-feeders. Bits of chaff and straw in the feed render it so bulky that little or no hay is required, and the lambs do not surfeit as easily as on corn. During the season of 1902[3] about 330,000 sheep and lambs were fattened in these feed-lots. Two years later the number fell below 200,000, and at the present time, because of prohibitory prices for screenings and their poor quality, Minnesota has ceased to be a factor of importance in the winter mutton supply. (**752**)

803. In the corn belt.—During the winter of 1899–1900[4] over a million "Plains" sheep were fattened in Nebraska alone. The system is similar to that described for Colorado, 20,000 to 30,000 head often being fed at a single point. From 2 to 3 bushels of corn are required per day for 100 sheep. To this may be added a few pounds of oil meal or other protein-rich concentrate. Alfalfa, sorghum, or wild hay and corn stover are the roughages fed. During the feeding period of about 100 days the sheep usually gain somewhat over 15 lbs. per head. The industry is an irregular and uncertain one, the profits depending upon the price of corn and the market.

804. Feeding small bands.—Fattening great numbers of lambs at a single point reached its zenith nearly a decade ago when corn and wheat screenings ruled low in price, and the large operator suffered little competition from the ranchman or farmer in finishing range lambs for the market. Now conditions have changed. The price of feed has increased, and the fattening of range lambs in the grazing districts is fast developing. In Montana and many other localities sheep are put in a fair condition by feeding alfalfa hay and roots without grain.[5] In South Dakota lambs are extensively fattened on local grains—barley, macaroni wheat, and emmer—along with al-

[1] Bul. 76.
[2] Wing, Sheep Farming in America.
[3] Breeder's Gazette, Vol. 46, p. 1000.
[4] Neb. Bul. 66.
[5] Wilcox, Farm Animals, p. 262.

falfa hay or other roughages. Most fortunately for a conservative agriculture, the large operator, who receives no benefit from the great accumulation of rich manure in the feed-lot, cannot compete with the farmer who fattens one or more carloads of lambs and uses the manure for enriching his land. Prudent farmers rightly hold that enough fertility is returned to their land thru the feed-lot to pay the entire labor cost of feeding. As sheep and lamb fattening on range and farm increases, the gradual decline of the old feed-lot is assured.

805. Pasturing upon field peas.—The fattening of lambs thru grazing on field peas has grown to great proportions in certain sections of the West, especially in the San Luis valley in Colorado, where, it is estimated,[1] over 380,000 lambs were fattened on peas alone in 1906. Mexican peas, similar to the common Canadian field peas, are sown at the rate of 30 to 50 lbs. per acre, together with a small quantity of oats or barley to act as a support for the vines and furnish additional feed. About November 1, as soon as most of the peas have matured, lambs or sheep are turned into the field, and without other feed are fattened in from 70 to 120 days. An acre of such peas will fatten from 8 to 15 lambs, each making a gain of from 6 to 8 lbs. per month. One acre of peas produces about $15 worth of lamb mutton at no expense for harvesting the crop. Confining the lambs to small areas by hurdles gives better results than allowing them to roam over the entire field. (**762**)

IV. Hothouse Lambs.

During recent years an increasing demand has developed for winter or ''hothouse'' lambs. The greatest obstacles to success in this specialty are getting the ewes to breed sufficiently early, and producing carcasses which meet the exactions of the epicure. The demand for winter lambs prevails between the last of December and the middle of March. The condition of the carcasses of such lambs is more important than their size. They must be fat and present a well-developed leg of mutton with plenty of tender, juicy lean meat and a thick caul to spread over the exposed flesh of the carcass when on exhibition. Winter lambs should weigh alive from 30 to 45 lbs. Large but lean and bony ones present a staggy appearance and bring unsatisfactory prices. Early in the season small lambs top the market, but later the heavier ones are in demand.

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[1] Breeder's Gazette, 49, p. 244.

806. Breeding for winter lambs.—Only the ewes of two breeds—the Dorset and the Tunis—can be depended on to breed sufficiently early to produce winter lambs. Dorsets excel in milk production—a vital factor in this industry. Other breeds, as the Hampshire, Shropshire, Southdown, and Merino, are occasionally recommended, tho ordinarily they cannot be relied on for this purpose. At the Minnesota Station[1] thru trials covering six years, Shaw found that the breeding habit of common grade ewes which usually drop their lambs in the spring may be so changed by two or three generations of judicious crossing and the selection of the early yeaned lambs for breeders that they will drop lambs in fall and early winter. This change can be hastened and more permanently fixed by mating the ewes with pure-bred Dorset rams. Where the ewes have the early breeding habit well fixed, superior lambs may be obtained by using dark-faced rams, such as Shropshire and Southdown. Shaw further found that ewes which have suckled winter lambs breed more readily before being turned to grass than subsequently, especially when fed a stimulating grain ration while still in the shed. At the New York (Cornell) Station[2] Dorset ewes bred earlier, stood forced feeding better, and were less affected by unfavorable weather than Shropshire ewes, and their lambs made more rapid gains. Miller and Wing[3] advise using a young ram, well fed during service but not too fat, turning him with the ewes not earlier than the middle of March nor later than the middle of May. The ewes should be in good condition and so fed as to be gaining in flesh. Even with favorable conditions, all the ewes will not breed at the desired time, and to secure 400 winter lambs about 500 ewes are necessary. Ewes which fail to breed are sold early, and those breeding late drop lambs useful for later sales. Ewes which are successful breeders are kept as long as possible, since those lambing in November are likely to breed at the right time the following year.

807. Care of the ewe.—During the summer the ewes need abundant pasture, water, and shade. Should the grass become scant, they should receive additional feed—rape, pumpkins, etc. If in good condition it is rarely necessary to feed grain before lambing, and then only in small amount. The ewes should be shorn in the fall or as early in winter as possible, the object being to keep them cool and allow more space. At weaning time the ewes should be removed to the lambing pen and fed lightly for a few days. The lambing pen should be warm so that the new-born lambs may not

[1] Bul. 78. [2] Bul. 88. [3] The Winter Lamb, p. 6.

be chilled. Alfalfa and clover hay serve best for roughage, while oats, bran, oil cake, and corn prove suitable concentrates. The object at all times is to produce the largest possible flow of milk to hasten the lamb's growth.

808. The lambs.—A creep should be provided and the lambs taught to eat from a trough as soon as possible. To this end, a little sugar may at first be sprinkled on the grain to render it specially palatable. The lambs begin to eat freely when 2 or 3 weeks old, and are forced on bran, cracked corn, linseed meal, ground oats, barley, gluten feed, etc. They should be induced not only to eat, but to eat a large quantity, and to keep eating, and varying the kinds and proportions of the feeds supplied is conducive to this end. Alfalfa, clover, or soybean hay is indispensable, while roots and silage are helpful. The feed troughs should be cleaned each morning, and the grain and hay supply be changed 2 or 3 times a day. When necessary, lambs are fed new milk from a teapot having a punctured rubber cot placed on the spout. Ewes bereft of their lambs thru sale are given one of a pair of twin lambs. Thus forced, the best lambs weigh from 40 to 47 lbs. alive at 6 weeks, and as much as 34 lbs. dressed. They are dressed in a special manner, the stomach and intestines being removed, while the head and feet remain, and the pluck is left undisturbed. The caul fat is carefully spread over the exposed parts, and the carcass sewed up in muslin after thoroly cooling. To be profitable, winter lambs must bring not less than $5 per head, and the best ones often bring as much as $12. This specialty can be conducted with profit only by experts who have gained their experience thru patient and discreet effort, and who have near-by markets that will pay the high prices such products must command.

CHAPTER XXXI.

INVESTIGATIONS WITH SWINE.

I. Miscellaneous Studies.

809. Period of gestation.—According to Coburn,[1] young sows carry their pigs from 100 to 108 days and old sows from 112 to 115, the average for all being 112 days. Spencer,[2] writing of English pigs, says: "The variations in the time which a sow will carry her pigs are very slight, and these are pretty well regulated by the age and condition of the sow; thus, old and weakly sows and yelts (young sows) will most frequently bring forth a day or two before the expiration of the 16 weeks. Sows in fair condition will generally farrow on the 112th day, while strong and vigorous sows will frequently go a few days over time."

810. Birth weight.—In a study by the author at the Wisconsin Station,[3] each pig as soon as farrowed was marked and its weight and condition recorded. The weights of the pigs of 3 litters are presented in the table which follows:

Weight of pigs, when farrowed, in the order of their birth.

Breed	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	Total
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Pure-bred Berkshire	2.1	1.9	2.2	2.0	*1.5	1.8	1.9	*1.9	2.6	*1.3	19 2
Cross-bred Pol.-Chester White	2.7	2.4	2.3	2.6	2.0	2.7	3.1	2.1	2.3	....	22.5
Pure-bred Pol.-China	2.1	2.7	2.5	2.8	3.0	3.0	2.6	......	......	....	18.7

*Farrowed dead.

It is shown that the individual pigs when farrowed weighed from 1.3 to 3.1 lbs., the litter aggregating from 18.7 to 22.5 lbs. The first-farrowed pig was neither heavier nor stronger, and the last was neither lighter nor weaker than the others. The so-called "titman," or weakling, found in a litter, is probably such thru lack of food or other extraneous cause, for if given good food and care it not infrequently outgrows its mates.

Carlyle[4] found that 4- and 5-year-old sows bore 9 pigs to the litter on the average, the litter weighing 26 lbs., while 1-year-old sows aver-

[1] Swine in America.
[2] Pigs, Breeds and Management.
[3] Rpt. 1897.
[4] Bul. 104.

aged less than 8 pigs, weighing but 15 lbs. From the records of 1,477 pure-bred sows of 8 breeds Rommel[1] found that on an average there were 9 pigs to the litter, 50.1 per ct. males and 49.9 per ct. females.

811. Milk yield.—At the Wisconsin Station[2] Carlyle studied the milk of 12 sows of 3 breeds. The pigs were kept from the dam except for short periods at 2-hour intervals by day and 4 by night, when they were put with her to suckle. They were weighed collectively before and after that operation, and the increase credited as milk drawn from the dam. With extreme difficulty samples of milk were obtained for analysis. The average yield of milk of 4 sows of each breed during 84 days between farrowing and weaning, determined in the above manner, is given below:

Yield of milk by sows between farrowing and weaning.

Breed	Av. wt. per sow	Av. no. pigs in litter	Av. daily milk yield	Av. total milk yield
	Lbs.		Lbs.	Lbs.
Berkshire	390	7.7	6.3	532
Poland China	393	7.5	4.9	429
Texas "Razorback"	247	6.3	5.2	434

We learn that these sows gave from 4.9 to 6.3 lbs. of milk daily, the total for 84 days, by which time they went dry, ranging from 429 to 532 lbs. A 4-yr.-old, 532-lb. sow with 10 pigs gave 669 lbs. of milk, while a 5-yr.-old, 490-lb. sow with 8 pigs gave only 337 lbs. Carlyle states that some sows yield almost twice as much milk as others.

812. Composition of sow's milk.—On analysis the milk of the sows reported in the preceding article showed the composition recorded in the following table, average cow's milk being added for comparison:

Average composition of sow's milk.

Breed	Fat	Casein and albumin	Milk sugar	Ash	Total solids	Specific gravity
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Berkshire	7.25	5.74	5.63	0.97	19.59	1.040
Poland China	6.79	5.94	5.74	0.98	19.19	1.041
Texas "Razorback"	6.64	6.50	5.56	1.01	19.70	1.043
Cow's milk (Babcock)	3.69	3.55	4.88	0.71	12.83	....

[1] U. S. Dept. Agr., Bur. Anim. Indus., Cir. 112.

[2] Bul. 104.

It is shown that in all constituents sow's milk is richer than that of the cow. Woll[1] found the fat globules of sow's milk only one-fourth as large as those of cow's milk, but 8 times as numerous. (**594**)

813. The sow as a milk producer.—Woll[2] found that a sow weighing 438 lbs. gave 7.7 lbs. of milk in 1 day, consuming in that time 4 lbs. of corn meal, 4 lbs. of wheat middlings, and 8 lbs. of skim milk. Such findings show that sows good for breeding purposes rank with good dairy cows in their ability to convert feed into milk. (**590-91**)

814. Gain of young pigs.—To show the rate of gain by young pigs before and after weaning, the following table is taken from a study by the author at the Wisconsin Station,[3] the data covering 70 days before and 49 days after weaning:

Weight of a litter of pigs at birth and gains before and after weaning.

Date	Days from birth	Wt. of sow	Weight of pigs							
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Before weaning										
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
May 24	------	332	------	------	------	------	------	------	------	------
May 25	0	-----	3.6	3.2	3.3	3.2	3.4	3.2	2.8	1.9
May 31	7	290	7.1	5.1	5.9	6.4	6.3	5.8	4.8	3.0
June 7	14	285	10.7	7.7	9.9	9.4	9.5	9.2	7.5	5.1
June 14	21	277	19.0	11.5	13.5	13.5	12.5	12.5	10.8	7.6
June 21	28	278	19.4	14.5	17.4	17.8	15.6	16.0	14.1	10.4
June 28	35	280	24.2	16.4	22.2	23.1	20.6	20.9	18.2	14.4
July 5	42	293	28.0	18.7	25.5	26.5	23.5	24.2	22.0	16.5
July 12	49	280	32.5	19.0	30.0	32.5	29.0	29.5	26.0	21.0
July 19	56	278	40.5	22.5	37.0	43.5	38.0	38.0	35.5	26.5
July 26	63	268	47.0	24.5	44.0	51.0	45.5	45.0	42.5	31.0
August 2	70	261	50.5	25.0	50.0	60.5	50.0	51.0	47.0	37.5
Gain	------	−29	46.9	21.8	46.7	57.3	46.6	47.8	44.2	35.6
After weaning										
August 2	0	-----	50.5	25.0	50.0	60.5	50.0	51.0	47.5	37.5
August 9	7	-----	53.0	25.0	57.5	68.0	57.5	55.0	54.5	44.0
August 16	14	-----	57.0	27.5	63.5	75.0	61.0	59.0	61.0	50.0
August 23	21	-----	62.5	33.5	72.5	86.5	67.0	69.0	72.0	56.0
September 6	35	-----	69.0	43.0	84.0	101.0	80.0	76.0	79.0	64.0
September 13	42	-----	77.5	48.0	94.0	105.0	86.0	88.0	88.0	74.0
September 20	49	-----	85.5	56.0	104.0	114.0	92.0	93.0	93.0	82.0
Gain	------	-----	35.0	31.0	54.0	53.5	42.0	42.0	45.5	44.5

It will be seen that the sow lost 29 lbs. in weight while suckling her pigs, which gained from 21.8 to 57.3 lbs. each in 10 weeks between farrowing and weaning. For the 7 weeks succeeding weaning the individual gains ranged from 31 to 54 lbs. It is possible for

[1] Rpt. 1897. [2] Loc. cit. [3] Rpt. 1890.

a suckling pig to weigh 70 lbs. when 70 days old, and sometimes, tho rarely, it may exceed that high figure.

815. Gain from birth to maturity.—At the Wisconsin Station[1] the author recorded the average gains of 12 litters, containing 84 pigs, during 10 weeks between farrowing and weaning time. The figures below the bar, derived from Article 819, are appended to show the decreasing rate of gain until the pig is ready for the market.

Weekly rate of gain of pigs from birth to maturity.

Age	Average weight	Av. gain in 7 days	Per cent gain
	Lbs.	Lbs.	
At birth	2.5		
First week	4.4	1.9	76
Second week	7.0	2.6	59
Third week	9.8	2.8	40
Fourth week	12.5	2.7	28
Fifth week	15.6	3.1	25
Sixth week	18.6	3.0	19
Seventh week	22.6	4.0	22
Eighth week	27.8	5.2	23
Ninth week	33.1	5.3	19
Tenth week	38.5	5.4	16
Under 100 pounds	78	5.8	7.4
Under 150 pounds	128	7.7	6.0
Under 200 pounds	174	8.7	5.0
Under 250 pounds	226	9.3	4.1
Under 300 pounds	271	10.2	3.8
Under 350 pounds	320	9.8	3.1

It is shown that the average pig, weighing 2.5 lbs. at farrowing, gained 1.9 lbs., or 76 per ct. of its birth weight, during the first week. During the second week it gained 2.6 lbs., but the per cent of gain reckoned on the weight at the beginning of the week dropped to 59. The average 320-lb. pig gained 9.8 lbs. in 1 week, which was but 3.1 per ct. of its initial weight. It thus appears that pigs gain more and more in pounds each week until they are mature and fat, while there is a steady decrease in the ratio of gain to body weight.

816. Economy of young pigs.—In trials by the author at the Wisconsin Station,[2] 5 sows and litters were fed 70 days on corn meal, wheat middlings, and sour skim milk. The unweaned pigs were also given all of the same food they would consume at a separate trough. At 10 weeks the pigs were weaned, and the feeding continued for 7 weeks with the sows and weaned pigs separately. While suckling

[1] Rpts. 1889, 1890, 1897. [2] Rpt. 1897.

their pigs, 1 sow lost and 2 gained in weight. The table shows the feed required for 100 lbs. of net gain with sows and pigs before and after weaning:

Feed for 100 lbs. gain by sows and pigs before and after weaning.

	Meal	Milk	Meal equivalent
	Lbs.	Lbs.	Lbs.
By sows and pigs 10 weeks before weaning	237	475	316
By pigs only, 7 weeks after weaning	288	576	384
By sows only, 7 weeks after weaning	710	1,420	947

It is shown that 237 lbs. of grain, together with 475 lbs. of separator skim milk, produced 100 lbs. of combined net gain with sows and their unweaned pigs. Reckoning 6 lbs. of skim milk equal to 1 of the mixed meal, it is shown that 316 lbs. of meal equivalent produced 100 lbs. net gain with sows and their unweaned pigs. For the 7 weeks following weaning the pigs required 384 lbs. of meal equivalent, or 27 per ct. more feed, for 100 lbs. of gain than before weaning. It thus appears that young, unweaned pigs are fed more economically thru the sow than after weaning. The table shows that, after their pigs were weaned, the sows required the surprisingly large amount of 947 lbs. of meal equivalent to make good each 100 lbs. of flesh lost while suckling their pigs. The prudent stockman always feeds both sows and pigs liberally before weaning, realizing that the sows should not be allowed to grow thin thru scant feeding. The good brood sow will usually lose weight despite the best of feed and care. (**472, 722**)

817. Maintenance of sow.—At the Wisconsin Station[1] Davies, recording the feed eaten by a 394-lb. Berkshire sow and her 7 suckling pigs 10 weeks between farrowing and weaning, obtained the following results:

	Concentrates	Skim milk
	Lbs.	Lbs.
Total feed consumed by sow	660	1,381
Calculated amount needed to maintain sow alone	242	484
Feed given to sow that went to nourish her pigs	418	897
Additional feed given to pigs	100	313
Total	518	1,210
Feed to sow and pigs for 100 lbs. gain by pigs	146	339
Feed required to maintain sow 1 day	3.5	6.9

[1] Rpt. 1904.

The concentrates fed consisted of half ground corn and half wheat middlings. Davies estimates that the equivalent of 1 per ct. of the weight of the sow in concentrates would support her for 1 day, and that but one-third of what she ate went for the support of her own body, while two-thirds was used in the elaboration of milk for her young. (**592**) It required but 146 lbs. of grain and 336 lbs. of skim milk fed to sow or pigs for 100 lbs. of gain by the pigs—an exceedingly small allowance.

By weighing the pigs at 6:30 a. m. and 6:30 p. m. daily, Davies found that they increased 84 lbs., or 29 per ct., in daytime and 202 lbs., or 71 per ct., in the night. These figures seem to indicate that most of the body increase of young pigs occurs at night.

818. Food and maintenance.—At the Wisconsin Station[1] Dietrich gradually reduced the feed of four 50-lb. pigs during 2 weeks until they were neither gaining nor losing in weight. They were held on this allowance for 7 days to confirm the figures and then gradually brought back to full feed again. When the pigs averaged 100 lbs. the process was repeated, with the results shown in the table:

Feed required to maintain a pig at different weights.

Standard weight	Corn meal	Wheat middlings	Skim milk	Water	Dry matter
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
When weighing 50 lbs.	0.15	0.15	1.2	2.3	0.37
When weighing 100 lbs.	0.40	0.40	1.6	2.0	0.87
When weighing 150 lbs.	0.80	0.80	1.6	3.0	1.54
When weighing 200 lbs.	0.67	1.33	......	6.5	1.76

The table shows that a 50-lb. pig held its weight on a daily allowance of but 0.15 lb. each of corn meal and wheat middlings and 1.2 lbs. of skim milk, drinking 2.3 lbs. of water. This quantity of food supplied only 0.37 lb. of dry matter. The maintenance requirements for other weights follow in the table. From these data Dietrich concludes that the pig can be maintained for 1 day on about 1 per ct. of its live weight of food in the form of wheat middlings.

After each maintenance period the pigs were gradually returned to full feed, which was continued until the next maintenance period was reached. The dry matter required for 100 lbs. of gain in the intermediate stages is given in the table, together with the estimated food of support and gain.

The table shows that the 50-lb. pig, when gaining nearly 1 lb. a day, used only 18 per ct. of this food for the support of the body,

[1] Rpt. 1899.

leaving 82 per ct. of all it consumed for gain in body weight. The food required for the support of the body gradually increased percentagely as the animal grew in size, until the 200-lb. pig was found to require 36 per ct. of all it ate for the support of the body, leaving but 64 per ct. of its food for gain in body weight. Here is another example showing that young animals make the most economical gains for a given amount of food. (**95**)

The food of gain and food of support of the pig.

	Av. daily gain	Dry matter for 100 lbs. gain	Percentage of food—	
			To support body	For gain
	Lbs.	Lbs.	Per cent	Per cent
When pig weighed 50 lbs.	0.93	224	18	82
When pig weighed 100 lbs.	1.66	208	25	75
When pig weighed 150 lbs.	1.85	312	27	73
When pig weighed 200 lbs.	1.22	396	36	64

819. Rate of gain and feed consumed.—The following data, condensed by the author from over 500 feeding trials with over 2,200 pigs at many American experiment stations, show the feed consumed daily by pigs of different weights, as well as the rate of gain, and gain from a given quantity of feed. In compiling this table 6 lbs. of skim milk or 12 lbs. of whey were rated as equal to 1 lb. of concentrates.

The relation of weight of pigs to feed consumed and rate of gain.

Wt. of pigs	Actual av. wt.	No. of animals fed	Av. feed eaten per day	Feed eaten daily per 100 lbs. live weight	Av. gain per day	Feed for 100 lbs. gain
Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Lbs.
15 to 50	38	174	2.2	6.0	0.8	293
50 to 100	78	417	3.4	4.3	0.8	400
100 to 150	128	495	4.8	3.8	1.1	437
150 to 200	174	489	5.9	3.5	1.2	482
200 to 250	226	300	6.6	2.9	1.3	498
250 to 300	271	223	7.4	2.7	1.5	511
300 to 350	320	105	7.5	2.4	1.4	535

The table shows that pigs weighing under 50 lbs. consumed on the average 2.2 lbs. of feed daily, while 300-lb. pigs consumed 7.5 lbs. daily. Based on weight, the 50-lb. pigs consumed 6.0 lbs. of feed per 100 lbs. of body, while 300-lb. pigs consumed only 2.4 lbs. per 100 lbs. In other words, young pigs consume far more feed for their weight than do large ones. The average gain per day started at 0.8 lb. for pigs under 50 lbs. each, and gradually increased until those weighing 250 lbs. showed a daily gain of 1.5 lbs. The last column shows that pigs weighing less than 50 lbs. each gained 100 lbs. for every 293 lbs. of feed or feed equivalent consumed, and that the quantity of feed required for 100 lbs. gain steadily increased as the pigs became larger, until at 300 lbs. weight it required 535 lbs. of feed to make 100 lbs. of gain. The great economy of young, growing pigs over older and more mature ones for making gain from a given quantity of feed is plainly brought out by the table. It should not be forgotten, however, that the flesh of the young pig contains much more water and usually less fat than that of more mature ones.

820. Danish studies of feed and gain.—The following table shows the grain or its equivalent required for 100 lbs. of gain as found in studies with 355 animals in 16 experiments by the Copenhagen (Denmark) Station.[1] These trials were with pigs ranging from 35 to 315 lbs., live weight:

Grain or equivalent required to produce 100 lbs. gain with pigs.

	Average weight of pigs						
	35–75 lbs.	75–115 lbs.	115–155 lbs.	155–195 lbs.	195–235 lbs.	235–275 lbs.	275–315 lbs.
No. of experiments	3	10	13	15	14	11	3
Av. feed required, lbs.	376	435	466	513	540	614	639

We notice a steady increase in the feed required to produce 100 lbs. of gain as the weight of the animals increased. Pigs weighing over 275 lbs. required nearly twice as much feed for 100 lbs. of increase as those weighing from 35 to 75 lbs.

821. Grinding grain.—At the Wisconsin Station[2] during each of 10 consecutive winters the author, at first alone and later with Otis, fed ground corn in comparison with shelled corn to fattening pigs during periods ranging from 63 to 98 days each. Iowa No. 3, year-old shelled corn was used, part of which was ground in a buhrstone mill to the usual fineness, while part was fed unground, as shelled corn. Since pigs do not thrive on corn alone, in all cases the ration was made up of one-third wheat middlings and two-thirds ground or shelled corn. The mixed ground corn and middlings were fed wet with a small quantity of water, while the shelled corn was fed dry and alone, the middlings having first been fed as a slop. Salt

[1] Rpt. 30, 1895. [2] Rpt. 1906.

and wood ashes were supplied at all times to both lots. The results are condensed in the table:

Summary of 10 winters' feeding ground corn and shelled corn.

Feed given	Total feed given			Total gain	Feed for 100 lbs. gain
	Whole corn	Corn meal	Wheat middlings		
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
140 pigs fed shelled corn and wheat middlings	46,736	--------	22,590	13,828	501
140 pigs fed ground corn and wheat middlings	--------	50,647	24,189	15,891	471

In 11 out of 18 trials conducted during the 10 years the saving from grinding corn ranged from 2.5 to 18.5 per ct., and in 7 cases there was a loss by grinding, ranging from 1.1 to 11.1 per ct. Dividing the total feed consumed by the total gains, it required 501 lbs. of whole corn and wheat middlings for 100 lbs. of gain, and only 471 lbs. of ground corn and middlings, a saving of 6 per ct. This means that when corn is worth 50 cts. per bushel there is a saving of 3 cts. on each bushel by grinding, allowing nothing for labor or expense. It was observed that the pigs getting ground corn ate more feed in a given time and gained more rapidly than did those getting shelled corn, which fact no doubt explains the general impression among farmers that pigs do better on ground corn than on shelled.

Rommel,[1] summarizing 9 trials at 5 stations where whole or ground grains—peas, wheat, rye, oats, and barley—were fed, either dry or soaked, to fattening pigs, found that it required approximately 473 lbs. of whole grain or 415 lbs. of ground grain to produce 100 lbs. of gain—a saving of 12 per ct. by grinding. We may then conclude that it pays to grind the small grains always, and to grind corn only when it is desirable to fatten pigs quickly. It is further probable that when pigs have been fed whole corn for a long time and have become quite fat, they then do better on finely ground corn than on whole corn.

822. The Iowa studies on corn preparation.—Kennedy and Robbins of the Iowa Station[2] conducted thoro, extensive, and conclusive studies on the value of corn prepared in various ways and fed to a total of 312 pigs of all ages. The last crop of corn was always used. Shelling corn cost 1 ct. per bu.; grinding shelled corn to meal, 2 cts., and grinding ear corn twice to fine corn-and-cob meal, 6 cts. All statements made are on the basis of 56 lbs. of shelled corn to the

[1] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47. [2] Bul. 106.

bushel. Ear corn was fed on the ground in a clean place, and corn meal in V-shaped troughs frequently moved. The corn was ground each week that it might be fresh. When given wet the shelled corn or meal was usually soaked for 12 hours before feeding, but sometimes for 24 hours, in fresh water so that it never soured. The meat meal fed contained 60 per ct. protein.

Feeding corn prepared in different ways to swine.

	Average ration			Feed for 100 lbs. gain	Return from bushel of corn
	Corn	Meat meal	Total feed		
3-months spring pigs, at weaning, on pasture	Lbs.	Lbs.	Lbs.	Lbs.	Cents
Lot I, Fed dry ear corn	4.0	0.2	4.2	439	60
Lot II, Fed soaked shelled corn	4.1	0.2	4.3	450	58
Lot III, Fed dry corn meal	4.1	0.2	4.3	498	50
Lot IV, Fed soaked corn meal	4.4	0.2	4.6	493	52
6-months pigs, fed in spring and summer in dry yards					
Lot I, Fed dry ear corn	5.7	0.5	6.2	465	56
Lot II, Fed soaked shelled corn	5.3	0.5	5.8	442	58
Lot III, Fed dry corn meal	5.2	0.5	5.6	463	53
Lot IV, Fed soaked corn meal	6.2	0.5	6.8	445	56
10-months 200-lb. hogs, fed in spring and summer in dry yards					
Lot I, Fed dry ear corn	7.4	0.7	8.1	468	55
Lot II, Fed soaked shelled corn	7.9	0.8	8.7	449	56
Lot III, Fed dry corn meal	8.2	0.8	9.0	452	54
Lot IV, Fed soaked corn meal	8.4	0.8	9.2	461	53
Same grade hogs as above, fed in summer, on pasture					
Lot I, Fed dry ear corn	7.1	-----	7.1	544	50
Lot II, Fed soaked shelled corn	7.2	-----	7.2	504	53
28-months old thin 225-lb. sows, fed in fall in dry yards					
Lot I, Fed dry ear corn	8.1	0.6	8.7	427	62
Lot II, Fed soaked shelled corn	9.2	0.7	9.9	398	66
Lot III, Fed dry corn meal	9.0	0.7	9.7	401	64
Lot IV, Fed soaked corn meal	9.2	0.7	9.9	405	63

The first column of the table describes the pigs and the form of corn fed. The last column gives the returns from a bushel of corn with live hogs valued at $5 per 100 lbs.

The last column shows plainly that in most cases the farmer would best feed dry ear corn to fattening hogs. When the pigs were 6 months of age or older and were fed in dry yards, soaked shelled corn gave somewhat better returns than dry ear corn. In no case did the returns justify grinding corn to meal. In general, as those who conducted these trials point out, "The scoop shovel is all that is needed to prepare corn for feeding to swine."

Iowa farmers feed not less than 100,000,000 bu. of corn annually to pigs. To shell and grind this amount at 3 cts. per bu. would cost $3,000,000, besides a vast amount of labor. And in most cases the meal so made would have less value than the ear corn from which it is made!

823. Cooking feed.—The early agricultural authorities uniformly and strongly advocated cooking feed for swine. The first definite results in opposition came from the Maine Agricultural College[1] in 1876, which reported that as the average of 9 years of continuous experimentation it had found that 89.9 lbs. of raw corn meal was as valuable for putting gains on fattening pigs as was 100 lbs. of corn meal that had been cooked. In not a single trial at this College in the 9 years did a given weight of corn meal on being cooked by steam prove as satisfactory as the same weight of uncooked meal. These results were so at variance with popular opinion that the matter was soon tried out at a number of stations, some of the findings of which are as follows:

Results of feeding cooked and uncooked grain to fattening hogs.

Station reporting	No. of trials	Kind of feed	How prepared	Feed for 100 lbs. gain	
				Cooked	Uncooked
				Lbs.	Lbs.
Wisconsin*	4	Ground barley	Steamed	628	589
Wisconsin*	2	Ground corn	Steamed	517	463
Wisconsin*	2	Whole corn, shorts	Steamed	564	484
Wisconsin*	3	Corn meal, shorts	Steamed	597	574
Ontario College†	2	Peas	Steamed	475	360
Kansas Agr. College‡	1	Whole corn	Steamed	750	630
Iowa Agr. Col'ge§	1	Shelled corn	Not stated	538	443
Iowa Agr. Col'ge§	1	Ground corn	Not stated	562	445
Ottawa‖	1	Ground peas, barley, rye	Steamed	417	425

*4th An. Rpt. †2d An. Rpt. ‡Rpt. 1885. §Coburn, Swine in America. ‖Rpt. 1891.

The trials above reported, which are but a fraction of all that have been made in this country, show that in most cases there is an actual loss of food value by cooking the various grains for fattening swine. Some few feeds, such as potatoes, are improved by cooking, but as a rule there is no gain and usually a loss by such operation. **(334, 337)**

824. Soaking feed.—Rommel[2] has summarized the work of the stations with wet and dry feeds for swine. In some cases the feed

[1] An. Rpt. Trustees Maine State Col. of Agr., 1876.
[2] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.

was only wet with water, but generally it was soaked from 12 to 36 hours before it was fed. Many kinds were used—corn meal, chopped wheat, barley meal, whole wheat, whole barley, peas, etc. The average of all the trials at 8 stations shows the amount of feed required for 100 lbs. gain to be:

Dry grain or meal required for 100 lbs. of gain	444 lbs.
Wet or soaked grain or meal for 100 lbs. of gain	434 lbs.
Amount of grain saved by soaking	10 lbs.

It is shown that 10 lbs., or but 2 per ct., of the food was saved in making 100 lbs. of gain by wetting or soaking whole or ground grain before it was fed. It is safe to hold that, if not unusually dry and hard, such large grains as corn and peas are at best but slightly improved by soaking, while all small, hard grains, such as wheat and rye, are materially improved thereby. Any grain so hard as to injure the mouths of animals during mastication should always be ground or soaked. (**339**)

825. Water in slop.—Plumb and Van Norman of the Indiana Station[1] fed 4 lots, each of four 60-lb. pigs, for 146 days, first on corn meal and shorts, equal parts, and later on shorts and hominy feed. Lot I was given dry feed, and the others increasing amounts of water. All lots had water in separate troughs.

Effect of varying amounts of water in the slop of pigs.

Average ration		Av. daily gain	Av. total gain	Feed for 100 lbs. gain
		Lbs.	Lbs.	Lbs.
Lot I, Dry meal, 3.9 lbs.	Water without limit	1.1	159	359
Lot II, Meal, 4.2 lbs.	Water in slop, 4.2 lbs.	1.1	161	380
Lot III, Meal, 4.2 lbs.	Water in slop, 8.4 lbs.	1.1	163	374
Lot IV, Meal, 3.9 lbs.	Water in slop, 11.7 lbs.	1.1	154	375

The table shows that the lot fed dry meal did rather better than the others, and that increasing amounts of water in the feed did not affect the gains. At the Copenhagen (Denmark) Station[2] in several trials with pigs getting skim milk or buttermilk along with grain, adding 1 to 2 times their volume of water to the skim milk or buttermilk had no effect on the gains produced. (**87, 924**)

826. Light v. heavy feeding.—In experiments at the Copenhagen (Denmark) Station[3] with sixty 35-lb. pigs, the influence of the intensity of feeding on gain was specially studied. One experiment

[1] Bul. 86. [2] Rpt. 10, 1887. [3] Rpt. 30, 1895.

lasted 120 days and the other 210 days, the feeds used being barley, buttermilk, skim milk, and whey.

Results from heavy and light feeding.

Character of feeding	Grain fed daily	Av. gain per day	Grain for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Light	3.61	0.92	391
Medium	4.23	1.07	397
Heavy	4.51	1.12	404

These results indicate a tendency toward a poorer utilization of the feed in the heavier feeding, tho the difference is not great.

827. Winter v. summer feeding.—While there are no available data on the comparative economy of summer and winter swine feeding for America, the Copenhagen (Denmark) Station[1] records 199 trials with about 2,500 summer- and winter-fed pigs. In these Danish trials all the skim milk, whey, roots, etc., fed have been reduced to their grain equivalent to facilitate the comparison.

Feed required to fatten Danish pigs in winter and in summer.

Weight	Grain equivalent per day per head		Grain equivalent for 100 lbs. gain	
	Winter	Summer	Winter	Summer
	Lbs.	Lbs.	Lbs.	Lbs.
35 to 75 lbs.*	2.66	2.65	371	346
75 to 115 lbs.	3.96	3.92	446	397
115 to 155 lbs.	5.26	5.25	516	457
Average	3.96	3.94	444	400

*Danish pound=1.1 avoirdupois lbs.

It is shown that winter-fed pigs required 444 lbs. feed for 100 lbs. gain, or 11 per ct. more than summer-fed pigs. In Denmark the summers are cool, and the winters more or less damp but not excessively cold. It is fair to hold that in the northern parts of America the difference between winter and summer feeding is somewhat greater than the Danish figures indicate, while over the greater part of our country there is no greater difference and often no difference at all. (**503**)

828. Wintering pigs in single-board cabins.—At the Ottawa Station[2] Grisdale kept lots, each of from 4 to 7 pigs weighing about 70 lbs. per head, during 60 days in winter in small board houses,

[1] Rpt. 30, 1895. [2] Rpt. 1904.

such as that Station used for summer shelter in the pastures. Check lots were kept in the well built Station piggery, which afforded much greater protection. Wheat shorts and gluten and oil meals were fed all lots with the following results:

Open compared with closed winter quarters for pigs in Canada.

Where sheltered	Av. daily gain	Feed for 100 lbs. gain
	Lbs.	Lbs.
In small single-board houses	0.68	526
In the Station piggery	0.70	366

It is shown that, while both lots made about the same daily gain, the pigs in the colder quarters required 160 lbs. more concentrates for 100 lbs. of gain, or 44 per ct. more feed than those in warm quarters. Grisdale reports that brood sows in the board houses required only 25 per ct. more feed, showing that large animals can withstand severe cold better than small ones. The health of the animals was good under both conditions. Shelton of the Kansas Agricultural College[1] found that during a cold winter large hogs in warm quarters likewise required 25 per ct. less feed than those in exposed quarters. (**495, 734**)

829. Wintering old brood sows.—Grisdale of the Ottawa Experimental Farms,[2] wintering 27 mature brood sows in single-board cabins, found the average total food consumed per head from November 1 to March 31 (133 days) to be:

Bran	221 pounds
Shorts	106 pounds
Roots	1,260 pounds
Clover hay	69 pounds

Grisdale reports that if young sows are to be kept thrifty and growing in winter they must get more meal than older sows.

830. Length of fattening period.—At the Wisconsin Station[3] the author fed in pens 18 pigs of good breeding and high feeding powers a ration consisting of one part wheat middlings and two parts ground corn, with salt and wood ashes additional. The gains by weeks and by 4-week periods were as shown on the next page.

It is seen that the heaviest and most economical gains were made early, and that as the trial progressed the weekly gains diminished and the feed consumed for 100 lbs. of gain steadily increased. Grouping the results into 4-week periods, we find that for the first

[1] Rpt. Prof. Agr., 1883. [2] Rpt. 1909. [3] Rpt. 1897.

4 weeks 418 lbs. of feed produced 100 lbs. of gain. During the second 4 weeks 461 lbs. feed, or 10 per ct. more, was required for 100 lbs. of gain, and during the last 4 weeks 559 lbs. or 33 per ct. more than was required during the first 4 weeks.

Influence of the length of the fattening period on the rate of gain.

Week of trial	Average weight	Average weekly gain	Feed eaten during week per pig	Feed for 100 lbs. gain	
				By weeks	By four-week periods
	Lbs.	Lbs.	Lbs.	Lbs.	
First week	222	11.4	41	362	First four weeks, 418 lbs.
Second week	235	13.3	48	362	
Third week	246	10.5	50	475	
Fourth week	257	10.7	50	473	
Fifth week	270	13.9	51	368	Second four weeks, 461 lbs.
Sixth week	281	10.1	51	510	
Seventh week	294	13.1	51	391	
Eighth week	303	8.9	51	574	
Ninth week	313	10.5	52	499	Third four weeks, 559 lbs.
Tenth week	322	8.9	52	587	
Eleventh week	332	9.6	52	549	
Twelfth week	340	8.8	52	598	

831. Effects of feed on teeth and skull.—Schwartzkopff of the Minnesota Station,[1] treating of the influence of feed upon the formation of the skull and the dentition of pigs, writes:

"1. The order of succession of teeth in our precocious pigs runs the same as in the primitive hog.

"2. The times when the teeth appear are variable, according to race, feeding, and health. The same breeds raised under the same conditions will show the same appearance.

"3. The form of the skull depends upon nutrition, health, and more or less employment of certain muscles of the head and neck. Skulls of poorly nourished pigs are more long and slender than from those well nourished. Pigs which are prevented from rooting will acquire a short, high, and rounded head, while those that are forced to root to secure a portion of their food will develop a long and slender form of head."

832. Length of intestines.—Darwin[2] states that the nature of the food supplied the pig by man has evidently changed the length of the intestines. He quotes Cuvier as reporting the total length of the intestines of the wild boar to be 9 times the body length; in the domestic boar 13.5 to 1; in the Siam boar 16 to 1. The writer[3]

[1] Bul. 7; Breeder's Gazette, 1889, pp. 536–7.
[2] Animals and Plants under Domestication.
[3] Rpt. Wis. Expt. Sta., 1889.

measured the intestines of 39 fattened hogs and found that the large intestine varied from 13 to 16 ft., and the small intestine from 54 to 60 ft., in length. The average extreme body length of these animals was 3.5 ft. This makes the small intestine alone from 16 to 19 times the length of the body, and the large and small intestines combined about 21 times the body length. From these figures it appears that the intestines of pigs of the improved breeds are longer in proportion to the body than those given by Cuvier. This may indicate that the modern pig can digest his food more thoroly than his ancestors, and also that he can eat a larger quantity of food in a given time. (28)

833. Breed tests.—Rommel,[1] collecting the data relative to the feed required for a given gain from 8 American experiment stations with 6 breeds of swine, gives the following summary:

Feed tests with 6 breeds of swine at 8 American experiment stations.

Breed	No. of tests	Total no. of pigs	Feed for 100 lbs. gain
			Lbs.
Tamworth	16	92	344
Chester White	13	71	347
Poland China	22	96	357
Berkshire	23	121	369
Large Yorkshire	11	67	407
Duroc-Jersey	11	66	418

Unprejudiced study will lead to the conclusion that there is no best breed of swine, tho some one breed is usually better than others for a given farmer or for a given region of country. In deciding which breed of swine to keep on a given farm, there are many factors to be taken into account besides the single one of the amount of feed consumed for a given gain. Studies of 4 breeds at the Copenhagen (Denmark) Station[2] revealed no difference save that the Poland-China breed gave firmer pork than the native swine.

834. Feral swine.—Carlyle of the Wisconsin Station[3] procured feral or semi-wild swine, styled "razorbacks," from Texas and the Indian Territory. In one trial 6 unmixed descendants from the original pair of razorbacks were fed in comparison with the same number of pigs obtained by crossing razorbacks on improved Berkshires or Poland Chinas.

The razorbacks made slower gains and required more feed for a given gain than did the cross-breds. Carlyle reports that they were also fickle in appetite. At one time they would gorge themselves,

[1] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47. [2] Rpt. 15, 1889. [3] Rpt. 1903.

and then eat sparingly, only to follow with another gorge. They seemed to thrive best with abundant pasture and bulky food. The second cross with the improved breeds produced pigs of fine form that were good feeders. None were immune from hog cholera, the original pair dying of that disease. Carlyle writes: "These trials show that this cross with razorbacks is capable of improving certain weaknesses in our pure-bred Berkshires and Poland Chinas."

Unmixed razorbacks compared with cross-breds.

Breeding	Av. grain consumed daily	Av. daily gain	Feed for 100 lbs. gain	
			Grain	Skim milk
	Lbs.	Lbs.	Lbs.	Lbs.
Razorback	4.2	1.02	420	565
Cross-bred	5.6	1.52	366	530

Stockbridge of the Florida Station,[1] comparing razorbacks with pure-bred Duroc-Jerseys, found that the natives gained equally well and gave a larger percentage of meat, which was superior in quality. (**100**)

835. Spayed and unspayed sows.—At the Utah Station[2] Foster and Merrill secured a daily gain of 0.82 lb. with spayed sows and 0,86 lb. with unspayed sows, no difference in their appetites being noticed.

836. Barrows v. sows.—In feeding trials mostly by the author at the Wisconsin Station,[3] the weights and gains of 98 sows and an equal number of barrows were as follows:

	Sows	Barrows
Av. weight at beginning of feeding period, pounds	136	144
Av. gain per animal during feeding period, pounds	102	107

It is shown that the barrows, weighing somewhat more than the sows, made slightly better gains. Data obtained in feeding 1,216 pigs at the Copenhagen (Denmark) Station[4] showed practically no difference between barrows and sows as to gain, shrinkage, or quality of carcass. (**507**)

837. Proportion of carcass.—Coburn[5] gives the following in relation to the percentage of dressed carcass that pigs will yield on slaughtering after being deprived of feed for 12 hours:

	Per ct. carcass		Per ct. carcass
Live weight, 100 lbs.	72	Live weight, 250 lbs.	77
Live weight, 150 lbs.	73	Live weight, 300 lbs.	79
Live weight, 200 lbs.	75	Live weight, 350-500 lbs.	80-87

[1] Rpt. 1901.
[2] Bul. 70.
[3] Rpts. 1897–1906.
[4] Rpt. 1895.
[5] Swine in America, p. 535.

It is shown that the small, immature, unfinished pig yields the least, and the large, mature fat one the greatest per cent of dressed carcass. For each 100 lbs. of live weight over the first 100 lbs. the yield is approximately 4 per ct. more dressed carcass.

838. Tuberculosis thru feeding.—At the Iowa Station[1] Kennedy, Robbins, and Bouska selected 40 pigs believed to be free from tuberculosis. Two lots of 10 pigs each were kept on separate pastures and 2 other lots of 10 pigs each confined in dry yards. Corn and creamery skim milk which had been pasteurized to destroy all disease germs was fed to all alike. The milk of one lot on pasture and one lot in the yard was, before feeding, infected with the germs of tuberculosis. When the pigs were slaughtered at the end of 196 days it was found that all that had been fed on infected milk, 20 in number, were tuberculous. Of those not given infected milk, 2 proved tuberculous and 18 were free from the disease.

This experiment shows the supreme necessity of pasteurizing all creamery by-products before they are returned to the farm for feeding purposes, a practice required by law in Denmark, and now followed by some creameries in this country.

Kennedy and Dinsmore of the same Station[2] grain-fed a carload of tuberculous cattle on pasture from October to December. Thirty healthy, vigorous pigs followed the cattle to work over the droppings, while 6 less thrifty pigs from the same lots were kept in a separate enclosure as a check. When the pigs were slaughtered in February, 80 per ct. of those that had run with the steers were found tuberculous, while all in the check lot were free from the disease. This shows that pigs running with tuberculous cattle may thereby become quickly infected with the disease.

II. Bacon Production.

839. Canadian bacon requirements.—The "Wiltshire side" of the English bacon trade is the entire half of the dressed pig, minus the head and feet. Day of the Ontario Agricultural College[3] states that to produce a good Wiltshire side requires in the pig "certain definite peculiarities as to weight, condition, and conformation." He places the live-weight limits at between 160 and 200 lbs., preferably 175 to 190 lbs. The bacon pig should be long from shoulder to ham, and light in the shoulders, neck, and head. The fat should be so placed that when the carcass is split lengthwise along the back the layer of

[1] Bul. 92. [2] Bul. 107. [3] Swine, p. 13.

fat will run uniformly from 1 to 1.5 inches in thickness, without excess over the shoulder. The proportion of lean to fat is much greater than in the lard hog. (**926**)

840. Soft pork.—In bacon production a varying number of carcasses are usually rejected by the packers after slaughter because too soft for the requirements of the bacon market. Olein, palmitin, and stearin are the three principal oils in the fat or lard of the pig. Olein is liquid at ordinary temperatures, while the others are solid. Shutt of the Ottawa Experimental Farms[1] concludes that soft pork is largely caused by an undue proportion of olein in the fat of the carcass. He finds that the fat of firm pork carries 68 per ct. olein or less, and that of soft pork 75 per ct. or more. Pigs fattened exclusively on corn give a lard carrying as much as 92 per ct. of olein, while an oats-peas-barley ration produces a lard with only 67 per ct. olein.

841. Causes of soft pork.—From the extensive studies of Fjord and Friis of the Copenhagen (Denmark) Station,[2] and those of Day, Grisdale, and Shutt of the Canadian Stations,[3] we learn that soft pork unsuited to the production of high quality bacon is due on the part of the animal to unthriftiness and lack of exercise, and only in a small way to the breed. Imperfect feeding, marketing before being finished, holding too long after finishing, and undue forcing—especially when immature—are other causes. In a large way, improper feeding stuffs and feeds improperly combined tend to produce low-quality bacon.

Feeding too much Indian corn to young pigs is always objectionable. Corn produces a soft pork when forming over half the finishing ration and tends to unduly thicken the layer of fat over the shoulder—a common defect. Wheat and rye middlings are unsatisfactory, and beans, soybeans, peanuts, and acorns produce a soft, oily pork. Barley ranks first for producing the highest grade of bacon, while oats and peas follow. Skim milk and whey in combination with the cereal grains, including corn, make a solid flesh that is particularly desirable. Rape, roots, and clover are helpful, but these and other succulent feeds should be judiciously used. Exercise favors firmness of flesh. Pigs that have been properly fed and have had freedom until they weigh 100 lbs., if in thin condition may be finished on almost any of the common meal mixtures and produce fine bacon. They should be fed slightly less than the full ration.

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[1] Bul. 38.
[2] Rpts. 1884, et seq.
[3] Rpts. and Buls. Ont. and Ottawa Expt. Stations, 1890–96.

Indian corn is so economical and so generally valuable for pig feeding in this country that its prohibition would often work hardship to the bacon producer. In feeding for bacon it is not recommended that corn be entirely withheld, for both the Danes and the Canadians use it. A little corn can be used at all times, and a very considerable amount when finishing, if combined with dairy by-products and such grains as barley, peas, oats, etc.

CHAPTER XXXII.

VALUE OF THE VARIOUS FEEDING STUFFS FOR SWINE.

I. Cereal Grains and their By-products.

842. Corn.—Indian corn, the grain of the maize plant, is the common swine food in the great pork-producing districts of America. It is most proper, then, that in our study of feeds for swine we first of all consider the value of unground shelled corn in pork production. The results of feeding trials at 9 stations in as many states are condensed in the following table:

Returns from a bushel, 56 lbs., of shelled corn.

Station reporting	No. of pigs	No. of days fed	Av. wt. at beginning	Av. daily gain	Corn for 100 lbs. gain	Gain per bushel of corn
			Lbs.	Lbs.	Lbs.	Lbs.
Alabama, Bul. 93	3	42	51	0.4	586	9.6
Colorado, Bul. 74	4	101	95	0.7	540	10.4
Illinois, Bul. 16	2	42	210	1.3	500	11.1
Kansas, Bul. 95	3	84	123	1.2	479	11.7
Kentucky, Bul. 101	4	70	139	0.7	587	9.5
Missouri Agr. Col., Bul. 1	4	78	150	1.9	482	11.6
Nebraska, Bul. 94	6	56	170	1.2	530	10.7
Ontario, Rpt. 1899	----	77	---------	0.7	547	10.2
West Virginia, Bul. 59	3	28	239	1.7	579	9.7
Average	-----	-------	---------	-------	537	10.5

The table shows that it required from 479 to 587 lbs. of shelled corn, or an average of 537 lbs., for 100 lbs. gain with fattening hogs. A bushel, 56 lbs., of shelled corn made 9.5 to 11.7 lbs. of gain, the average for all being 10.5 lbs.

Article 821 shows that, on the average, shelled corn ground to a meal is about 6 per ct. more valuable for fattening hogs than whole corn, a sum too small in most cases to pay for grinding. As is pointed out in that article, pigs eat more corn meal than whole corn in a given time and consequently gain faster, a matter of importance in some cases.

In the corn belt most of the corn is fed on the cob, a commendable practice since it involves the least labor by the feeder and is satisfactory to the animals. (**822**) Where early fall feeding is desirable, corn in the roasting-ear stage may be supplied, stalks and all, but in limited quantity at first, for if much is eaten digestive derangements follow. As the kernels harden, the corn may be more liberally supplied. Pigs that have grazed on clover, alfalfa, or other pasture incur the least risk from new corn. Coburn[1] quotes Atkinson as stating that a given area of standing corn will go three times as far after it begins to dent as it will if fed off when in the roasting-ear condition. (**16**) The Virginia Station[2] found that pigs fed new ear corn made as good gains as others fed old corn.

843. Soft corn.—Coburn[3] states that soft corn is considered excellent for swine and especially for young pigs, many breeders believing they can obtain better gains from soft than from sound, hard corn. As soft corn contains less starch than mature corn, it is advisable to feed some old corn for finishing. Soft corn may be used during cold weather without danger, but should not be carried over into the warm season, as it will ferment and thereby become unfit for use. (**154**)

844. Field feeding corn.—Gaumnitz, Wilson, and Bassett of the Minnesota Station[4] turned 1 lot of pigs into ripe standing corn and fed another lot ear corn in a yard, with the results shown in the following table. Rape sown broadcast in the corn field before the last cultivation furnished succulent feed to the foraging lot, and both lots received an allowance of wheat shorts. The amount of corn eaten in the field was carefully estimated.

Field feeding of corn compared with feeding corn in yard.

How fed	No. of pigs fed	Length of trial	Average daily gain	Ear corn and shorts for 100 lbs. gain
		Days	Lbs.	Lbs.
First trial				
Lot I, foraging corn	26	49	1.3	835*
Lot II, fed ear corn	13	49	1.0	1,042*
Second trial				
Lot I, foraging corn	32	61	1.4	635
Lot II, fed ear corn	8	61	1.1	677

*Weight of green corn used.

The table shows that the foraging pigs made larger gains and required less concentrates for 100 lbs. gain than those fed ear corn. The foraging pigs wasted no more corn than those fed in the yard, picking it up as close as is usually done in husking. The cost of annually fencing off the cornfields into small areas, $1 to $2.50 per

[1] Swine in America, p. 287.
[2] Bul. 167.
[3] Swine in America, p. 276.
[4] Bul. 104.

acre, is less than that of husking the corn. Pigs weighing from 100 to 140 lbs. are best for foraging, and those reared on pasture, being more active, are better than pen-reared pigs. It was found best to so confine the pigs that they would clean up a fenced portion of the field in 20 or, better, 14 days, tho some farmers prefer to let the pigs range the whole field. The following table shows the days required by 125-lb. pigs to forage an acre yielding various amounts of marketable corn:

Number of days required by pigs to clean up 1 acre of corn.

Number of pigs	Yield of corn per acre			
	40 bu.	50 bu.	60 bu.	70 bu.
	Days	Days	Days	Days
When 20 pigs forage	15	19	23	26
When 40 pigs forage	8	9	11	14
When 60 pigs forage	5	6	8	9
When 80 pigs forage	4	5	6	7

Field feeding of corn is most successful when the weather is dry. It is not judicious to keep pigs in the fields after heavy rains, for they then waste corn and injure the land. Pumpkins and rape are helpful and economical in field-feeding pigs, since there is no cost for harvesting, and these feeds supplement the corn and add variety to the ration.

845. Corn-and-cob meal.—The studies of the stations on the merits of corn-and-cob meal for swine feeding have shown widely discordant results. Those of Kennedy and Robbins of the Iowa Station,[1] which are by far the most detailed, complete, and satisfactory, are condensed in the following table:

Corn-and-cob meal compared with whole corn and corn meal for pigs.

Kind of corn fed	Av. wt. at beginning	Av. daily gain	Corn for lbs. 100 gain	Lbs. gain per bu. of corn
	Lbs.	Lbs.	Lbs.	Lbs.
Dry ear corn	148	0.74	456	12.3
Soaked shelled corn	134	0.63	513	10.9
Dry corn meal	128	0.61	595	9.4
Soaked corn meal	145	0.72	555	10.1
Dry corn-and-cob meal	118	0.51	604	9.3
Soaked corn-and-cob meal	123	0.56	583	9.6

[1] Bul. 106.

The corn-and-cob meal used was twice ground in order to reduce it to proper fineness. The table shows that all the labor and expense required in grinding ear corn to corn-and-cob meal was more than lost. This seems reasonable in the case of the pig, which has a digestive tract that can at best but poorly utilize a hard, fibrous material such as the corn cob, even after it is ground. Where the pig's food is limited in quantity the cob particles may be useful in distending the digestive tract. Even in such cases the feeder should supply woody matter of better character, such as clover and alfalfa hay furnish. With the other farm animals, where the roughage supply is costly or scant, corn-and-cob meal may possibly be of advantage at times, as pointed out elsewhere. (**156-7, 523**)

846. Gluten meal.—At the Cornell Station[1] Clinton compared gluten meal and skim milk with corn meal and skim milk, feeding 2 lots, each of 8 pigs averaging 70 lbs., for 50 days with the results shown below:

Gluten meal compared with corn meal.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain	
			Meal	Milk
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I				
Gluten meal, 2.4 lbs.				
Skim milk, 6.4 lbs.	0.9	46	255	684
Lot II				
Corn meal, 2.7 lbs.				
Skim milk, 7.3 lbs.	1.3	65	206	569

Gluten meal gave the poorer results with skim milk, probably because it is excessively rich in protein and poor in carbohydrates, so valuable in pork production. At the same Station[2] a mixture of 1 part gluten meal and 4 parts corn meal proved 7 per ct. more valuable than wheat meal when both were fed with skim milk. Grisdale of the Ottawa Experimental Farms[3] states that gluten meal seems unpalatable and produces soft bacon. (**158**)

847. Hominy feed.—At the Massachusetts (Hatch) Station[4] Lindsey found hominy meal or hominy feed as valuable, pound for pound, as corn meal for fattening pigs when both feeds were fed in combination with skim milk. (**159**)

848. Wheat.—About the year 1893, when the price of wheat ruled excessively low, several stations compared the value of wheat with

[1] Bul. 199. [2] Bul. 89. [3] Bul. 51. [4] Rpt. 1899.

that of corn for fattening pigs, obtaining the results shown in the table given below:

Wheat meal for fattening pigs.

Station and reference	Av. ration		Av. daily gain		Feed for 100 lbs. gain	
	Corn meal	Wheat meal	Corn meal	Wheat meal	Corn meal	Wheat meal
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Kansas, Bul. 53	7.5	7.3	1.70	1.78	439	411
Ohio*	6.0	5.9	1.29	1.39	453	438
South Dakota, Bul. 38	6.4	6.4	1.40	1.32	458	481
Wisconsin, Rpt. 1895	6.4	6.4	1.28	1.22	499	522
Wisconsin, Rpt. 1895	8.0	8.0	1.60	1.72	496	465
Average					469	463

*Kan. State Bd. Agr., 1894.

Averaging the trials we find that it required 6 lbs. more corn meal than wheat meal to produce 100 lbs. of gain. The difference being small, we may conclude that wheat and corn are equally valuable for fattening swine. At the Oregon Station[1] Withycombe found that 528 lbs. of whole wheat, 445 lbs. of finely ground wheat, and 410 lbs. of crushed wheat produced 100 lbs. of gain with fattening pigs. Grinding to a meal saved 16 per ct.. and crushing or rolling 29 per ct., over the whole grain.

Grisdale of the Ottawa Experimental Farms[2] found that from 360 lbs. to 400 lbs. of frozen wheat were required to produce 100 lbs. of gain with fattening pigs—a most favorable showing for such grain. Frozen wheat alone produced as satisfactory gains as 2 parts of frozen wheat and 1 part of wheat middlings, corn, or barley. (**161**)

849. Red-dog flour.—At the Virginia Station[3] 54-lb. pigs were fed soaked red-dog flour and corn meal, equal parts, for 58 days. They gained 1.3 lbs. daily, requiring but 390 lbs. of the mixture for 100 lbs. of gain, while on the same feed given dry 490 lbs. were required. The high value of red-dog flour when properly fed is here shown. This feed serves its highest purpose with quite young pigs, which need a highly digestible, palatable feed, containing little fiber. (**164**)

850. Wheat middlings.—At the Wisconsin Station[4] the author fed 3 lots, each of 3 pigs averaging 60 lbs., giving to the first corn meal, to the second high-grade wheat middlings, and to the third a mixture of equal parts of the two. The feeding period covered 6 weeks, with the results shown on the following page.

It will be seen that high quality wheat middlings fed alone proved somewhat superior to corn meal. From trials extending over several

[1] Bul. 80. [2] Rpt. 1908. [3] Bul. 167. [4] Rpt. 1885.

years, Sanborn of the Missouri Station[1] held that good wheat middlings were worth 8 per ct. more than corn meal when each is fed alone. In the above trial the mixture of corn meal and wheat middlings proved 16 per ct. superior to wheat middlings alone, and 18 per ct. superior to corn meal alone. Wheat middlings should never be fed alone to pigs, but always in combination with corn or other starchy feeds, and only the best grades should be used. (**166**)

Comparative value of high-grade wheat middlings and corn meal.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Corn meal, 4.4 lbs.	0.8	35	537
Lot II, Wheat middlings, 4.0 lbs.	0.8	32	522
Lot III, Corn meal and middlings, 3.8 lbs.	0.9	36	439

851. Wheat shorts.—In a 60-day trial at the New Hampshire Station[2] Shaw compared wheat shorts with corn meal as a feed for 47-lb. pigs, obtaining the results shown below:

Low-grade wheat shorts compared with corn.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Concentrates	Skim milk
	Lbs.	Lbs.	Lbs.
Lot I Wheat shorts, 2.2 lbs.	0.3	787	----------
Lot II Corn meal, 3.0 lbs.	0.5	591	----------
Lot III Wheat shorts, 2.1 lbs. Skim milk, 8.3 lbs.	0.5	412	1,647
Lot IV Corn meal, 3.2 lbs. Skim milk, 13.0 lbs.	1.3	255	1,019

In this trial the wheat shorts proved unsatisfactory for young pigs whether fed alone or with skim milk. They were doubtless ground-over bran with mill dust and sweepings added, judging by the results. Such feed has little value compared with cost and should be avoided by the pig feeder. (**166**)

852. Wheat bran.—At the Maine Station[3] Jordan fed 200-lb. pigs either wheat bran and skim milk or wheat middlings and skim milk for 72 days and found that:

413 lbs. wheat middlings and 1,126 lbs. skim milk made 110 lbs. gain
413 lbs. wheat bran and 1,126 lbs. skim milk made.......54 lbs. gain

[1] Bul. 14. [2] Bul. 113. [3] Rpt. 1889.

It is shown that the wheat middlings proved twice as valuable as wheat bran.

The Copenhagen (Denmark) Station[1] found that bran alone did not produce as good results as a mixture of equal parts bran and grain. In several instances bran-feeding caused sickness among the pigs. The pork from wheat bran was poorer than that from grain, and the pigs shrank more in dressing. Where clover or alfalfa hay, roots, or other better bulky feeds are not available, a limited amount of wheat bran is helpful in adding nutriment and volume to the otherwise meager ration usually given brood sows and shotes not being fed for gain. (**165**)

853. Rye.—Extensive trials by the Copenhagen (Denmark) Station[2] showed that rye meal ranks a little below corn meal and about equal to barley meal as a feed for swine. The pork from rye-fed pigs was satisfactory, especially when the ground rye was fed with other grains, milk, or whey. Rye shorts and middlings had a lower feeding value than rye meal and produced a poorer quality of pork. In 1 trial pigs fed rye meal became sick. Coburn[3] recommends feeding ground rye as a thin slop, since dry rye meal forms a sticky paste in the pig's throat on which he is liable to choke. A field of rye may often be profitably harvested by turning pigs into it to forage at will. The waste of grain in such cases will usually be small. (**177**)

854. Barley.—The value of barley as a pig feed has been studied at a number of stations with the results summarized below:

Ground barley compared with corn.

Station and average ration	Length of period	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain
	Days	Lbs.	Lbs.	Lbs.
Ottawa[1]				
Lot I, Barley meal, 4.3 lbs.	112	73	1.0	435
Lot II, Corn meal, 3.6 lbs.	112	74	0.9	416
Ontario[2]				
Lot I, Barley meal, 5.3 lbs.	77	121	1.2	456
Lot II, Corn meal, 3.8 lbs.	77	122	0.7	547
South Dakota[3]				
Lot I, Barley meal, 7.0 lbs.	56	109	1.5	458
Lot II, Corn meal, 7.0 lbs.	56	126	1.5	453
Wisconsin[4]				
Lot I, Barley meal, 10.1 lbs.	56	208	2.1	471
Lot II, Corn meal, 11.1 lbs.	56	209	2.5	435

[1] Bul. 33. [2] Rpt. 1899. [3] Bul. 63. [4] Rpt. 1890.

[1] Rpt. 26, 1892. [2] Rpts. 1887, 1890. [3] Swine in America, p. 347.

Two of the trials show that the barley-fed pigs made as rapid gains as those on corn, but in three cases it required more barley than corn for a given gain. Fed alone, barley has about 10 per ct. less value than corn for fattening swine. However, barley should never be fed separately, but always in combination with corn, wheat middlings, skim milk, roots, alfalfa, etc., when it will be found one of the best of feeds for pork production. Barley kernels, being small and hard, should always be ground or, better, rolled before feeding. (**171**)

855. Oats.—At the Wisconsin Station[1] the author fed whole and ground oats with corn meal to 115-lb. pigs for 60 days with the following results:

Whole oats compared with ground oats.

Feed	Av. ration	Av. daily gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Whole oats			
Lot I, ⅔ oats, ⅓ corn meal	3.8	0.68	564
Lot II, ⅓ oats, ⅔ corn meal	4.0	0.82	492
Ground oats			
Lot I, ⅔ oats, ⅓ corn meal	4.4	1.03	429
Lot II, ⅓ oats, ⅔ corn meal	5.1	1.27	402

We observe that the pigs getting whole oats ate less feed and gave poorer returns than those fed ground oats. The best returns were with a ration of one-third ground oats and two-thirds ground corn. In both trials the feed requirements for 100 lbs. of gain were very low where ground oats were used, showing the high value of ground oats when combined with corn.

Grisdale of the Ottawa Experimental Farms[2] found that pigs fed soaked shelled corn and skim milk made 49 per ct. greater gains than those fed soaked whole oats and skim milk—a good example of the great waste which follows the wrong combination of feeding stuffs. Oats and corn, or skim milk and corn, are proper combinations, while oats and skim milk are not. Again, oats must be ground if they are to be fed in quantity to swine, especially when the pigs are young. For pigs while still quite small there is nothing more helpful than ground oats with the hulls sieved out. For breeding stock and for shotes not being fattened, there is no more useful feed than whole oats, fed by scattering thinly on the ground or on a feeding floor. (**169**)

[1] Rpt. 1889.

[2] Bul. 51.

856. Buckwheat.—In a trial lasting 77 days at the Ottawa Experimental Farms[1] Robertson fed lots of five 100-lb. pigs on ground buckwheat and ground wheat soaked 30 hours before feeding, with the results given below:

Buckwheat meal compared with wheat meal.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Ground buckwheat, 5.5 lbs.	1.2	95	445
Lot II, Ground wheat, 3.3 lbs.	0.8	62	410

It is shown that while buckwheat has a high value it is hardly equal to wheat as a feed for pigs—a reasonable conclusion, for wheat is one of the most potent of grains. In another trial R. Robertson of the Nappan, Nova Scotia, Experimental Farm[2] found that buckwheat, fed with skim milk to 85-lb. pigs, was a little lower in feeding value than the same weight of wheat middlings. Grisdale of the Ottawa Experimental Farms[3] states that buckwheat produces a poor quality of bacon. (**180**)

857. Emmer (speltz).—In a trial at the Nebraska Station[4] lasting 94 days, Burnett and Snyder compared emmer meal with corn and barley meal as a feed for fattening pigs. In a second trial lasting 42 days, an allowance of half emmer and half corn meal was fed against one of corn meal only. In both trials alfalfa hay was fed to the pigs in addition to the meal:

Emmer meal compared with corn and barley meal for pigs.

Daily grain allowance	Av. wt. at beginning	Av. daily gain	Grain for 100 lbs. gain
First trial	Lbs.	Lbs.	Lbs.
Lot I, Corn meal, 4.8 lbs.	82	1.02	470
Lot II, Barley meal, 4.8 lbs.	80	0.81	590
Lot III, Emmer meal, 4.8 lbs.	81	0.77	618
Second trial			
Lot I, Corn meal, 7.2 lbs.	160	1.53	470
Lot II, Corn meal and emmer, 6.6 lbs.	146	1.35	482

The table shows that in the first trial it required 148 lbs., or 31 per ct., more emmer meal than corn meal, and 5 per ct. more emmer meal than barley meal, to produce 100 lbs. of gain. In the second

[1] Rpt. 1894.
[2] Ottawa Expt. Farms, Rpt. 1901.
[3] Bul. 51.
[4] Bul. 99.

trial emmer meal combined with corn meal proved nearly equal to corn meal alone. For swine emmer should always be ground and fed with other feeds, such as corn, barley, wheat middlings, and alfalfa hay. (**178**)

858. Kafir.—At the Kansas Station[1] Georgeson conducted 2 trials with lots of 3 or 4 pigs each to determine the relative value of kafir meal and corn meal, with the following results:

Kafir meal compared with corn meal.

Average ration	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain
First trial	Lbs.	Lbs.	Lbs.
Lot I			
Kafir meal, 7.1 lbs.	153	1.4	515
Lot II			
Corn meal, 7.4 lbs.	152	1.7	439
Second trial			
Lot I			
Kafir meal, 3.1 lbs.	63	0.5	621
Lot II			
Corn meal, 3.9 lbs.	64	0.8	482
Lot III			
Kafir meal, 3.8 lbs. Ground soybeans, 1.9 lbs.	62	1.4	396
Lot IV			
Corn meal, 3.6 lbs. Ground soybeans, 1.8 lbs.	62	1.5	369

The table shows that when fed alone, kafir meal falls from 17 to 29 per ct. below corn meal in feeding value for pigs. Kafir, tho rich in carbohydrates, lacks protein, is constipating, and pigs, especially young ones, tire of it sooner than of corn. For pigs, kafir should always be ground and mixed with some laxative protein-rich supplement, such as ground soybeans, wheat middlings, etc. In the last trial the pigs fed kafir meal and soybean meal made nearly as large gains as those fed corn meal and soybeans. The great advantage of using a protein-rich supplement when either corn or kafir is fed is forcefully shown by the large and remarkably economical gains made by the last 2 lots of pigs in the second trial. (**183**)

859. Milo.—According to Cottrell of the Colorado Station,[2] 100 lbs. of milo is equal to 90 lbs. of corn for fattening hogs. The grain should always be ground or soaked before it is fed. Milo is constipating, and some such laxative feed as alfalfa hay, sorghum fodder, cured when green, tankage, wheat bran, linseed meal, or soybean meal should be given with it. (**184**)

[1] Buls. 53, 61.

[2] Bul. 146.

860. Millet.—Wilson and Skinner of the South Dakota Station[1] fed "hog" millet (*Panicum Miliaceum*) meal against barley and wheat meal to lots of 2 pigs each for 84 days, with the results shown in the table:

Millet meal compared with wheat and barley meal.

Average ration	Av. wt. at beginning	Daily gain per head		Feed for 100 lbs. gain for both periods
		1st period, 56 days	2d period, 28 days	
	Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Millet meal, 6.8 lbs.	116	1.32	0.76	595
Lot II, Barley meal, 6.2 lbs.	125	1.34	1.07	495
Lot III, Wheat meal, 8.2 lbs.	168	1.75	1.51	487

For the first 8 weeks the pigs fed millet meal gave substantially as good returns as those fed barley meal, but during the next 4 weeks they made poorer gains. Combining both periods, it required about 20 per ct. more millet than barley to produce a given gain. Millet meal should never be fed alone, but always in combination with some other grain, such as corn or barley, or, better, with some protein-rich concentrate, such as soybeans, linseed meal, heavy wheat middlings, alfalfa hay, etc. It is not so useful for fattening hogs in cold weather as wheat or barley, and produces a softer pork than those grains. (**185**)

861. Sorghum seed.—Erf and Kinzer of the Kansas Station[2] found a mixture of 4 parts sorghum-seed meal and 1 part soybean meal almost equal to corn meal alone as a feed for pigs, but 33 per ct. poorer than a mixture of 4 parts kafir meal and 1 part soybean meal. Heavy, clean sorghum seed should rank but little below kafir or milo in feeding value. (**181**)

862. Dried distillers' grains.—May of the Kentucky Station[3] found that pigs did not relish dried distillers' grains and would not eat them if they could get corn. Fed with an equal amount of corn the grains produced average daily gains of only 0.14 lb. When 1 part distillers' grains and 4 parts of corn was fed the pigs made larger gains than on corn alone. Distillers' grains should not form over 20 per ct. of the ration when fed with corn. The low value of this feed when much of it is fed is due, as is the case with bran, to the large amount of fiber contained. (**317**)

863. Rice by-products.—At the Massachusetts (Hatch) Station[4] Lindsey divided a litter of six 10-weeks-old pigs into 2 lots and fed

[1] Bul. 83. [2] Bul. 136. [3] Bul. 101. [4] Rpt. 1897.

them the following rations for 92 days to determine the value of rice meal:

Rice meal compared with corn meal.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Meal	Milk
	Lbs.	Lbs.	Lbs.
Lot I, Rice meal, 3.1 lbs. Skim milk, 13.0 lbs.	1.4	225	914
Lot II, Corn meal, 3.1 lbs. Skim milk, 13.0 lbs.	1.4	225	914

This trial shows that rice meal is equal to corn meal when both are fed with skim milk. Connor of the South Carolina Station[1] found rice meal slightly superior to corn meal. He stated, however, that some feeders have noticed that the excessive use of rice meal tends to weaken the intestines of pigs to which it is fed.

Duggar of the Alabama Station[2] found 79 lbs. of rice polish equal to 100 lbs. of corn meal for fattening pigs. (**179**)

864. Pigeon-grass seed.—Western grain elevators screen great quantities of pigeon-grass seed from wheat. At the Wisconsin Station[3] the author tested its value as a food for swine. Since the pigs refused to eat any large quantity of the raw pigeon-grass seed meal, it was cooked, after which treatment it was readily consumed. A ration containing 2 parts cooked pigeon-grass seed meal and 1 part corn meal was found to be fully equal to one of corn meal for fattening pigs. A lot fed 1 part raw pigeon-grass seed meal and 2 parts corn meal gave poorer returns, tho still justifying the use of this weed seed when it can be had at low cost or would otherwise be wasted. To be satisfactory for pigs, pigeon-grass seed should be both ground and cooked.

865. Lamb's quarter or pig weed.—Lamb's quarter, *Chenopodium album*, is a common weed in the wheat fields of Manitoba and the North-West Territories. In a trial at the Manitoba Experimental Farms[4] 100 lbs. of lamb's quarter seed screened from wheat was found to be equal to 60 lbs. of mixed grain when constituting one-fifth of the ration for pigs.

II. Leguminous and Oil-bearing Seeds and By-products.

866. Canada field pea.—On the next page are given the results of trials at the Utah,[5] South Dakota,[6] and Wisconsin[7] Stations in which pea meal or whole peas were fed to fattening pigs.

[1] Bul. 55.
[2] Bul. 122.
[3] Rpt. 1894.
[4] Ottawa Expt. Farms, Rpt. 1902.
[5] Bul. 34.
[6] Bul. 38.
[7] Rpt. 1902.

The table shows pea meal superior to corn meal whether fed alone or in combination with wheat bran. This is made especially plain in the long feeding period at the Wisconsin Station where both feeds were severely tested.

Feeding Canada field peas.

Station and average ration	No. of pigs	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain
Utah Station		Lbs.	Lbs.	Lbs
Lot I, Pea meal, 2.0 lbs. Wheat bran, 2.0 lbs.	3	111	1.1	363
Lot II, Corn meal, 1.4 lbs. Wheat bran, 1.4 lbs.	3	112	0.6	455
South Dakota Station				
Lot I, Soaked whole peas, 5.0 lbs.	2	82	1.2	421
Lot II, Soaked corn meal, 6.4 lbs.	2	96	1.4	458
Wisconsin Station				
Lot I, Pea meal, 3.8 lbs.	12	60	0.8	474
Lot II, Corn meal, 3.2 lbs.	12	60	0.6	549

Grisdale of the Ottawa Experimental Farms[1] states that pigs fed solely on pea meal do not thrive and produce a hard, dry, inferior pork. This valuable grain should always be fed in combination with corn, barley, ground oats, shorts, etc.

Cottrell of the Colorado Station[2] reports that in the San Luis Valley, Colorado, field peas are seeded on unplowed ground and irrigated once or twice. The vines cure on the ground, and pigs turned into the fields fatten on the peas alone, an acre of good peas producing about 400 lbs. of gain. Sometimes the unthreshed vines, after being stacked, are fed to pigs in yards, an acre of good peas producing from 600 to 800 lbs. of gain. Pork from pigs so fattened is firm, sweet, and tender, with a delicious flavor. Cottrell recommends feeding barley, wheat, potatoes, or roots once a day to pigs foraging on peas. (**205**)

867. Cull beans.—At the Michigan Station[3] Shaw and Anderson compared cooked cull table beans with a mixture of equal parts of cooked beans and corn meal, feeding 26 pigs averaging 160 lbs. for periods of 56 to 70 days with the results given below. The beans were carefully cooked in a limited quantity of water to which salt had been added.

It is seen that, fed alone or with corn, cooked beans have a high value for swine. Being unusually rich in protein, they should be fed in combination with some starchy feed such as corn meal. Fed

[1] Bul. 51. [2] Bul. 146. [3] Bul. 243.

alone or in excess, they produce a soft pork lacking quality. Salt should always be added to a ration containing beans, and the beans thoroly cooked. (**207**)

Cooked beans compared with corn meal and cooked beans.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Cooked beans, 4.7 lbs.	1.1	62	421
Lot II, Cooked beans, 3.0 lbs. Corn meal, 3.0 lbs.	1.5	94	406

868. Soybeans.—At the Indiana Station[1] Skinner compared ground soybeans with wheat middlings and tankage as a feed for swine. Four lots, each of 4 pigs averaging 61 lbs., were fed for 84 days with the results shown in the table:

Soybeans compared with wheat middlings and tankage.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Corn meal, 3.0 lbs.	0.5	46	557
Lot II, Corn meal, 1.9 lbs. Wheat middlings, 1.9 lbs.	1.1	91	343
Lot III, Corn meal, 2.5 lbs. Ground soybeans, 1.2 lbs.	1.2	101	311
Lot IV, Corn meal, 3.1 lbs. Tankage, 0.6 lb.	1.0	87	331

The table shows that corn alone is a poor feed for young pigs, while combined with a protein-rich feed, like the soybean, it is most valuable. While in all cases the gains from the mixed feeds were large, the soybean-corn meal ration proved the best.

In another trial Skinner and Cochel[2] compared ground soybeans and linseed meal as supplements to corn meal in 2 trials lasting 60 and 70 days respectively. Nine pigs in all, averaging 99 lbs. in weight, were fed each ration with the results averaged below:

Ground soybeans v. linseed meal as a supplement to corn.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
Lot I	Lbs.	Lbs.	Lbs.
Corn meal, 4.9 lbs. Linseed meal, 0.8 lb.	1.5	97	378
Lot II			
Corn meal, 4.9 lbs. Soybeans, 0.8 lb.	1.6	102	360

[1] Bul. 108. [2] Indiana Expt. Sta., Bul. 126.

Lot II, receiving ground soybeans and corn meal, made slightly larger and more economical gains than Lot I, fed linseed meal and corn meal. This shows that home-grown soybeans are fully equal to linseed meal as a supplement to corn meal in fattening pigs. At the Wisconsin Station[1] Humphrey found ground soybeans 10 per ct. superior to wheat middlings for feeding with corn meal to fattening pigs, but the pork was less firm and the grain of the meat and the distribution of fat and lean less satisfactory. (**201**)

869. Cowpeas.—Duggar of the Alabama Station[2] and Newman and Pickett of the South Carolina Station[3] compared cowpeas and corn for pig feeding with the results which follow:

Cowpeas and corn compared.

Station and average ration	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Alabama Station			
Lot I, Corn, 2.5 lbs.	58	0.5	487
Lot II, Cowpeas, 2.8 lbs.	60	0.6	481
Lot III, Corn, 1.4 lbs. Cowpeas, 1.4 lbs.	62	0.6	433
Alabama Station			
Lot I, Corn, 3.5 lbs.	63	0.7	478
Lot II, Corn, 1.7 lbs. Cowpeas, 1.9 lbs.	67	0.9	395
South Carolina Station			
Lot I, Corn, 9.2 lbs.	156	1.4	602
Lot II, Grcund cowpeas, 6.7 lbs.	160	1.1	491

In the Alabama trials cowpeas and corn were practically equal in feeding value when fed separately, but a mixture of the two proved more satisfactory than either alone. The South Carolina test was decidedly in favor of the cowpeas. The great value and importance of cowpeas and corn for pork production in the South is here made plain. (**206**)

870. Peanuts.—In a feeding trial with pigs at the Georgia Station[4] Flint secured the following returns:

274 lbs. corn and shorts produced 56 lbs. gain.
254 lbs. corn and 449 lbs. skim milk produced 76 lbs. gain.
160 lbs. corn and $\frac{1}{6}$ acre soybeans produced 56 lbs. gain.
160 lbs. corn and $\frac{1}{6}$ acre Spanish peanuts produced 71 lbs. gain.

The soybeans and peanuts were pulled and carried to the pigs daily. In ordinary practice the pigs would have done their own foraging. (**202**)

[1] Rpt. 1905. [2] Buls. 82, 143. [3] Bul. 52. [4] Bul. 87.

871. Linseed oil meal.—Forbes of the Missouri Station[1] fed 6 lots, each of 5 pigs averaging 93 lbs., for 90 days on corn meal supplemented with various feeds as shown below:

Comparison of various supplements to corn.

Amount of supplement fed with each 100 lbs. of corn	Average ration	Av. daily gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I			
Wheat middlings, 100 lbs.	5.2	1.0	502
Lot II			
Wheat middlings, 50 lbs.	5.0	1.0	518
Lot III			
Linseed meal, 20 lbs.	6.4	1.4	445
Lot IV			
Germ oil meal, 10 lbs.			
Linseed meal, 10 lbs.	5.5	1.2	476
Lot V			
Gluten meal, 10 lbs.			
Linseed meal, 10 lbs.	5.6	1.2	483
Lot VI.			
Gluten feed, 10 lbs.			
Linseed meal, 10 lbs.	5.9	1.3	452

It is shown that Lot III, fed linseed meal with corn meal, made the largest and most economical gains. The lots fed middlings and corn required from 13 to 16 per ct. more concentrates for 100 lbs. gain than those fed linseed meal and corn. When germ oil meal, gluten meal, or gluten feed was substituted for half the linseed meal, the rate of gain was lowered and the amount of grain required for 100 lbs. gain increased. Gluten feed proved slightly more valuable than gluten meal or germ oil meal. Forbes writes that the pork from pigs fed linseed meal was characterized by hard, white fat. (**200**)

872. Cotton-seed meal.—As now prepared, cotton-seed meal is poisonous to swine. All the various proposed ways for safely feeding this meal have failed under careful and continued tests. Pigs thrive at first on the meal, but usually in from 4 to 6 weeks some die—not all, as a rule,—but so many that all possible profits from the use of this feed are lost. A few feeders continue to use the meal, experience enabling them to avoid most of the losses. If cotton-seed meal is not fed continuously for over 40 days and does not form over one-fourth of the ration, and if the pigs are freely supplied with green forage or grazed on pasture, the risk from this feed is slight.

[1] Bul. 67.

It is not entirely safe to place pigs with fattening cattle that are being fed cotton-seed meal. Whether the trouble comes to the pigs from working over the droppings of the steers or from eating the meal which falls from the feed boxes is not definitely known. Now that the nature of the poison in the cotton-seed meal is known it is reasonable to expect that ere long a way will be found to use this otherwise most valuable feed safely for swine feeding. (**188, 192, 194**)

III. Roots; Dairy By-products; Tankage; Proprietary Stock Foods.

873. Roots.—Several stations have compared rations composed solely of grain with others where roots were added, with the results shown in the following table:

Feeding grain with and without roots.

Station and average ration	No. of pigs	Av. no. of days fed	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain	
					Grain	Roots
*Ottawa**			Lbs.	Lbs.	Lbs.	Lbs.
Lot I, Grain, 4.1 lbs.	8	161	76	1.0	421	....
Lot II, Grain, 3.6 lbs. Roots, 2.4 lbs.	8	161	49	0.9	388	260
Utah†						
Lot I, Grain, 5.5 lbs.	5	85	78	1.3	629	....
Lot II, Grain, 2.1 lbs. Roots, 12.1 lbs.	5	85	78	1.1	280	1,568
Ohio‡						
Lot I, Grain, 6.0 lbs.	5	84	140	1.0	583	....
Lot II, Grain, 6.1 lbs. Roots, 2.9 lbs.	5	84	141	1.1	543	257
Indiana‖						
Lot I, Grain, 4.0 lbs.	10	88	53	1.0	377	....
Lot II, Grain, 3.0 lbs. Roots, 2.6 lbs.	10	88	52	0.8	341	278
Montana§						
Lot I, Grain, 6.4 lbs.	7	66	111	1.2	532	....
Lot II, Grain, 5.4 lbs. Roots, 1.8 lbs.	7	66	115	1.3	426	142

*Rpt. 1891. †Rpt. 1891. ‡Rpt. 1884. ‖Buls. 79-82. §Bul. 27.

Averaging the above findings we learn that 100 lbs. of grain was replaced by feeding 557 lbs. of roots. Day of the Ontario Station[1] found 442 lbs. of roots equal to 100 lbs. of grain. He attributes this high value to the good effect of roots on the digestive organs. Root-fed pigs utilized their food better than those getting no roots.

[1] Rpt. 1901.

Pigs getting roots showed more thrift and growth, produced bacon of superior quality, and showed less inclination to fatten than those fed grain alone. Indeed, so great was the growing tendency that it was necessary to reduce the root allowance when finishing the pigs in order to fatten them properly. (**918**)

Shaw of the Michigan Station,[1] on turning pigs receiving one-third of a normal grain ration into a beet field to do their own foraging, found that 1 acre of sugar beets produced 716 lbs. and 1 acre of half sugar beets and half mangels 792 lbs. of gain.

At the Utah Station[2] Clark fed sugar beets, wet beet pulp, and beet molasses in combination with wheat shorts to 4 lots of 130-lb. pigs for 48 days with the results shown below:

Sugar beets, beet pulp, and beet molasses fed to pigs.

Average ration	Av. daily gain	Feed for 100 lbs. gain			
		Shorts	Beet pulp	Sugar beets	Molasses
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Lot I					
Shorts, 7.6 lbs.	1.7	444	-------	-------	---------
Lot II					
Shorts, 3.2 lbs.					
Sugar beets, 8.3 lbs.	1.2	268	-------	697	---------
Lot III					
Shorts, 3.3 lbs.					
Beet pulp, 12.3 lbs.	1.2	275	1,030	-------	---------
Lot IV					
Shorts, 3.0 lbs.					
Beet pulp, 9.4 lbs.					
Beet molasses, 4.4 lbs.	1.6	186	600	-------	281

The table shows that while the shorts-fed pigs gained 1.7 lbs. each daily, those fed a half allowance of shorts with sugar beets or beet pulp additional gained 1.2 lbs. each daily. In this trial 609 lbs. of wet beet pulp or 396 lbs. of sugar beets replaced 100 lbs. of wheat shorts. Shorts, beet pulp, and beet molasses combined produced nearly as large gains as shorts alone. One hundred lbs. of beet molasses saved 32 lbs. of shorts and 153 lbs. of beet pulp. All the pork was of good quality except that from the molasses-fed pigs, which had a peculiar, unsavory taste.

Overfeeding with beet molasses causes pigs to scour. In a trial at the Cornell Station,[3] after feeding five 87-lb. pigs a ration of 1.6 lbs. corn meal, 2.4 lbs. sugar-beet molasses, and 4 lbs. milk for 3 days, 2 pigs died suddenly. The molasses was then withdrawn from the ration, but the remaining pigs did not thrive, doubtless due to

[1] Bul. 233. [2] Bul. 101. [3] Bul. 199.

the effects of the molasses. Buffum and Griffith of the Colorado Station[1] found that sugar beets, fed alone, rather more than maintained pigs. When fed with equal parts of wheat and barley, sugar beets and sugar-beet pulp proved equally valuable. (**275**)

874. Danish studies with roots.—The Danish (Copenhagen) Experiment Station,[2] in trials with 204 pigs fed whole or sliced roots in combination with skim milk, whey, and grain, found that 1 lb. of ground barley was equal in feeding value to:

	Dry matter	Sugar
7.5 lbs. mangel beets containing	11.0 per ct.	6.7 per ct.
6.5 lbs. mangel beets containing	13.6 per ct.	8.9 per ct.
5.0 lbs. fodder beets containing	16.5 per ct.	10.9 per ct.
4.0 lbs. sugar beets containing	21.2 per ct.	14.0 per ct.

Thus it is shown that 7.5 lbs. of mangels or 4 lbs. of sugar beets are as useful in pig feeding as 1 lb. of ground barley, when all are combined with dairy waste products. Carrots proved as valuable as beets when measured by the dry substance contained. Since roots are almost wholly digestible, their relative feeding value depends upon the total dry matter they contain, rather than the variety or kind. The extensive and successful use of roots by the Danes for pork production should be copied by American farmers in many cases, for adding variety to the ration, maintaining the health of the animals, inducing a heavier consumption of feed, and for producing pork of high quality.

875. Potatoes.—In two trials by the author at the Wisconsin Station[3] potatoes were cooked in an open kettle, using as little water as possible, and corn meal added to form a thick mush which was eaten by pigs with great relish. Corn meal wet with water was fed to a second lot for comparison. The results were as follows:

440 lbs. of corn meal, fed alone, produced 100 lbs. of gain.
262 lbs. of corn meal with 786 lbs. of potatoes, weighed before cooking, produced 100 lbs. of gain.

From this we learn that 786 lbs. of potatoes, when fed to pigs after being cooked, effected a saving of 178 lbs. of corn meal, 442 lbs. of potatoes taking the place of 100 lbs. of corn meal.

At the Copenhagen Station[4] Fjord found 400 lbs. of cooked potatoes equal to 100 lbs. of mixed grains for swine. Since corn has a somewhat higher feeding value than the grains used by Fjord, it is fair to hold that 4.5 bu. (of 60 lbs. each) of potatoes after cooking

[1] Bul. 74. [2] Rpt. 26, 1892. [3] Rpt. 1890. [4] Rpt. 19, 1890

are equal to 1 bu. (56 lbs.) of corn in pig feeding. Grisdale of the Ottawa Experimental Farms[1] reports that raw potatoes alone will scarcely maintain life in pigs, but given in small quantities they help to keep them in health when other succulent food is lacking. (**273**)

876. Artichokes.—French of the Oregon Station[2] placed pigs in a field of artichokes, estimated to yield 740 bu. per acre. As the pigs made little gain on the tubers alone, a small allowance of mixed wheat and oats was supplied in addition, about 310 lbs. of mixed grain being then required to produce 100 lbs. of gain. In this case the artichokes saved from 150 to 200 lbs. of grain for each 100 lbs. of gain made. Sweitzer of the Missouri Station[3] rates artichokes equal to potatoes for pig feeding. Grisdale of the Ottawa Experimental Farms[4] found artichokes economical and slightly more valuable than potatoes. Altho long grown in a small way and often extolled, no extended feeding trials have yet been made with artichokes, nor does their use by feeders seem to increase. (**274**)

877. Sweet potatoes.—Trials at several southern stations show that swine do not relish the sweet potato as they do peanuts and chufas, which crops can usually be grown instead to greater advantage. Newman and Pickett of the South Carolina Station[5] found that it required over 500 lbs. of sweet potatoes, when fed alone, to equal 100 lbs. of corn. Duggar of the Alabama Station,[6] allowing pigs to harvest sweet potatoes at will, secured 100 lbs. of gain by feeding 313 lbs. of grain additional, thereby saving about 200 lbs. of grain for each 100 lbs. of increase while fattening. Duggar states that it is probably advisable to give pigs feeding on sweet potatoes protein-rich feeds, such as cowpeas and peanuts, in addition. (**288**)

878. Peanuts.—At the Alabama Station[7] Gray, Duggar, and Ridgeway fed 3 lots of 61-lb. pigs for 60 days upon the rations shown in the table on the next page, to determine the value of peanuts in supplementing corn for fattening pigs.

The table shows that pigs fed 3.8 lbs. corn gained only 0.7 lb. daily, while those getting 1.6 lbs. of corn daily and foraging in the peanut field gained 0.9 lb. Lot III, fed 2 parts corn and 1 part cotton-seed meal while in the peanut field, made slightly larger gains than Lot II on corn and peanuts. It was found that 1 acre of good peanuts was equal to about 3,200 lbs. of corn in feeding value. When a legume crop like peanuts is foraged by pigs, the

[1] Bul. 57.
[2] Bul. 54.
[3] Bul. 29.
[4] Bul. 51.
[5] Bul. 52.
[6] Bul. 122.
[7] Bul. 143.

increased fertility of the land, as measured by the succeeding cotton crop, will more than pay the expense of growing the legume crop. (**291**)

Peanuts as a supplement to corn.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Concentrates	Peanut pasture
	Lbs.	Lbs.	Acres
Lot I			
Corn, 3.8 lbs.	0.7	560	-------
Lot II			
Corn, 1.6 lbs.			
Foraging peanut field	0.9	177	0.12
Lot III			
Corn, 1.1 lbs.			
Cotton-seed meal, 0.5 lb.			
Foraging peanut field	1.0	158	0.08

879. Peanuts and chufas.—At the Arkansas Station[1] Bennett allowed pigs to forage in fields planted to peanuts or chufas with the following results, another lot being fed corn as a check:

One acre of peanuts gave 1,252 lbs. of gain.
One acre of chufas gave 592 lbs. of gain.
One acre of corn gave 436 lbs. of gain.

The pork from the chufas, like that from corn, was dry and firm, while that from the peanuts was soft and oily. Pigs fed peanuts should be finished on corn. (**290**)

880. Pumpkins.—Rommel,[2] summarizing the findings of 3 stations, reports that 273 lbs. of grain, together with 376 lbs. of raw pumpkins, gave 100 lbs. of gain with fattening pigs. When cooked it required 1,150 lbs. of pumpkins and 222 of grain for 100 lbs. of gain. From these data we may conclude that cooking is of no advantage with this vegetable. Cottrell of the Colorado Station[3] states that some Colorado stockmen fatten hogs exclusively on raw squashes. They report favorable returns per acre, with meat of good flavor but having an undesirable yellow color. (**280**)

881. Whole cow's milk.—Scheven[4] found that when unskimmed cow's milk was fed to 12-weeks-old pigs, from 900 to 1,620 lbs. was required to produce 100 lbs. of gain, the average being 1,253 lbs. These figures show that ordinarily one cannot afford to feed unskimmed cow's milk to pigs. (**301**) Beach of the Connecticut (Storrs) Station[5] has shown that cow's milk rich in fat is far from satisfactory as a feed for young pigs. (**123**)

[1] Bul. 54.
[2] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 47.
[3] Bul. 146.
[4] Martiny, Die Milch.
[5] Bul. 31.

882. Skim milk fed alone.—At the Connecticut (Storrs) Station[1] Beach fed 25-lb. pigs on separator skim milk alone and in combination with grain during an 86-day trial with the following results:

Feeding separator skim milk alone and in combination with grain.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Skim milk	Grain
	Lbs.	Lbs.	Lbs.
Lot I, Skim milk, 19.7 lbs.	0.72	2,739	....
Lot II, Skim milk, 17.2 lbs. Grain, 2.2 lbs.	1.28	1,341	168
Lot III, Skim milk, 12.9 lbs. Grain, 3.2 lbs.	1.38	935	233
Lot IV, Grain, 2.1 lbs.	0.47	....	445

This trial shows the great loss from feeding even young pigs entirely on skim milk, for when so fed they required over 2,700 lbs. of milk for 100 lbs. of gain. By feeding meal with the milk far more rapid and economical gains were made. Skim milk, rich in protein and mineral matter, should always be combined with starchy carbohydrates, such as corn, barley, kafir, milo, etc., in which case it becomes one of the most useful of all available feeds for the pig. (**302**)

883. Meal value of separator skim milk.—Fjord at the Copenhagen (Denmark) Station,[2] Grisdale at the Ottawa Experimental Farms,[3] Linfield at the Utah Station,[4] and the author at the Wisconsin Station,[5] found the average feeding value of separator skim milk, when given in combination with corn meal or meal of the mixed grains, to be as follows:

The Copenhagen (Denmark) Experiment Station	600 pounds
The Ottawa (Canada) Experimental Farms	604 pounds
The Utah Experiment Station	495 pounds
The Wisconsin Experiment Station	475 pounds

The Wisconsin trials were usually with quite young pigs, thereby giving a higher value to the milk than would have been obtained with older animals. It is shown that, when properly combined with concentrates, from 500 to 600 lbs. of separator skim milk has a feeding value for pigs equal to 100 lbs. of corn meal or mixed meal.

884. Proper ratio of milk to meal.—At the Wisconsin Station[6] the author conducted 19 feeding trials with 88 pigs of all ages to determine the value of separator skim milk when fed in combination with varying amounts of corn meal. For convenience the results are arranged in groups, the first comprising trials in which not over

[1] Bul. 39.
[2] Rpt. 10, 1887.
[3] Bul. 33.
[4] Bul. 94.
[5] Rpt. 1895.
[6] Rpt. 1895.

3 lbs. of skim milk were fed with 1 lb. of corn meal, the second where from 3 to 5 lbs. were given to 1 lb. of corn meal, etc. The quantity of meal and milk required for 100 lbs. of gain follows:

Separator skim milk and corn meal required for 100 lbs. of gain.

Ratio of milk to meal	Feed for 100 lbs. gain	
	Meal	Milk
When feeding	Lbs.	Lbs.
1 lb. corn meal with 1 to 3 lbs. skim milk	321	585
1 lb. corn meal with 3 to 5 lbs. skim milk	265	1,048
1 lb. corn meal with 5 to 7 lbs. skim milk	250	1,434
1 lb. corn meal with 7 to 9 lbs. skim milk	207	1,616

Assuming that 500 lbs. of corn meal fed alone would have produced 100 lbs. of gain with these pigs, we derive the following from the above data:

When feeding with each pound of meal	Milk required to save 100 lbs. of corn meal
From 1 to 3 pounds skim milk	327 pounds
From 3 to 5 pounds skim milk	446 pounds
From 5 to 7 pounds skim milk	574 pounds
From 7 to 9 pounds skim milk	552 pounds
Average	475 pounds

The above brings out plainly the important fact that not over 300 lbs. of skim milk should be fed with each 100 lbs. of corn meal, for if more is given much of its feeding value is lost.

885. Money value of skim milk.—The feeder desirous of knowing the money value of skim milk compared with corn at varying prices will gain help from the following table derived from the previous study:

Money value of 100 lbs. of skim milk.

	When 1 lb. of meal is fed		Average of all trials
	With 1 to 3 lbs. of milk	With 7 to 9 lbs. of milk	
When corn is worth	Cents	Cents	Cents
$16 per ton or 44.8 cents per bushel	24	15	17
18 per ton or 50.4 cents per bushel	28	16	19
20 per ton or 56.0 cents per bushel	31	18	21
30 per ton or 84.0 cents per bushel	46	27	32

The table shows that when corn is worth $16 per ton, or 44.8 cents per bu. of 56 lbs., separator skim milk has a value of 24 cents per 100 lbs., provided not over 3 lbs. of skim milk is fed with each lb.

of corn. Should the feeder give as much as 7 to 9 lbs. of skim milk with each lb. of corn, then the milk is worth but 15 cents per 100 lbs.

The above measures in a general way the value of skim milk when combined with corn for fattening pigs. Those familiar with this feeding stuff and its worth for bone and muscle building know that in many cases, especially for young pigs and brood sows, its value is much higher than stated.

A rule by Hoard for finding the money value of skim milk when fed to fattening hogs is in substance:

> To find the value of 100 lbs. of skim milk when fed alone, multiply the market price of live hogs in cents per lb. by 5; if fed in combination with corn or barley, multiply by 6.

According to this rule, when live hogs are worth 5 cents per lb., each 100 lbs. of milk is worth 25 cents when fed alone, and 30 cents when fed with corn or barley meal.

The Gurler rule proposed many years ago is:

> The value of 100 lbs. of skim milk when fed along with corn to fattening hogs is half the market price of corn per bushel.

By this rule, when corn is worth 50 cents per bu., skim milk is worth 25 cents per 100 lbs. for fattening hogs, if combined with corn or some other suitable grain.

Clinton of the New York Station[1] recommends that, in starting pigs on a ration containing a large quantity of skim milk, care be exercised lest at first the pigs be overfed.

Cooke of the Vermont Station[2] found that pigs fed sour skim milk were more thrifty than those getting sweet skim milk. This is in accord with Day's findings at the Ontario Station[3] with sweet and sour whey.

886. Buttermilk.—At the Massachusetts Station[4] Goessmann fed lots of 3 pigs averaging 48 lbs. each on buttermilk or skim milk in combination with corn meal with the results shown in the table:

Buttermilk compared with skim milk.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Corn meal	Milk
	Lbs.	Lbs.	Lbs.
Lot I, Buttermilk, 22.7 lbs. Corn meal, 1.9 lbs.	1.7	116	1,351
Lot II, Skim milk, 23.3 lbs. Corn meal, 1.9 lbs.	1.7	115	1,390

[1] Bul. 199. [2] Rpt. 1891. [3] Rpt. 1897. [4] Rpt. 1884.

This trial supports the general experience that, where no water has been added, buttermilk is fully equal to skim milk for pig feeding.

887. Whey.—In pig-feeding trials by Day at the Ontario Agricultural College[1] and by the author at the Wisconsin Station[2] whey fed in combination with meal of the mixed grains gave the following returns:

481 lbs. of mixed grain when fed alone produced 100 lbs. of gain
303 lbs. of mixed grain with 1,398 lbs. of whey produced 100 lbs. gain

Since 1,398 lbs. of whey saved 178 lbs. of grain, 785 lbs. of whey was equal to 100 lbs. of grain. The whey used in the Wisconsin trials was richer in fat than the average. Fjord of the Copenhagen (Denmark) Station[3] estimates that for swine feeding in Denmark, where the whey is poorer than with us, 1,200 lbs. is equal to 100 lbs. of mixed grain. From the above we may conclude that, when properly combined with corn and barley meal, 1,000 lbs. of ordinary whey is worth 100 lbs. of corn meal for fattening swine. Accordingly, whey is worth about half as much as skim milk for pig feeding.

Day,[4] after studying the relative merits of sweet and sour whey and taking into consideration the health of the animals, their gains, and the quality of their flesh, states that the first slight fermentation which whey undergoes does not seriously detract from its value for pig feeding. Day[5] further found that ordinary whey was worth from 25 to 30 per ct. more than separated whey. (**304**)

888. Tankage, meat meal.—At the Nebraska Station[6] Burnett fed 3 lots, each of 10 pigs, on alfalfa pasture for 56 days to test the value of tankage for supplementing corn. Plumb and Van Norman of the Indiana Station[7] fed tankage to 3 lots of 4 pigs each for 127 days, and Kennedy and Robbins of the Iowa Station[8] conducted a similar trial with meat meal, feeding 4 lots of 12 pigs each for 100 days. These various trials are summarized on the next page.

In the Nebraska trial the gains of the pigs fed tankage were larger and more economical than of those fed soaked corn only. Where the pigs were on alfalfa pasture, the ration containing 5 per ct. of tankage produced as large gains as that containing twice that amount. In the Indiana trial the ration containing 9 per ct. tankage produced larger and more economical gains than the one containing 13 per ct. In this trial 100 lbs. of tankage, when forming 9

[1] Rpt. 1896.
[2] Rpt. 1891.
[3] Rpt. 1887.
[4] Ontario Agr. Col., Rpt. 1897.
[5] Loc. cit., Rpt. 1909.
[6] Bul. 94.
[7] Bul. 90.
[8] Bul. 91.

per ct. of the ration, replaced 555 lbs. of corn. In the Iowa trial the ration containing 9 per ct. meat meal produced the largest gains, 100 lbs. of the meat meal replacing 359 lbs. of corn. Owing to their high price not over 9 or 10 per ct. of tankage or meat meal should be added to the ration, and 5 per ct. would suffice where the pigs are on alfalfa or clover pasture.

Tankage and meat meal as supplements to corn.

Average ration	Supplement fed	Av. wt. at beginning	Av. daily gain	Feed for 100 lbs. gain
	Per ct.	Lbs.	Lbs.	Lbs.
Nebraska Station				
Lot I, Soaked corn, 5.2 lbs.	0	145	1.3	416
Lot II, Tankage, 0.3 lb. Soaked corn, 5.3 lbs.	5	144	1.5	371
Lot III, Tankage, 0.6 lb. Soaked corn, 5.0 lbs.	10	144	1.5	366
Indiana Station				
Lot I, Corn meal, 3.5 lbs.	0	64	0.7	520
Lot II, Tankage, 0.4 lb. Corn meal, 3.9 lbs.	9	66	1.2	370
Lot III, Tankage, 0.7 lb. Corn meal, 3.9 lbs.	17	65	1.2	378
Iowa Station				
Lot I, Corn meal, 6.5 lbs.	0	135	1.2	557
Lot II, Meat meal, 0.8 lb. Corn meal, 7.6 lbs.	9	137	1.9	451
Lot III, Meat meal, 0.9 lb. Corn meal, 7.3 lbs.	11	140	1.7	457
Lot IV, Meat meal, 1.0 lb. Corn meal, 6.7 lbs.	13	136	1.8	436

Carlyle of the Wisconsin Station[1] found that 152-lb. pigs fed corn and beef meal had thigh bones that broke at a strain of 1,200 lbs., or 8 times the body weight, while others weighing 192 lbs., fed corn and heavy wheat shorts, gave bones breaking at 835 lbs., or but 4 times the body weight.

Day of the Ontario Agricultural College[2] found tankage at $33 per ton more economical as a supplement to grain for pigs than skim milk at 15 cents per 100 lbs. Blood meal produced nearly as large gains as tankage. Day states that since blood meal is an exceedingly concentrated food it must be fed in small amount and with care to avoid injurious results. **(306, 920)**

889. Tankage v. linseed meal.—At the Indiana Station[3] Skinner and Cochel, in 3 trials averaging 57 days, compared tankage and linseed meal as supplements to corn meal with a total of 43 pigs, averaging 164 lbs. in weight. Since tankage contains almost twice as much digestible crude protein as linseed meal, only half as much of the former was fed.

[1] Bul. 104. [2] Rpt. 1905. [3] Bul. 126.

The table shows that when fed with corn 0.3 lb. tankage produced slightly larger and more economical gains for feed consumed than twice as much linseed meal.

Tankage compared with linseed meal as supplements to corn.

Average ration	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, Corn, 6.0 lbs. Tankage, 0.3 lb.	1.6	94	381
Lot II, Corn, 5.5 lbs. Linseed meal, 0.6 lb.	1.5	89	394

890. Tankage for pigs following corn-fed steers.—At the Ohio Station[1] Carmichael placed one 108-lb. pig with each 2 steers fattening on a ration composed mostly of corn. The corn voided by the steers was ample for the pigs, not all being consumed. Half of the pigs were each given one-third of a pound of tankage daily. The pigs on droppings alone gained 1 lb. each daily, and those getting tankage in addition, 1.5 lbs. For each 100 lbs. of tankage fed, the pigs made 162 lbs. of extra gain.

891. Blood meal v. skim milk.—In experiments at the Virginia Station[2] Quick and Spencer found blood meal and skim milk about equal in value as supplements to corn, when fed on the basis of equal pounds of protein. Blood meal at $3 per 100 lbs. was as valuable as skim milk at 25 cents per 100 lbs. It was found necessary to mix blood meal with about its own weight of wheat middlings in order that the pigs would relish it.

892. Ground bone.—At the Nebraska Station[3] during each of 2 years Burnett fed 4 lots, each of four 79-lb. pigs, for 137 days to determine the value of wheat shorts, tankage, and steamed ground bone as supplements to corn meal. The breaking strength of the right and left femur, tibia, humerus, radius, and ulna of the legs of each pig was determined at the close of the trial. During the first 5 weeks of the first trial and the first 12 weeks of the second. all lots were on alfalfa pasture.

Ground bone and tankage as supplements to corn.

Average ration	Av. daily gain	Concentrates for 100 lbs. gain	Av. breaking strength of bones
	Lbs.	Lbs.	Lbs.
Lot I, Corn, 5.0 lbs.	1.0	511	303
Lot II, Shorts, 1.3 lbs. Corn, 3.7 lbs.	1.0	491	354
Lot III, Tankage, 0.5 lb. Corn, 4.5 lbs.	1.1	456	497
Lot IV, Ground bone, 0.5 lb. Corn, 4.5 lbs.	1.0	507	575

[1] Cir. 73. [2] Bul. 176. [3] Bul. 107.

Due to the alfalfa pasture, the lot on corn alone made satisfactory and economical gains. The pigs receiving ground bone in addition to the corn required about the same amount of concentrates for 100 lbs. of gain as those fed corn alone, but had the strongest bones of any. Shorts strengthened the bones somewhat, and tankage with corn produced much stronger bones than corn alone. (**90**)

893. Proprietary stock foods.—At the Ottawa Experimental Farms[1] Grisdale fed groups of 4 pigs, ranging in weight from 45 to 75 lbs. each, for 90 days to test the value of certain proprietary stock foods when added to a mixture of half shorts and half mixed ground grains—peas, oats, and barley. The results of the trial are shown below:

Value of proprietary stock foods in pork production.

Average ration	Av. daily gain	Feed for 100 lbs. gain		Cost of 100 lbs. gain
		Meal	Other feed	
	Lbs.	Lbs.	Lbs.	Dollars
Lot I				
Mixed meal, 5.2 lbs.	1.2	438	--------	4.38
Lot II				
Mixed meal, 4.3 lbs.				
Anglo-Saxon stock food, 0.22 lb.	1.0	432	22	6.52
Lot III				
Mixed meal, 4.0 lbs.				
International stock food, 0.12 lb.	0.9	437	12	6.17
Lot IV				
Mixed meal, 4.9 lbs.				
Herbageum, 0.13 lb.	1.3	393	10	5.15
Lot V				
Mixed meal, 3.5 lbs.				
Sour skim milk, 3.7 lbs.	1.2	295	309	3.42
Lot VI				
Mixed meal, 4.8 lbs.				
Clover and rape pasture	1.2	421	Pasture	4.21

Of those receiving stock food, only Lot IV, fed herbageum, made larger gains than Lot I, fed a straight meal ration. Valuing the mixed meal at $1, skim milk at 15 cents per 100 lbs., and the stock foods at market prices, the lots receiving stock food made more expensive gains than Lot I. Skim milk at 15 cents per 100 lbs. lowered the gain-cost materially, and clover and rape pasture to a less degree. In this trial the stock food was added to a palatable, well-balanced ration of mixed grains.

Michaels and Kennedy of the Iowa Station[2] conducted trials with pigs fed corn, with and without some proprietary stock food

[1] Rpt. 1904.

[2] Bul. 113.

additional, to ascertain whether the stock food aided in digesting the corn. At the same time other pigs were fed corn in a practical way, some getting stock food additional and others getting none. Three proprietary stock foods were used, viz.: International, Iowa, and Standard. The conclusions were that stock foods did not have any beneficial effect on the digestion, and that a bushel of corn produced as much or more pork when corn was fed alone than it did when stock foods were added to it. (**343, 445**)

IV. Pasture; Rape; Soilage; Hay; Silage.

894. Mixed pasture.—The results of trials extending over 12 years at the Utah Station[1] to determine the value of pasture consisting of alfalfa and mixed grasses, principally the former, for pigs averaging from 60 to 75 lbs. each at the beginning, are summarized below:

Value of pasture for fattening pigs.

	No. of pigs	Av. daily gain	Grain for 100 lbs. gain
		Lbs.	Lbs.
Full grain ration, in pens	74	0.9	484
Full grain ration, on pasture	20	1.2	413
Three-fourths grain ration, on pasture	17	1.0	383
One-half grain ration, on pasture	16	0.7	304
One-fourth grain ration, on pasture	10	0.5	247
Pasture only	19	0.2	
Green alfalfa only, in pens	2	0.3*	

*Loss.

We learn that the pigs on a full grain ration in pens gained 0.9 lb. each daily and required 484 lbs. of grain for 100 lbs. of gain, while those getting a full grain ration on pasture gained 1.2 lbs. each daily, pasturage effecting a saving of about 15 per ct. in the grain required to produce 100 lbs. gain. The pastured pigs getting a limited grain ration ate less grain for each 100 lbs. of gain than when fed a full grain ration, but also made smaller daily gains, the fattening period being thereby lengthened. If the full grain ration on pasture would have fattened pigs in 100 days, the quarter grain ration would have required 245 days.

Linfield states[2] that pigs fed a limited grain ration on pasture, when later put on full feed, made rapid gains at slightly less cost than those fed a full ration from the start. Hence, for growing pigs to be fattened later, a part grain ration on pasture is an econom-

[1] Bul. 94.

[2] Loc. cit.

ical way of carrying them over summer. Pasture alone did not furnish a satisfactory ration for pigs, since it but little more than maintained them. Pigs lost in weight when fed green alfalfa in pens, and pigs fed skim milk and grain gained nothing from pasture. Grazing stimulates the appetites of pigs getting grain but no milk, and hence they eat more grain and make larger and more economical gains.

Lloyd of the Mississippi Station[1] found that alfalfa pasture alone furnished little more than a maintenance ration for pigs, and the studies of Morrow and Bone of the Oklahoma Station[2] confirm this conclusion. Snyder of the Nebraska Station[3] found that during a period of 70 days, mature hogs, thin in flesh, gained about 0.5 lb. daily on alfalfa pasture without grain. Hitchcock,[4] referring to the conditions west of the Mississippi river, states that there is no danger of bloat from alfalfa pasture, and that a limited number of pigs work no serious injury to the alfalfa field. A well-set, vigorous field will carry from 15 to 25 pigs per acre. The number should never be large enough to keep down growth, but it should be necessary to cut the hay at intervals, so that the plants may be rejuvenated. **(246)**

895. Alfalfa and rape pasture.—In a feeding trial with pigs at the Kansas Station[5] Otis supplemented alfalfa and rape pasture with a full grain ration. Thirty 52-lb. shotes were divided into 3 lots of 10 each. One lot was pen-fed while the others ranged on alfalfa or rape pasture, the trial lasting 98 days:

Pasturing pigs on rape and alfalfa.

Feed	Area pastured	Av. daily gain	Grain for 100 lbs. gain
	Acres	Lbs.	Lbs.
Lot I, Grain only		1.04	372
Lot II, Grain and rape pasture	1.0	1.09	302
Lot III, Grain and alfalfa pasture	0.5	1.10	301

The 3 lots made nearly equal daily gains. Rape and alfalfa produced 100 lbs. of gain with practically the same grain allowance, and either feed when combined with grain gave better results than grain alone. One acre of alfalfa proved equal to 2 acres of rape. Snyder of the Nebraska Station[6] found that, after their pigs were weaned, 260-lb. brood sows, fed 8.5 lbs. each of shelled corn daily and grazing on alfalfa pasture, made 8 per ct. larger gains than others fed 11 lbs. of shelled corn each daily in dry lots—

[1] Rpt. 1905.
[2] Rpt. 1899.
[3] Bul. 99.
[4] Farmers' Bul. 214, U. S. Dept. Agr.
[5] Bul. 124.
[6] Bul. 99.

a saving of 43 per ct. in the amount of grain for 100 lbs. of gain, due to the alfalfa pasture. (**282**)

896. Feeding corn on alfalfa pasture.—Snyder of the Nebraska Station[1] grazed 3 lots of 47-lb. pigs on alfalfa pasture during each of 2 summers. One lot received a light, the second a medium, and the third a full allowance of shelled corn. The combined results of the trials, lasting 98 and 119 days respectively, are averaged below:

Light, medium, and heavy corn feeding on alfalfa pasture.

Daily allowance of corn	Av. daily gain	Corn for 100 lbs. gain
	Lbs.	Lbs.
Lot I, Shelled corn, 0.5 lb.	0.4	128
Lot II, Shelled corn, 1.1 lbs.	0.5	221
Lot III, Shelled corn, 2.6 lbs.	0.8	331

It is shown that Lot I, fed a light grain allowance on alfalfa pasture, required only 39 per ct. as much grain for 100 lbs. gain as Lot III, fed a full corn allowance. Lot III, however, made twice as rapid gains as Lot I. Snyder concludes that a light grain allowance on alfalfa pasture is not economical for growing pigs unless alfalfa is abundant, grain high in price, and market conditions warrant holding the pigs. It is usually more profitable to feed 2 lbs. or more of corn per 100 lbs. of pigs than to feed a lighter ration. Cottrell of the Colorado Station[2] states that alfalfa makes the best hog pasture, and that hogs fed some grain daily will make from 500 to 1,000 lbs. of gain during the pasture season from an acre of good alfalfa, after deducting the gain which the grain would make if fed alone.

897. Cowpea pasture.—Duggar of the Alabama Station[3] placed three 50-lb. pigs in a field of cowpeas, giving corn additional, while a second lot was fed corn only. The trial lasted 42 days with the results shown in the table:

Feeding corn to pigs ranging in cowpea field.

Feed given	Av. daily gain	Corn for 100 lbs. gain
	Lbs.	Lbs.
Lot I, Corn alone in a dry lot	0.4	586
Lot II, Cowpea pasture and corn	1.0	307

[1] Bul. 99. [2] Bul. 146. [3] Bul. 93.

It will be seen that the pigs ranging in the cowpea field gained nearly 3 times as fast as those getting corn alone in the dry lot. The area grazed by the pigs equaled one-sixth of an acre and the yield of peas was estimated at 13.2 bushels per acre. In this trial the seed of the cowpeas must have furnished most of the nutriment, and the leaves but little. (**261**)

898. Soybean pasture.—At the Alabama Station[1] Gray, Duggar, and Ridgeway fed 2 lots, each of 6 pigs averaging 75 lbs., for 35 days on the following rations to determine the value of soybean pasture as a supplement to corn:

Soybean pasture as a supplement to corn.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Corn	Pasture
	Lbs.	Lbs.	Acres
Lot I, Corn, 3.7 lbs.	0.8	456	
Lot II, Corn, 1.6 lbs. Soybean pasture	1.0	157	0.28

The pigs on soybean pasture made 25 per ct. greater gains than those fed corn alone, and required only 157 lbs. corn for 100 lbs. of gain. In this trial 1 acre of poor soybean pasture proved equal to 1,068 lbs. of corn. When one considers the small amount of corn required for 100 lbs. of gain, the great value of the soybean crop for pork production is shown. It is probable that the soybean seeds furnished most of the nutriment supplied by the pasturage. (**201**)

899. Rape v. clover pasture.—At the Wisconsin Station[2] in 60-day trials during each of 2 years, Carlyle hurdled one lot of 104-lb. pigs on rape with access to a blue-grass pasture, while others grazed in a field of second-growth clover. Both lots were fed a mixture of 2 parts corn meal and 1 part shorts with the results given below:

Rape pasture compared with clover pasture.

	Daily conc. allowance	Av. daily gain	Concentrates for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I, On rape pasture	3.7	1.1	362
Lot II, On clover pasture	3.7	1.0	390

The pigs in Lot I grazing on rape made somewhat larger daily gains and required less corn for 100 lbs. of gain than those on

[1] Bul. 143.

[2] Rpt. 1901.

clover. From numerous trials Carlyle concludes that with pigs from 4 to 10 months old an acre of good rape has a feeding value equal to 2,436 lbs. of mixed corn meal and wheat shorts, when grazed in combination with those feeds.

At the Oregon Station[1] an acre of rape pasture with no grain produced 154 lbs. of gain with pigs. Grisdale of the Ottawa Experimental Farms[2] pastured 60 pigs that finally reached an average weight of 185 lbs. each on 1.5 acres of rape, feeding in addition thereto about 500 lbs. of grain to each pig. At the Alabama Station[3] 1 lot of pigs pastured on rape in summer and another lot pastured in winter required about 300 lbs. of concentrates in addition to the rape for 100 lbs. of gain, showing that the rape saved about 200 lbs. of grain for each 100 lbs. of gain made. (**254, 282**)

900. Forage crops at the South.—Bennett of the Arkansas Station[4] pastured pigs on red clover, sorghum stalks and seed, and peanuts. A sow and 5 suckling pigs were placed in a clover pasture on March 30. On May 13 the sow was removed from the trial. The pigs fed on the clover and sorghum until September 21, when they were turned into a peanut field. On December 2 they were put on corn, remaining on this feed until January 3, when the trial was closed. During the trial the pigs made a total gain of about 1,200 lbs., and grazed 0.25 acre of clover, 0.25 acre of sorghum, and 0.60 acre of peanuts—a total of 1.10 acres.

During this time the following amounts of concentrates were consumed:

By sow before weaning pigs	518 lbs. corn and 67 lbs. bran
By pigs while grazing	280 lbs. corn and 31 lbs. bran
By pigs while fattening	1,064 lbs. corn
Total additional feed given	1,862 lbs. corn, 98 lbs. bran

Allowing 400 lbs. of gain for the corn fed in this trial, there remains 800 lbs. of gain to be credited to the 1.1 acre of clover, sorghum, and peanuts. Such data should go far toward stimulating profitable pork production in a vast region of the South now but little devoted to that industry. (**202, 222**)

901. Soilage.—At the Missouri Station[5] Waters fed 4 lots, each of 6 high-grade 48-lb. Poland-China pigs, the ration shown on the next page, for 102 days to determine the value of various green supplements to corn. The fresh-cut green forage was fed twice daily.

It is shown that Lot II, fed green alfalfa, required the least concentrates for 100 lbs. gain, Lot III, fed clover, following close.

[1] Bul. 89. [2] Bul. 51. [3] Bul. 122. [4] Bul. 41. [5] Bul. 79.

Lot IV, fed blue grass, made poorer gains and required more concentrates for 100 lbs. gain than Lot I, fed corn meal and middlings, showing that blue-grass stems and leaves are a poor supplement to corn. In this trial 100 lbs. of concentrates was replaced by 78 lbs. of green alfalfa or 112 lbs. of green clover. The importance of correct supplements and their great value in pig feeding is well brought out in this trial. (**326, 330**)

Various soilage crops compared.

Average ration		Av. daily gain	Feed for 100 lbs. gain	
			Concentrates	Soilage
		Lbs.	Lbs.	Lbs.
Lot I, Middlings, 1.4 lbs.	Corn meal, 2.1 lbs.	0.7	518	--------
Lot II, Green alfalfa, 0.8 lb.	Corn meal, 3.3 lbs.	0.8	401	91
Lot III, Green clover, 0.7 lb.	Corn meal, 3.3 lbs.	0.8	435	93
Lot IV, Green blue-grass, 0.7 lb.	Corn meal, 3.4 lbs.	0.6	531	113

902. Clover hay.—At the Montana Station[1] Linfield conducted 2 trials with 90-lb. pigs to determine the value of clover hay as a supplement to a mixture of 2 parts ground barley and 1 part wheat bran. The results of the trials, lasting 81 and 98 days respectively, are averaged below:

Clover hay as a supplement to mixed grains.

Average ration	Av. daily gain	Feed for 100 lbs. gain	
		Concentrates	Hay
Lot I	Lbs.	Lbs.	Lbs.
Concentrates, 4.9 lbs.	0.9	529	------
Lot II			
Concentrates, 4.9 lbs.			
Clover hay, 1.0 lb.	1.0	487	101

It is shown that pigs receiving 1 lb. of clover hay daily required 7 per ct. less concentrates for 100 lbs. gain than those fed a mixture of ground barley and wheat bran alone. In this trial 100 lbs. of clover hay properly fed with concentrates was equal to 42 lbs. of mixed barley and bran. (**254**) The prudent stockman, endeavoring to maintain the health and vigor of his herd and at the same time economize on expensive concentrates, will always provide a store of the choicest early-cut clover hay or other legume roughage to feed all classes of animals, from small pigs to grown brood sows.

903. Alfalfa hay.—At the Nebraska Station[2] Smith fed 8 lots, each of seven 85-lb. pigs, for 84 days on corn meal combined with

[1] Bul. 57. [2] Press Bul. No. 20.

either wheat bran, wheat shorts, or alfalfa hay as shown in the following table:

Measuring the value of alfalfa hay.

Feed given	Av. daily gain	Av. total gain	Feed for 100 lbs. gain
	Lbs.	Lbs.	Lbs.
Lot I			
Corn meal only	1.0	86	496
Lot II			
Corn meal 3 parts, wheat bran 1 part	0.8	67	589
Lot III			
Corn meal 3 parts, wheat shorts 1 part	1.1	92	466
Lot IV			
Corn meal 3 parts, cut alfalfa hay 1 part	1.1	90	477
Lot V			
Corn meal 3 parts, ground alfalfa hay 2 parts	1.1	89	481
Lot VI			
Corn meal 2 parts, wheat shorts 2 parts	0.9	76	548
Lot VII			
Corn meal 2 parts, cut alfalfa hay 2 parts	0.9	78	544
Lot VIII			
Corn meal 2 parts, ground alfalfa hay 2 parts	0.9	75	566

The table shows the great value for swine fattening of alfalfa hay when rightly combined with corn. When the ration consisted of one-fourth alfalfa hay, that amount of hay was worth its weight of corn meal and was superior to the same weight of wheat bran. When alfalfa hay formed half the ration the returns were less satisfactory, showing that too much roughage was being fed. Ground alfalfa hay showed no superiority over cut hay. The farmer desirous of reducing the cost of producing pork should carefully study this experiment.

In a trial at the same Station[1] Snyder found that, when forming one-fourth of the ration, 100 lbs. of alfalfa hay, cut and mixed with corn meal and fed wet in troughs, saved 20 per ct. and the same amount of uncut alfalfa hay 7 per ct. of the grain required for 100 lbs. gain when no hay was fed. In view of the cost of grinding corn and cutting hay Snyder concludes that it is usually best to feed third-crop alfalfa hay uncut in racks, with shelled or ear corn additional.

Hoard[2] states that for years his brood sows have been wintered on third cutting alfalfa hay with a little skim milk and no grain until about 2 weeks before farrowing. Sows so maintained keep in good flesh, bear fine litters of strong, healthy pigs, and give an abundance of milk. (**245**)

[1] Bul. 99.

[2] Rpt. Wis. Dairymen's Ass'n, 1905.

904. Silage.—May of the Kentucky Station[1] found that hogs receiving shelled corn and corn-and-soybean silage made larger gains than those fed shelled corn alone, 100 lbs. of silage equaling 22 lbs. of corn in feeding value. The pigs first picked out the grain in the silage and then chewed the remainder, tho swallowing but little of it. At the Ottawa Experimental Farms[2] clover and alfalfa silage invariably proved useful, and corn silage was fairly well eaten. The addition of some dry meal to the silage caused it to be eaten quite readily. Clover, alfalfa, or other legume hay should generally prove more satisfactory than silage of any kind. Silage from the corn plant is both too woody and too low in digestible matter to serve with any satisfaction as a feed for swine that are being properly maintained. If shotes and breeding stock live on a limited allowance of rich concentrates alone, they will suffer for lack of proper bulk in the ration. For such pigs, silage, and even corn silage, will be helpful in distending the digestive tract.

[1] Bul. 101. [2] Bul. 51.

CHAPTER XXXIII.

MANAGEMENT AND FEED OF SWINE—HOME MARKETS AND BACON PRODUCTION.

I. Care and Management.

The digestive organs of the pig, with the contents, comprise but 7.5 per ct. and those of the ox over 14 per ct. of the total weight of the body. (**28**) The horse, ox, and sheep are normally herbivorous, living on the finer and more delicate portions of plants and their seeds, while the omnivorous pig feeds not only on the tender leaves, stems, roots, and seeds, but on animal matter as well. Because of the limited capacity of the stomach and the nature of its digestive apparatus the pig requires food that is more concentrated and digestible and less woody than that of the other large farm animals. Not only is the pig an omnivorous feeder, but in nature it lives close to the earth, gathering some of its food from beneath the surface and swallowing considerable earthy matter in doing so. The intelligent swine feeder takes cognizance of all such facts and is helped by them in managing his herd.

905. Summer care of swine.—Breeding stock should live all summer in the open on uncontaminated soil, grazing on succulent pastures in order to develop bone, muscle, and constitution. The grasses do not provide a satisfactory pasture for swine. Far better are rape and the legumes—clover, alfalfa, vetch, etc. While the pig can barely subsist on grass alone, the legumes and rape will somewhat more than sustain life and so leave for producing increase all the extra feed which may be supplied. (**894-901**) In addition to good legume or rape pasture there should be fed a proper allowance of muscle- and bone-building feeds, such as wheat middlings, bran, soybeans, cowpeas, linseed oil meal, tankage, dairy by-products, etc. These need not, however, constitute over one-third of the feed supplied. The remainder, carbohydrate in character and cheaper in price, should consist of corn, barley, kafir, milo, emmer, etc. The daily concentrate allowance should be sufficient to keep the pigs thrifty and gaining, but in no case so abundant as to make them lazy and shiftless, for pigs, if heavily fed, do little foraging, but lie idly in the shade. Observation will soon determine the quantity of feed which will keep pigs gaining normally while actively foraging to appease their hunger.

Boars and brood sows of the larger breeds should reach the weight of about 250 lbs. at one year of age if rightly fed and managed. The feed and care of the boar does not differ from that of the sow. Too often both are closely confined in filthy quarters, away from the wholesome earth, without opportunity for exercise or for gathering food on their own account. Such mismanagement weakens the constitution, and is far more expensive than the simpler and more natural method of keeping all stock from spring until fall away from buildings and feed yards, out in the fields on fresh, uncontaminated soil. Here a little extra feed, with suitable forage and a natural life, makes possible the most economical gains and the healthiest animals.

906. Winter care.—In the northern portion of the corn belt where the winters are long and severe, inexpensive shelter is all that is necessary for swine, unless one chooses otherwise. Small houses, called "cabins," of simple board construction and placed on runners, will each shelter from 6 to 8 shotes or 3 or 4 sows. (**828**) These cabins, located on dry ground, should be moved from time to time to keep everything sanitary and to better scatter the droppings of the animals. Animals quartered in several cabins can be fed at one point where are troughs and a feeding floor. When snow covers the ground, paths can be broken out with a snow plow. In winter, even where the cold is severe, pigs housed in cabins in small colonies and forced to take daily exercise thrive amazingly. If a permanent hog house is desired there should still be abundant exercise at all times for breeding and stock animals.

Breeding stock and shotes should not be heavily fed during winter lest they grow too fat. If rich concentrates only are given and the animals not overfed, the feed allowance will not have enough volume or bulk to properly distend the stomach and intestines, and this leaves the animals unsatisfied, restless, and quarrelsome. To correct this trouble and because such feed is cheap and wholesome, all stock hogs should be daily fed some fine, well cured legume hay or some roots, or better, both hay and roots. If, unfortunately, neither is available, then bran and oats, tho more costly, will be helpful in giving bulk to the ration. The concentrates fed to stock hogs should always be given as a thin, watery slop to help distend the digestive tract at meal time.

Stock hogs that do not otherwise get exercise in winter should be provided with a feeding floor, covered if possible, on which shelled corn and whole oats are thinly scattered so as to force the hogs to pick up a grain at a time to satisfy their hunger. Here too can be placed racks holding legume hay. In this way pigs may be kept out of their beds and on their feet for hours at a time. Young breeding stock and shotes should gain from half to three-fourths of a pound daily in winter, the supply of feed being regulated to that end.

907. At farrowing time.—Sows thin in flesh should have their feed gradually increased so as to be in good condition before farrowing. As this period approaches let the feed be both sloppy and limited in amount. Costiveness, common at this time, should be forestalled by feeding wheat bran, linseed oil meal, roots, or the finer parts of some legume hay, and by keeping the animals out of doors and forcing them to exercise. Kennedy[1] reports that in England sows are commonly given from 4 to 5 oz. of Epsom salts 2 days before farrowing. Nothing but lukewarm water should be given the sow during the 24 hours previous to farrowing unless she shows signs of hunger, in which case a thin, warm slop containing a little ground oats, wheat middlings, or linseed meal may be supplied. The desire of the sow to eat her young shows abnormal feed or care, or both, for such mothers are usually costive and feverish. When trouble is apprehended Bell[2] recommends feeding about 3 lbs. of salt pork, cut in strips. Harbert would apply mucilage containing equal parts of a tincture of aloes and asafetida to the pigs with a sponge as soon as they are dry. Sows do not like this and will let pigs so treated alone. It is far more rational to forestall such possible trouble by enforcing exercise, giving coarse, bulky feeds, and especially in seeing that the bowels move freely and that the sows are not feverish at farrowing time. For three or four days after farrowing feed lightly with skim milk and oat or barley meal, linseed meal, wheat middlings, or bran in the form of a thin slop.

The farrowing place should be comfortable and so sheltered that a deep nest is not necessary to prevent the new-born pigs being chilled, for they may be crushed in a deep, bird-like nest. Long hay or straw is not suitable for bedding, for it may entangle the pigs. Cut straw or hay, chaff, and leaves are satisfactory, pro-

[1] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 77.
[2] Breeder's Gazette, 1907, Vol. 51, p. 535.

vided they are reasonably free from dust. A board or scantling placed about 8 inches from the floor and standing out 8 inches about the sides of the farrowing pen lessens the danger of the mother crushing her young. In the case of heavy, clumsy sows, separate the pigs from the dam by placing them in a chaff-lined box or barrel for a couple of days. Sows properly handled before farrowing will not usually resent such separation. The pigs will then be safe, and the attendant can pass them to the dam for nourishment at short intervals. A chilled pig may be revived by immersion in water as warm as the hand will bear.

908. Care of sow and litter.—Farrowing time over, with the increased flow of milk the ration should be gradually made more liberal. The coarse feeds, so useful at other times, must now largely give way to rich concentrates such as skim milk, heavy flour middlings, ground oats, soybeans, cowpeas, and linseed meal to furnish nitrogenous matter, and corn, barley, kafir, or milo meal in large proportion to furnish the carbohydrates. Water should be liberally added to form a thin slop. Sows with litters should be most liberally fed, for at no other time will feed go so far or give such large returns. (**816**) Good mothers with large litters will usually lose flesh despite the most liberal feeding.

909. Feeding the litters.—When two or three weeks old the unweaned pigs should be encouraged to eat with the mother by providing thin, sloppy food in a shallow, low-set trough. Because the sucklings cannot fully satisfy their hunger by such provision, there should be further provided a separate, low trough which cannot be reached by the dam. For young pigs dairy by-products, in combination with various ground grains and milling by-products, are easily the best of all feeds. For very young pigs there is nothing better among the grains than ground oats with the hulls sieved out and red-dog flour. Corn, barley, kafir, and milo meal, dark feeding flour, flour wheat middlings, and ground emmer with the chaff removed, etc., may all be freely used for sows and pigs as the young things come on. Soaked whole corn thinly scattered over a feeding floor gives feed and enforces exercise. Pigs separately fed before weaning grow faster and draw less on the sow—a matter of importance where the litters are large. The litters are usually weaned at ten weeks, but by properly feeding both dam and young the pigs will gradually wean themselves. Where young sows have large litters or are unable to properly nourish their young it is well to remove and wean the strongest pigs at seven weeks.

910. Exercise for young pigs.—Well-nurtured young pigs often become excessively fat, and may die unless abundant exercise is provided. If sufficient exercise cannot be given, the danger can usually be averted by reducing the feed supply, tho this checks growth. In the absence of more natural exercise the herdsman should turn the pigs out of doors two or three times a day and drive them about the yard. Selle[1] describes a means of exercise for winter pigs as follows: Wagon loads of sods are placed in the cellar in the fall, and in winter these, along with bits of meat scrap or cracklings, are thrown into the pens. In searching for the cracklings the pigs get exercise as well as some feed. On weaning, pigs of the same size should be placed in groups of not over 20. Where large numbers of pigs of varying sizes range together, the weaker ones are at a disadvantage at the feed trough and are liable to permanent injury from lack of feed and rough treatment.

911. Shotes.—In summer shotes should range the pastures, getting part of their nourishment from succulent alfalfa, clover, vetch, or rape, or, if nothing better is at hand, from the grasses. Green herbage of the proper kind will a little more than maintain the animal, leaving available for growth all the feed supplied. Canada peas, cowpeas, soybeans, peanuts, wheat middlings, and all the common grains may be successfully employed in supplementing the pasture. To force shotes to forage the fields for their entire feed is unwise and expensive. They should gain from half to three-fourths pound per day, and sufficient concentrates to produce this gain should be fed. (**815**)

In winter shotes should be liberally fed the finer parts of some legume hay, such as alfalfa or clover, and roots. These are not only the cheapest of feeds so far as they can be used, but they are helpful in developing a roomy digestive tract capable of utilizing a large amount of feed when the fattening period arrives. (**894-903**) Legume hay also furnishes nitrogenous matter and lime, both essentials with these animals. But roughage alone is not sufficient for the growing pig, and therefore such coarse feed should be supplemented with a reasonable supply of rich concentrates containing but little woody fiber. Corn, barley, kafir, milo, and the other cereal grains should be given to furnish heat and lay on fat, while a supply of skim milk, wheat middlings, soybeans, and other nitrogenous feeds will furnish the protein for muscle building.

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[1] Wis. Farmers' Inst., Bul. 1894.

912. The fattening period.—Having developed a strong framework of bone, ample lean-meat tissues, and a roomy, vigorous digestive tract, there now remains the final operation of laying on fat. If the pig has been properly cared for up to this point this is the simplest and easiest part of the whole process. Fattening is best accomplished by restricting the amount of exercise, reducing the allowance of coarse feed, and giving all the palatable carbohydrate-rich concentrates, such as corn, barley, kafir, milo, emmer, etc., the pigs will consume. In the beginning the pigs can still be fed some coarse feed, such as alfalfa, clover, cowpeas, or vetch, green or cured, and at all times rape, roots, middlings, and bran. As fattening progresses exercise should be more and more restricted and the roughage almost entirely eliminated. A limited quantity of nitrogenous feeds such as Canada peas, cowpeas, soybeans, peanuts, linseed meal, wheat middlings, tankage, and dairy by-products are extremely helpful in stimulating the lagging appetite and furnishing the now limited nitrogenous requirement. Nearly all the nutriment should come from the rich, starchy, fat-making feeding stuffs, such as corn, barley, kafir, milo, emmer, etc. If the fattening period is short, only the small grains need be ground, but as the animals grow fat and the digestive system loses in vigor because of confinement and long feeding, all grains should be ground to meal in order that the intake of feed may be as large as possible without cloying. (**822**)

If the shotes have been properly brought forward the fattening period should not exceed eight weeks, unless the animals are to be made unusually fat or there is a rising market which warrants continued feeding. After the first few weeks of heavy feeding more and more feed is required to produce a given gain, and this fact should always be remembered by the feeder. (**830**) All fattening animals should drink water freely, being forced to do so, if necessary, by placing it in their feed. At all times coal ashes, wood ashes, lime, etc., should be accessible, as elsewhere recommended. (**922**) Fattening pigs should be fed twice daily, and possibly three times toward the close of the period when on ground feed and getting little or no roughage.

II. Feeds for Swine.

913. Corn.—Indian corn must continue to be the great fattening food for swine in America, because of the enormous quantities produced and the great potentiality of this starch-bearing grain in fat production. For breeding stock corn should never constitute over half the ration, the proportion fed being smallest with young animals. (**115**) As pigs increase in size and the demand for nitrogenous and mineral matter becomes less, more of this starchy grain can be fed, until at fattening time it may well form most of the ration. Corn should usually be fed whole and on the cob, except to young pigs and those in the last stages of fattening. Where the kernels are hard and cannot be readily chewed, corn should be ground or soaked. (**842-5**)

914. The minor cereals.—Only wheat that is below grade can now be profitably used for swine feeding. The hard, small kernels should always be ground to meal and mixed with corn or barley, since such combinations are superior to either grain fed alone. (**848**) The milling by-products of wheat are most valuable for swine, low-grade or red-dog flour being particularly suitable for very young pigs, while flour middlings serve admirably with all classes, especially in combination with corn. Middlings produce a soft pork if too liberally fed. (**849, 850**) Bran is a muscle-building food, but its chaffy nature renders it unsatisfactory for the young pig. It is eminently useful with breeding stock otherwise living on rich concentrates and in a limited way with fattening swine. Bran is rich in nitrogenous matter and phosphorus, but is low in lime and has laxative properties. These facts should always be in the mind of the feeder. (**165, 852**)

From the European standpoint barley leads the cereals in the quality of the pork it produces, while in the quantity of pork produced it falls slightly below corn. Where high-grade bacon is desired the barley grain will prove particularly useful. In all cases barley should be ground to a meal, or preferably rolled, before it is fed. (**854**) Kafir and milo, both rich in starch, rank below corn for pig feeding, but lead in the regions where they flourish. (**858-9**) Emmer, because of the chaffy hull, and millet, because of its hard, fibrous seed coat, should always be ground and the chaff or hulls removed before feeding to young pigs, while these parts may remain for the older animals if bulk is needed in the ration. (**857, 860**)

915. The legume seeds.—Canada peas, cowpeas, soybeans, and peanuts are rapidly advancing in importance and usefulness for swine feeding. They furnish nitrogenous matter in great abundance, and some carry much fat. While the starchy cereal grains are the great fattening concentrates, the leguminous seeds are essential in furnishing nitrogenous matter for building the muscular tissues and organs of the body. It is of vast import that the pork producer in every section of America can successfully and economically grow at least one of the leguminous forage and grain crops, and therefore is not forced to purchase expensive nitrogenous feeds. No one can study the requirements and possibilities of pork production in this country without realizing that the leguminous plants are destined to occupy a vastly more important position than they hold at present. (**866-870**)

916. The legume roughages.—With the prices of feeding stuffs ruling high, the swine feeder must make the largest possible use of alfalfa, clover, vetch, cowpea, soybean, and other legume pasture in summer, and in winter feed freely of specially cured hay from the legumes in order to have healthy animals and to keep down the cost of production. The finer parts of clover and alfalfa hay, especially the first cutting of clover and the last cutting of alfalfa, are often as valuable for feeding pigs as is the same weight of wheat middlings. The southern planter has a specially choice list of equally valuable legumes in the cowpea, soybean, velvet bean, peanut, etc. Legume hay may be fed to pigs from slatted racks or from open boxes with openings low on the sides from which the animals can eat at will. In special cases it is best to soak the fine portions of legume hay with the swill before feeding. The legume hays not only furnish nitrogenous matter so essential to building all the red meat tissues and organs of the body, but they also carry much lime, which is needed in bone building. They are therefore doubly useful in supplementing Indian corn and other cereals which are rather poor in nitrogenous matter and lime. (**895-904**)

917. Rape.—The rape plant is valuable for pigs of all ages and conditions. The seed is inexpensive, the crop is easily grown under a great variety of conditions, and the pigs do the harvesting. Rape sown at any time from early spring until the middle of July will furnish feed 8 to 10 weeks later or when the plants are 12 inches high. A field of rape will support a drove of swine grazing thereon, so that all the concentrates given will go to the production of gain. The resourceful stockman who has pigs to feed will make large use of the rape plant, in combination with the legumes, in order to reduce feed bills and increase profits. White-haired pigs running in rape when the dew is on sometimes suffer from a skin eruption. The trouble is avoided by keeping them out of the field until the dew rises. (**895, 899**)

918. Root crops.—Danish farmers grow no Indian corn, and yet by means of waste products of the dairy, purchased feeding stuffs, and root crops, mostly beets, they lead the world in the production of pork, both as to quantity and quality. Prices for both grain and pork in this country are now so high that most farmers can profitably grow either mangels or low-grade sugar beets for their pigs. A supply of these will add variety to the ration, reduce the amount of expensive concentrates required, and increase the healthfulness of the animals. Grisdale of the Ottawa Experimental Farms[1] reports sugar beets the most palatable of roots for swine, tho hardly as suitable as mangels and turnips. As high as 25 lbs. per day of mangels have been fed to dry sows or those not far advanced in pregnancy, the allowance being decreased and the meal ration somewhat increased as pregnancy advanced. Pigs that have been fed sugar beets or mangels do not like turnips, but where other roots have not been fed they will prove satisfactory, especially after being cooked with meal. Grisdale states that during October or earlier in the season pigs will economically harvest roots left in the field. (**873**)

919. Importance of legumes, rape, and roots.—If this country is to make any further great advancement in pork production, such progress must come in no small measure thru the wider and more intelligent use of legumes, rape, and roots. Because the hog shows supreme fondness for corn and because that grain is widely and easily grown, we have come to think of corn and the hog as the beginning and end of pork production. It is true we provide meagerly of other feeds, but grudgingly and under protest as it were, regarding anything other than corn as something to be given in small amount rather than liberally. Let us now change the viewpoint and hold that it is not only best but also more economical to grow the pig largely on the legumes, rape, and roots, and use a heavy allowance of corn for fattening only. The feeder who will conduct his operations on this basis will find his pork output greatly increased and his income correspondingly advanced. Instead of measuring the possible pork output by the quantity of corn available, one should figure on what is possible from all the available corn plus the gains that the pigs can make from the freest use of all such crops as alfalfa, clover, Canada peas, soybeans, cowpeas, peanuts, rape, and roots that the farm will economically grow. By the wisest and largest use of these crops thruout the land the amount

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[1] Bul. 51.

of pork now produced in the United States can easily be doubled without any corresponding increase in the total cost of production. The large and general use of the legumes, rape, and roots by those who raise swine means larger litters of pigs, a reduction in the present heavy death rate of the young, and the more rapid growth of sturdy, vigorous shotes that will finally fatten more quickly and on less corn than under the still too common system of well-nigh continuous corn feeding from birth to slaughter.

Growing legumes and roots will so improve the soil that all of the feed from this source which is fed to the pig is produced at small cost. Fields as well as pigs will be benefited by this rational expansion which should rapidly come in our system of pork production thru combining the feeding of legumes and roots with the proper use of corn and the other cereal grains.

920. Tankage.—The slaughter-house by-product, tankage, carries a large percentage of highly digestible protein, and that which contains ground raw bone also carries much phosphorus and lime in addition. This by-product is always helpful in feeding young pigs, especially when little or no dairy waste is available. Where corn is otherwise the sole feed employed in fattening swine, tankage will greatly cut down the feed requirements and induce the more rapid laying on of fat. The feeder should bear in mind the peculiar properties and advantages of tankage and never hesitate to use it when necessary. (**888**)

921. Dairy by-products.—Skim milk and buttermilk are ideal feeds for swine, especially brood sows and growing pigs. Rich in digestible protein and carrying much mineral matter, they should never be fed alone but always in combination with such starchy feeds as corn, barley, kafir, milo, emmer, and millet. This combination stands unexcelled for producing economical growth and for fattening. So useful are these feeds that the breeder of pure-bred swine should in many cases keep a dairy in order to have these by-products for the sows and their young. Skim milk, fresh or slightly soured, combined with any of the cereal grains will give to young pigs quality and finish possible from no other feed. Before skim milk and whey from the factory are returned to the farm they should always be sterilized to forestall danger of tuberculosis. (**881-7**)

922. Correctives of mineral nature.—Pigs often show a strong craving for unnatural substances—soft brick, mortar, rotten wood, charcoal, ashes, soap suds, and many other articles being greedily devoured when offered. The desire for these may often be charged to unnatural conditions, but it shows under a wide range of feed and care. As a rule, the feeder would best supply what the pig craves, and search for explanations later. Ashes from either wood or coal are always helpful in the feeding pen and even in the pasture. Dietrich[1] recommends that salt, charcoal, air-slacked lime, bone meal, and wood ashes be kept in different compartments of a covered trough where they are accessible to the pigs at all times. Ground rock phosphate should be added to the list, since we now know that the pig can utilize the phosphorus and possibly the lime it furnishes for bone building. (**89, 90, 115, 892**)

923. The administration of feed.—Sucking pigs take nourishment from the dam about every two hours, and we should accept Nature's rule in feeding very young animals. Dietrich's experiments[2] lead to the conclusion that young pigs should be fed at least three times daily, giving little less each time than they will readily consume. With large animals getting considerable coarse feed, such as legume hay, rape, or roots, two feeds a day should suffice, since coarse food remains longer in the digestive tract. During the last stages of fattening and when living wholly on finely ground rich concentrates containing little fiber, swine should be fed three times daily.

Since dry meal is more slowly masticated than moistened meal it might be supposed that the greater addition of saliva consequent on slow eating would increase the digestibility of meal so fed, but the trials so far made favor moistening the feed with water. The pig does not take kindly to dry meal, eating it slowly, and often rooting much of it out of the trough. On the whole, sloppy feeds are best. (**824**)

924. Water required by pigs.—Dietrich,[3] who has given the subject much careful study, concludes that the proper water supply for the pig ranges from 12 lbs. daily per 100 lbs. of animal at the time of weaning down to 4 lbs. per 100 lbs. during the fattening period. He holds that pigs do not usually drink enough water in winter, and that they should be forced to take more by giving it, warm if necessary, in their slop. He states that the total quantity of water drank seems to be of greater importance than the manner in which it is fed. The best results have been obtained by feeding the bulk of the water after the rest of the feed has been eaten, using enough water to wet the dry feeds. During the hottest weather

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[1] Swine, p. 161. [2] Loc. cit., p. 194. [3] Loc. cit., p. 156.

Dietrich finds that it seems to be necessary to add somewhat more water to the dry feed. On protein-rich feeds the pig needs more water than when on starchy feeds. (**825**)

III. Home Markets and Bacon Production.

925. Home markets.—With pork consumption increasing more rapidly than production there have sprung up over our land good local markets for all manner of pork products, from the dressed carcass to sausages, hams, bacon, etc. Consumers are calling for leaner pork, and many farmers who are feeding pigs will find it to their advantage to supply the home demand for high-grade pork products. Knowledge of how to grow the pig economically on such roughages as the legume hays, roots, and rape is of great value in producing a high-grade product, especially with eastern farmers, who are unable to produce corn as cheaply as it is grown in the corn belt where the lard hog is still the favorite. Most helpfully, local establishments are springing up where pork products of the highest quality are being manufactured, and the success attained by some of these show that expansion in this direction is possible, as it is also desirable. Since the pig, next to the cow, is the most economical four-footed farm animal for the production of human food, there is every reason to anticipate greatly increased interest in pork production in all the agricultural districts of our country.

926. Danish pork production.—Quality and quantity considered, the Danes lead the world in bacon production. This surprising fact is due to their ability to use wisely dairy by-products, to their spirit of coöperation, and to the high degree of intelligence shown by the people in feeding and caring for their pigs, this intelligence being acquired thru their agricultural colleges and other educational institutions, which are aided and directed by a wise and sympathetic government. The total area of Denmark is but little over one-fourth that of Iowa, yet measured in money this little country exports about one-sixth as much pork products, mostly bacon, as the entire United States. Kennedy,[1] studying the subject on the ground, gives the following excellent summary of pig feeding methods as practiced by the Danes:

"As a rule pigs are marketed at about six or seven months of age, when they weigh from 160 to 200 lbs., live weight. The Danish buyer demands pigs which are uniform in size, with an even thickness of fat on the back, which should be about three-fourths to one

[1] U. S. Dept. Agr., Bur. Anim. Indus., Bul. 77.

inch in depth. The fat should be clear white in color, the flesh firm in all parts, and there should be a high percentage of lean in proportion to the fat.

"Any method of feeding which is undesirable will cause discrimination on the part of the buyers, and, thru the existence of the coöperative bacon factories, which are owned by the farmers themselves, feeders are in very close touch with the work. They have an excellent opportunity to follow their pigs through the slaughter-houses and have the faults of the carcasses pointed out by experts. In this manner farmers have learned many valuable lessons, so that they are very well versed in the influence of different feeds and rations on the quality of the carcass. The seller is entitled to a report on each lot of pigs marketed, and if he has made any changes from the rations previously used he can ascertain whether or not they are desirable.

"The following rations are used by successful feeders: Ground barley, cooked potatoes, and skim milk; shorts and skim milk; 2 parts shorts, 2 parts ground barley, 1 part corn meal, and skim milk; 2 parts ground barley, 1 part wheat bran, 1 part ground rye, and skim milk; 2 parts ground barley, 1 part ground oats, 1 part corn meal, and skim milk. Corn meal is fed with care, especially during warm weather; when fed in small quantities with barley, shorts, oats, and bran, combined with a liberal allowance of skim milk, there are no bad results. Some good feeders use corn meal to the extent of one-third or one-half of the grain ration during the first three or four months and then omit it and finish with oats or similar feed. Feeders are sometimes compelled to use corn on account of the low price of bacon. Ground rye to the extent of about one-third of the ration gives good results, but rye shorts are not satisfactory and are only used in small quantities. The best feeds are ground barley, crushed oats, and wheat shorts. Roots are fed during winter and soiling crops during summer." (**839**)

APPENDIX.

TABLE I. AVERAGE PERCENTAGE COMPOSITION OF AMERICAN FEEDING STUFFS.

This table is compiled from data in *Farmers' Bulletin 22*, U. S. Department of Agriculture; reports and bulletins of the Connecticut, Massachusetts, New York (Geneva), Wisconsin, New Jersey, and numerous other experiment stations. Other sources include *Zusammensetzung der Futtermittel,* Dietrich and König; *Farm Foods,* Wolff, English edition, Cousins; *Handbook for Farmers and Dairymen,* Woll; *Forage Crops,* Voorhees, etc.

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's		Fat	No. of analyses
				Fiber	N-free extract		
Grains, seeds, and their parts							
CONCENTRATES	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Dent corn	10.6	1.5	10.3	2.2	70.4	5.0	86
Flint corn	11.3	1.4	10.5	1.7	70.1	5.0	68
Sweet corn	8.8	1.9	11.6	2.8	66.8	8.1	26
Pop corn	10.7	1.5	11.2	1.8	69.6	5.2	4
Corn meal	15.0	1.4	9.2	1.9	68.7	3.8	77
Corn cob	10.7	1.4	2.4	30.1	54.9	0.5	18
Corn-and-cob meal	15.1	1.5	8.5	6.6	64.8	3.5	7
Gluten meal	9.5	1.5	33.8	2.0	46.6	6.6	12
Gluten feed	9.2	2.0	25.0	6.8	53.5	3.5	102
Hominy feed (chop)	9.6	2.7	10.5	4.9	64.3	8.0	106
Germ oil meal	8.6	2.4	21.7	3.8	47.3	11.2	23
Corn bran	9.4	1.2	11.2	11.9	60.1	6.2	6
Wheat, all analyses	10.5	1.8	11.9	1.8	71.9	2.1	310
Spring wheat	10.4	1.9	12.5	1.8	71.2	2.2	13
Winter wheat	10.5	1.8	11.8	1.8	72.0	2.1	262
Wheat flour	12.4	0.4	12.0	------	74.0	1.2	6
Red dog flour	9.9	2.6	18.4	3.0	63.5	4.0	23
Flour wheat middlings	10.0	3.2	19.2	3.2	59.6	4.8	106
Standard wheat middlings (shorts)	11.2	4.4	16.9	6.2	56.2	5.1	94
Wheat bran, all analyses	11.9	5.8	15.4	9.0	53.9	4.0	88
Winter wheat bran	11.5	6.4	15.7	8.7	53.4	4.3	27
Spring wheat bran	11.0	6.2	15.7	9.8	52.4	4.9	52
Wheat feed (shorts and bran)	10.9	5.6	16.3	7.5	55.1	4.6	101
Wheat screenings	11.6	2.9	12.5	4.9	65.1	3.0	10
Rye	8.7	2.1	11.3	1.5	74.5	1.9	57
Rye flour	13.1	0.7	6.7	0.4	78.3	0.8	4
Rye middlings	11.8	1.7	14.3	2.4	66.9	2.9	5
Rye bran	11.6	3.4	14.6	3.5	63.9	2.8	29
Rye feed (shorts and bran)	12.4	3.2	15.7	4.1	61.5	3.1	21

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's		Fat	No. of analyses
				Fiber	N-free extract		
CONCENTRATES—con.							
Grains, seeds, and their parts—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Barley	10.8	2.5	12.0	4.2	68.7	1.8	22
Barley screenings	12.2	3.6	12.3	7.3	61.8	2.8	2
Barley feed	8.9	4.4	13.8	9.1	59.9	3.9	12
Emmer (speltz)	8.0	3.9	11.5	11.1	62.9	2.2	1
Oats	10.4	3.2	11.4	10.8	59.4	4.8	126
Oat meal	7.9	2.0	14.7	0.9	67.4	7.1	6
Oat middlings	8.8	4.5	16.2	7.1	56.5	6.9	10
Oat feed	7.0	5.3	8.0	21.5	55.3	2.9	110
Oat dust	6.5	6.9	13.5	18.2	50.2	4.8	2
Oat hulls	7.4	6.7	3.4	30.7	50.5	1.3	11
Rough rice	11.2	4.9	7.3	8.0	66.6	2.0	2
Rice	12.4	0.4	7.4	0.2	79.2	0.4	10
Rice polish	10.8	4.8	11.9	3.3	62.3	7.2	21
Rice meal	10.2	8.1	12.0	5.4	51.2	13.1	2
Rice bran	9.7	9.7	11.9	12.0	46.6	10.1	24
Rice hulls	8.8	15.6	3.2	36.2	35.2	1.0	17
Canada field pea	15.0	2.4	23.7	7.9	50.2	0.8	------
Pea meal	10.5	2.6	20.2	14.4	51.1	1.2	2
Pea bran	11.0	2.7	10.0	39.7	35.6	1.0	2
Cowpea	14.6	3.2	20.5	3.9	56.3	1.5	2
Soybean	11.7	4.8	33.5	4.5	28.3	17.2	16
Soybean cake	11.3	5.9	42.7	6.0	28.1	6.0	------
Bean meal	10.9	5.7	23.2	3.8	54.9	1.5	1
Cull beans	10.0	3.2	21.6	3.7	47.5	1.2	------
Horse bean	11.3	3.8	26.6	7.2	50.1	1.0	1
Sesbania macrocarpa	9.2	3.3	31.7	13.5	37.9	4.3	1
Buckwheat	13.4	2.0	10.8	11.7	59.7	2.4	33
Buckwheat flour	14.6	1.0	6.9	0.3	75.8	1.4	4
Buckwheat middlings	12.8	5.0	26.7	4.4	44.3	6.8	40
Buckwheat bran	8.2	4.9	12.6	32.9	37.9	3.5	4
Buckwheat feed	11.6	3.9	18.3	19.2	42.1	4.9	19
Buckwheat hulls	13.2	2.2	4.6	43.5	35.3	1.1	2
Kafir corn	9.9	1.6	11.2	2.7	71.5	3.1	19
Ground kafir heads	13.6	2.8	9.2	8.0	63.8	2.6	3
Milo maize	9.0	2.3	10.7	3.0	72.2	2.8	14
Ground milo heads	9.7	2.7	9.2	6.5	69.5	2.4	3
Sorghum seed	12.8	2.1	9.1	2.6	69.8	3.6	10
Broom-corn seed	12.8	2.8	9.9	7.0	64.3	3.2	4
Millet seed	12.1	2.8	10.9	8.1	62.6	3.5	6
Hungarian grass seed	9.5	5.0	9.9	7.7	63.2	4.7	1
Flax seed	9.2	4.3	22.6	7.1	23.2	33.7	50
Linseed meal, old process	9.8	5.5	33.9	7.3	35.7	7.8	191
Linseed meal, new process	9.0	5.5	37.5	8.9	36.4	2.	52
Cotton seed	10.3	3.5	18.4	23.2	24.7	19.9	5
Cotton seed, roasted	6.1	5.5	16.8	20.4	23.5	27.7	2

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's: Fiber	Carbohydrat's: N-free extract	Fat	No. of analyses
CONCENTRATES—con.							
Grains, seeds, and their parts—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Cotton-seed meal	7.0	6.6	45.3	6.3	24.6	10.2	319
Cotton-seed hulls	11.1	2.8	4.2	46.3	33.4	2.2	20
Cotton-seed kernels without hulls	6.2	4.7	31.2	3.7	17.6	36.6	2
Cocoanut cake	10.3	5.9	19.7	14.4	38.7	11.0	------
Palmnut cake	10.4	4.3	16.8	24.0	35.0	9.5	600
Sunflower seed	8.6	2.6	16.3	29.9	21.4	21.2	2
Sunflower seed, kernels	6.9	2.8	30.5	2.6	14.5	42.8	2
Sunflower-seed cake	10.8	6.7	32.8	13.5	27.1	9.1	------
Peanut with hull	6.6	2.7	23.2	18.4	14.2	35.0	------
Peanut kernel, without hull	7.5	2.4	27.9	7.0	15.6	39.6	7
Peanut cake	10.7	4.9	47.6	5.1	23.7	8.0	2480
Rape-seed cake	10.0	7.9	31.2	11.3	30.0	9.6	500
Sesame oil cake	7.4	8.8	36.7	3.8	17.3	26.0	1
Palmnut cake	10.4	4.3	16.8	24.0	35.0	9.5	600
Cocoanut cake	10.3	5.9	19.7	14.4	38.7	11.0	------
FACTORY BY-PRODUCTS, ETC.							
Wet brewers' grains	75.7	1.0	5.4	3.8	12.5	1.6	15
Dried brewers' grains	8.7	3.7	25.0	13.6	42.3	6.7	53
Malt sprouts	9.5	6.1	26.3	11.6	44.9	1.6	47
Dried distillers' grains	7.6	2.0	31.2	11.6	35.4	12.2	49
Wet beet pulp	89.8	0.6	0.9	2.4	6.3	------	16
Dried beet pulp	8.4	4.5	8.1	17.5	60.8	0.7	7
Beet molasses	20.8	10.6	9.1	------	59.5	------	35
Molasses beet pulp	7.0	5.5	9.6	16.1	61.3	0.5	5
Porto Rico molasses	25.9	6.3	2.7	------	65.1	------	------
Molasses grains	10.4	6.5	17.1	11.9	51.2	2.9	20
Alfalmo	9.1	11.2	13.1	22.4	42.1	2.1	5
Bakery refuse	13.0	10.1	8.0	0.3	63.0	5.6	1
Cassava starch refuse	12.0	1.6	0.8	6.1	78.8	0.7	1
Starch refuse	12.0	1.8	4.8	3.8	76.3	1.3	2
Wet starch feed	68.8	0.4	5.0	2.9	19.9	3.0	4
Potato pomace	91.7	0.3	0.7	1.0	6.4	0.1	2
Dried blood	8.5	4.7	84.4	------	------	2.5	3
Meat scrap	10.7	4.1	71.2	------	0.3	13.7	144
Tankage	7.0	15.9	53.9	5.8	5.6	11.8	21
Fresh bone	34.2	22.8	20.6	------	1.9	20.5	------
Raw ground bone	8.0	64.4	23.9	------	3.4	0.3	1
Meat and bone meal	6.0	37.4	39.5	------	6.3	10.8	37
Dried fish	10.8	29.2	48.4	------	------	11.6	6
Cow's milk	87.2	0.7	3.6	------	4.9	3.7	793
Cow's milk, colostrum	74.6	1.6	17.6	------	2.7	3.6	42
Mare's milk	91.0	0.4	2.1	------	5.3	1.2	------
Ewe's milk	81.3	0.8	6.3	------	4.7	6.8	------
Goat's milk	86.9	0.9	3.7	------	4.4	4.1	------
Sow's milk	80.8	1.1	6.2	------	4.8	7.1	7

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's		Fat	No. of analyses
				Fiber	N-free extract		
FACTORY BY-PRODUCTS, ETC.—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Skim milk, gravity	90.4	0.7	3.3	------	4.7	0.9	96
Skim milk, centrifugal	90.6	0.7	3.1	------	5.3	0.3	97
Buttermilk	90.1	0.7	4.0	------	4.0	1.1	85
Whey	93.8	0.4	0.6	------	5.1	0.1	46
DRIED ROUGHAGE							
Field-cured corn forage							
Fodder corn (ears, if any, remaining)	42.2	2.7	4.5	14.3	34.7	1.6	35
Corn stover (ears removed)	40.5	3.4	3.8	19.7	31.5	1.1	60
Corn husks	50.9	1.8	2.5	15.8	28.3	0.7	16
Corn leaves	30.0	5.5	6.0	21.4	35.7	1.4	17
Sweet corn forage	40.0	3.7	5.5	12.6	36.7	1.4	21
Amber cane forage	41.7	3.0	3.2	17.0	32.2	2.9	1
Milo forage	40.9	2.9	2.9	19.1	31.8	2.3	2
Kafir forage	52.1	2.4	2.5	21.0	20.1	1.8	1
Hay from the grasses, etc.							
English hay	14.0	5.3	7.9	27.7	42.8	2.3	102
Mixed grasses	15.3	5.5	7.4	27.2	42.1	2.5	126
Timothy, all analyses	13.2	4.4	5.9	29.0	45.0	2.5	68
Timothy, full bloom	15.0	4.5	6.0	29.6	41.9	3.0	12
Timothy, after bloom	14.2	4.4	5.7	28.1	44.6	3.0	11
Timothy, nearly ripe	14.1	3.9	5.0	31.1	43.7	2.2	12
Orchard grass	9.9	6.0	8.1	32.4	41.0	2.6	10
Red top, different stages	8.9	5.2	7.9	28.6	47.5	1.9	9
Red top, in bloom	8.7	4.9	8.0	29.9	46.4	2.1	3
White top	14.0	6.0	11.2	24.4	41.5	2.9	1
Rhode Island bent	7.1	6.7	6.1	31.9	46.3	1.9	1
Meadow fox tail	6.6	9.8	9.3	32.3	38.9	3.1	------
Meadow fescue	20.0	6.8	7.0	25.9	38.4	2.7	9
Tall oat grass	14.0	4.6	6.4	30.9	42.1	1.9	4
Italian rye grass	8.5	6.9	7.5	30.5	45.0	1.7	4
Perennial rye grass	14.0	7.9	10.1	25.4	40.5	2.1	4
Fowl meadow grass	10.1	6.5	8.7	27.9	44.4	2.3	1
Kentucky blue grass	21.2	6.3	7.8	23.0	37.8	3.9	10
Kentucky blue grass, in milk	24.4	7.0	6.3	24.5	34.2	3.6	4
Kentucky blue grass, ripe	27.8	6.4	5.8	23.8	33.2	3.0	4
Canada blue grass	14.3	4.5	7.6	21.7	49.0	2.9	------
Blue joint	6.9	5.5	11.2	37.2	35.8	3.4	------
Prairie grass	9.2	7.8	6.2	34.1	39.9	2.8	------
Gama grass	11.8	6.2	6.8	30.4	43.1	1.8	------
Buffalo grass	15.0	8.8	4.9	19.7	48.4	3.2	------
Hungarian grass	7.7	6.0	7.5	27.7	49.0	2.1	13
Barnyard millet	14.0	7.9	10.6	27.8	37.1	1.7	9
Cat tail millet	11.0	8.1	11.6	26.8	40.2	2.3	1
Macaroni wheat forage	7.0	6.8	6.8	26.5	51.2	1.8	1
Rye forage	9.5	5.7	10.8	32.6	38.7	2.7	2

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's Fiber	Carbohydrat's N-free extract	Fat	No. of analyses
DRIED ROUGHAGE—con.							
Hay from the grasses, etc.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Barley, in milk	15.0	4.2	8.8	24.7	44.9	2.4	1
Oat, in milk	14.0	5.7	8.9	27.4	41.2	2.8	4
Bald barley forage	6.9	8.7	5.4	23.2	53.9	1.8	1
Emmer forage	6.6	11.1	10.7	34.1	35.8	1.4	1
Wild oat forage	14.3	3.8	5.0	25.0	48.8	3.3	1
Cheat forage	8.4	6.9	8.0	26.4	48.3	2.0	1
Quack (couch) grass	14.3	6.0	8.8	28.6	47.4	1.9	5
Texas blue grass	14.3	10.0	9.1	27.3	36.1	3.2	------
Bermuda grass	7.1	3.5	10.7	51.0	25.0	2.9	------
Johnson grass	10.2	6.1	7.2	28.5	45.9	2.1	2
Guinea grass	------	3.2	5.5	28.2	54.6	0.9	2
Para grass	------	3.3	9.1	36.0	42.9	1.1	4
Crab grass	14.3	10.8	8.4	27.5	36.6	2.4	------
Broom sedge	6.6	6.4	4.7	38.7	42.3	1.4	2
Swamp grass	11.6	6.7	7.2	26.6	45.9	2.0	8
Salt marsh grass	10.4	7.7	5.5	30.0	44.1	2.4	10
White daisy	10.3	6.6	7.7	30.0	42.0	3.4	2
Buttercup	9.3	5.6	9.9	30.6	41.1	3.5	2
Australian saltbush	9.0	21.7	12.9	14.7	39.6	1.9	4
Hay from the legumes							
Red clover	15.3	6.2	12.3	24.8	38.1	3.3	38
Red clover in bloom	20.8	6.6	12.4	21.9	33.8	4.5	6
Mammoth red clover	21.2	6.1	10.7	24.5	33.6	3.9	10
Alsike clover	9.7	8.3	12.8	25.6	40.7	2.9	9
White clover	9.7	8.3	15.7	24.1	39.3	2.9	7
Crimson clover	9.6	8.6	15.2	27.2	36.6	2.8	7
Burr clover	9.0	5.0	13.6	30.6	38.2	3.6	1
Japan clover	11.0	8.5	13.8	24.0	39.0	3.7	2
Wheat and vetch	15.0	6.8	14.5	27.2	34.4	2.1	4
Cowpea	10.5	8.9	14.2	21.2	42.6	2.6	17
Soybean	11.8	7.0	14.9	24.2	37.8	4.3	12
Alfalfa,	8.1	8.8	14.6	28.9	37.4	2.1	92
Alfalfa, leaves	4.9	14.5	23.3	13.2	41.2	3.0	1
Vetch	11.3	7.9	17.0	25.4	36.1	2.3	5
Serradella	9.2	7.2	15.2	21.6	44.2	2.6	3
Flat pea	8.4	7.9	22.9	26.2	31.4	3.2	5
Peanut vine, without nuts	7.6	10.8	10.7	23.6	42.7	4.6	6
Peanut vine, with nuts	6.3	6.0	13.5	29.2	36.3	15.1	------
Sweet clover	9.2	9.9	18.0	28.0	41.8	3.2	------
Velvet bean	10.0	5.9	14.0	37.7	30.6	1.8	------
Beggar weed	9.2	4.7	11.8	29.3	42.1	2.9	2
Sanfoin	15.0	7.3	14.8	20.4	39.5	3.0	1
Rowen	14.0	6.4	11.4	23.9	41.3	3.0	29
Mixed rowen	16.6	6.8	11.6	22.5	39.4	3.1	23
Mixed grasses and clovers	12.9	5.5	10.1	27.6	41.3	2.6	17
Oat and pea	10.0	7.1	10.3	28.3	41.2	2.6	6
Oat and vetch	15.0	7.4	12.8	26.7	35.8	2.3	3

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's		Fat	No. of analyses
				Fiber	N-free extract		
DRIED ROUGHAGE—con.							
Straw, chaff, etc.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Wheat	9.6	4.2	3.4	38.1	43.4	1.3	7
Rye	7.1	3.2	3.0	38.9	46.6	1.2	7
Oat	9.2	5.1	4.0	37.0	42.4	2.3	12
Barley	14.2	5.7	3.5	36.0	39.0	1.5	97
Buckwheat	9.9	5.5	5.2	43.0	35.1	1.3	3
Millet	15.0	5.2	4.1	34.2	39.7	1.8	4
Soybean	10.1	5.8	4.6	40.4	37.4	1.7	4
Horse bean	9.2	8.7	8.8	37.6	34.3	1.4	1
Wheat chaff	14.3	9.2	4.5	36.0	34.6	1.4	------
Oat chaff	14.3	10.0	4.0	34.0	36.2	1.5	------
Flax shives	10.0	3.9	5.1	42.7	35.2	3.1	------
Sorghum bagasse	11.2	2.9	3.4	30.5	50.4	1.4	1
FRESH GREEN ROUGHAGE							
Fresh green corn forage							
Fodder corn, all varieties	79.3	1.2	1.8	5.0	12.2	0.5	126
Dent varieties	79.0	1.2	1.7	5.6	12.0	0.5	63
Dent, kernels glazed	73.4	1.5	2.0	6.7	15.5	0.9	7
Flint varieties	79.8	1.1	2.0	4.3	12.1	0.7	40
Flint, kernels glazed	77.1	1.1	2.7	4.3	14.6	0.8	10
Sweet varieties	79.1	1.3	1.9	4.4	12.8	0.5	21
Sweet corn, ears removed	80.0	1.2	1.4	4.9	12.0	0.5	2
Corn leaves and husks	66.2	2.9	2.1	8.7	19.0	1.1	4
Stripped corn stalks	76.1	0.7	0.5	7.3	14.9	0.5	4
Sorghum	79.4	1.1	1.3	6.1	11.6	0.5	11
Sugar cane	84.2	1.1	1.2	4.0	9.0	0.5	2
Teosinte	90.1	1.4	1.4	2.7	4.1	0.3	1
Yellow milo maize	83.2	1.5	1.7	5.5	7.5	0.6	1
Red kafir corn	81.6	1.3	1.8	4.8	9.9	0.6	1
White kafir corn	83.4	1.4	1.9	4.6	8.0	0.7	1
Fresh grass, etc.							
Pasture grass	80.0	2.0	3.5	4.0	9.7	0.8	------
Kentucky blue grass	65.1	2.8	4.1	9.1	17.6	1.3	18
Timothy, different stages	61.6	2.1	3.1	11.8	20.2	1.2	56
Orchard grass, in bloom	73.0	2.0	2.6	8.2	13.3	0.9	4
Red top, in bloom	65.3	2.3	2.8	11.0	17.7	0.9	5
Italian rye, coming in bloom	73.2	2.5	3.1	6.8	13.3	1.3	24
Tall oat, in bloom	69.5	2.0	2.4	9.4	15.8	0.9	3
Bermuda grass	71.7	2.1	2.2	5.9	17.2	0.9	------
Oat fodder	62.2	2.5	3.4	11.2	19.3	1.4	6
Barley fodder	79.0	1.8	2.7	7.9	8.0	0.6	1
Rye fodder	76.6	1.8	2.6	11.6	6.8	0.6	7
Wheat fodder	77.3	1.8	2.4	5.9	11.9	0.7	1
Johnson grass	75.0	1.4	1.2	8.9	13.2	0.3	1
Orchard grass	73.0	2.0	2.6	8.2	13.3	0.9	8
Hungarian grass	71.1	1.7	3.1	9.2	14.2	0.7	14

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's Fiber	Carbohydrat's N-free extract	Fat	No. of analyses
FRESH GREEN ROUGHAGE—con.							
Fresh grass, etc.—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Pearl millet	81.5	1.5	1.2	6.2	9.3	0.3	2
Common millet	80.0	1.0	1.5	6.5	10.5	0.3	16
Hog millet	80.0	1.4	1.5	6.5	10.2	0.4	1
Japanese millet	75.0	1.5	2.1	7.8	13.1	0.5	12
Barnyard millet	75.0	1.9	2.4	7.0	13.1	0.6	2
Meadow fescue, in bloom	69.9	1.8	2.4	10.8	14.3	0.8	4
Spurry	72.0	2.6	2.9	7.0	15.4	0.1	------
Ragweed	61.0	4.4	3.9	13.4	15.2	2.1	1
Ramie	77.9	3.5	2.2	7.1	8.4	0.9	1
Fresh legumes, etc.							
Red clover, different stages	70.8	2.1	4.4	8.1	13.5	1.1	43
Mammoth red clover	80.0	1.9	3.0	5.8	8.9	0.4	4
Alsike clover	74.8	2.0	3.9	7.4	11.0	0.9	4
Crimson clover	80.9	1.7	3.1	5.2	8.4	0.7	3
Sweet clover	80.0	1.9	3.8	6.3	7.4	0.6	4
Burr clover	73.8	2.3	5.5	5.9	10.5	2.0	1
Alfalfa	71.8	2.7	4.8	7.4	12.3	1.0	23
Spring vetch	85.0	1.4	2.7	4.5	6.1	0.4	4
Sand vetch	85.3	2.1	3.6	4.0	4.6	0.4	14
Cowpea	83.6	1.7	2.4	4.8	7.1	0.4	10
Soybean	75.1	2.6	4.0	6.7	10.6	1.0	27
Serradella	79.5	3.2	2.7	5.4	8.6	0.7	9
Horse bean	84.2	1.2	2.8	4.9	6.5	0.4	2
Velvet bean	82.2	1.9	3.5	5.1	6.6	0.7	1
Canada field pea	84.7	1.3	2.8	4.4	6.3	0.5	26
Sanfoin	75.0	2.1	4.4	6.0	11.6	0.9	1
Mixed grasses and clovers	75.0	1.6	2.9	8.0	11.7	0.8	2
Oat and peas	79.7	1.6	2.4	6.1	9.6	0.6	7
Barley and peas	80.0	1.6	2.8	6.8	8.2	0.6	1
Oats and vetch	80.0	1.8	3.0	6.3	8.4	0.5	3
Wheat and vetch	80.0	1.6	3.4	6.4	8.1	0.5	4
Barley and vetch	80.0	1.2	2.8	6.5	9.0	0.5	2
Roots and tubers							
Common beet	88.5	1.0	1.5	0.9	8.0	0.1	9
Sugar beet	86.5	0.9	1.8	0.9	9.8	0.1	19
Mangel	90.9	1.1	1.4	0.9	5.5	0.2	9
Turnip	90.1	0.9	1.3	1.2	6.3	0.2	8
Rutabaga	88.6	1.2	1.2	1.3	7.5	0.2	4
Carrot	88.6	1.0	1.1	1.3	7.6	0.4	8
Parsnip	88.3	0.7	1.6	1.0	10.2	0.2	------
Potato	79.1	0.9	2.1	0.4	17.4	0.1	41
Sweet potato	68.3	1.1	1.9	1.1	26.8	0.7	48
Artichoke	79.5	1.0	2.6	0.8	15.9	0.2	2
Chufa	79.5	0.4	0.7	2.2	10.5	6.6	------
Cassava	66.0	0.7	1.1	1.8	30.2	0.2	------

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's Fiber	Carbohydrat's N-free extract	Fat	No. of analyses
MISCELLANEOUS	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Dwarf Essex rape	85.7	2.5	2.2	2.1	7.0	0.5	5
Dwarf Essex rape, summer	85.0	2.8	2.1	2.7	6.9	0.5	1
Dwarf Essex rape, winter	85.0	3.3	2.3	1.8	7.1	0.5	1
Cabbage	90.0	0.8	2.6	0.9	5.5	0.2	1
Spurry	75.7	4.0	2.0	4.9	12.7	0.8	1
Sugar-beet leaves	88.0	2.4	2.6	2.2	4.4	0.4	------
Field pumpkin	90.9	0.5	1.3	1.7	5.2	0.4	------
Garden pumpkin	80.8	0.9	1.8	1.8	7.9	0.8	------
Prickly comfrey	88.4	2.2	2.4	1.6	5.1	0.3	41
Acorns	55.3	1.0	2.5	4.4	34.8	1.9	------
Apples	80.8	0.4	0.7	1.2	16.6	0.4	3
Apple pomace	83.0	0.6	1.0	2.9	11.6	0.9	6
Purslane	91.0	1.5	2.3	1.6	3.4	0.2	1
Dandelion	84.3	2.2	1.2	------	8.2	4.1	------
Prickly pear	84.2	3.1	0.7	2.4	9.0	0.3	4
Cane cacti	78.5	3.6	1.4	3.6	12.3	0.6	67
Australian saltbush	75.8	5.8	3.5	3.9	10.5	0.5	4
Greasewood	46.0	14.4	19.8	24.5	34.3	2.5	------
Common little sage	35.0	4.3	13.7	14.3	30.3	2.4	1
Common sage	49.6	3.6	4.6	11.3	20.3	10.5	1
Dried oak leaves, gathered in July	4.9	9.7	9.5	25.8	45.1	4.5	7
Dried tree leaves, gathered in July	16.0	7.0	10.5	14.2	49.3	3.0	------
Dried beech twigs, gathered in winter	15.3	2.6	4.0	38.5	38.0	1.6	------
Dried banana tops	------	4.1	13.2	31.9	42.1	2.3	------
Dried banana butts	------	3.6	6.4	38.6	35.5	2.4	------
SILAGE							
Corn, immature	79.1	1.4	1.7	6.0	11.0	0.8	99
Corn, recent analyses	73.6	2.1	2.7	7.8	12.9	0.9	17
Corn, ears removed	73.7	1.6	2.2	6.5	15.1	0.9	------
Sorghum	76.1	1.1	0.8	6.4	15.3	0.3	6
Rye	80.8	1.6	2.4	5.8	9.2	0.3	1
Millet	74.0	2.4	1.7	7.5	13.6	0.8	3
Red clover	72.0	2.6	4.2	8.4	11.6	1.2	5
Soybean	74.2	2.8	4.1	9.7	6.9	2.2	1
Cowpea	79.3	2.9	2.7	6.0	7.6	1.5	2
Field pea	50.1	3.5	5.9	13.0	26.0	1.6	1
Apple pomace	85.0	0.6	1.2	3.3	8.8	1.1	1
Corn cannery refuse, husks	83.8	0.6	1.4	5.2	7.9	1.1	------
Corn cannery refuse, cobs	74.1	0.5	1.5	7.9	14.3	1.7	------
Pea cannery refuse	76.8	1.3	2.8	6.5	11.3	1.3	------
Wet brewers' grains	70.3	1.2	6.3	4.5	15.6	2.1	4

TABLE I. Average composition of American feeding stuffs—*continued.*

Feeding stuffs	Water	Ash	Crude protein	Carbohydrat's		Ash	No. of analyses
				Fiber	N-free extract		
SILAGE—con.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Corn and soybean	76.0	2.4	2.5	7.2	11.1	0.8	4
Cowpea and soybean	69.8	4.5	3.8	9.5	11.1	1.3	1
Barnyard millet and soybean	79.0	2.8	2.8	7.2	7.2	1.0	9
Milo	74.6	1.8	2.2	7.9	12.7	0.7	1
Durra	79.7	1.8	1.2	7.0	9.5	0.7	3
Kafir	67.2	2.9	2.1	11.2	15.2	1.4	3
Teosinte	66.8	4.0	2.5	12.3	13.6	0.8	1
Barley	75.0	2.6	2.6	9.4	9.4	1.0	2
Sugar beet pulp	90.0	0.3	1.5	3.1	4.7	0.4	1

TABLE II. AVERAGE DIGESTIBILITY OF AMERICAN FEEDING STUFFS, WITH ADDITIONS FROM THE GERMAN TABLES.

The data of this table are mainly from digestion trials by American experiment stations, as compiled by Holland in the *Massachusetts* (Hatch) *Experiment Station Report* for 1906. Coefficients from this source are marked "M" in the last column of the table. To render the table more complete, additions marked "L" have been made from the German tables given in Mentzel and Lengerke's *Landwirtschaftliche Kalender* for 1908. Those marked "K" are from *Zusammensetzung der Futtermittel,* Dietrich and König. Those unmarked are from American stations, not reported by Holland.

A. *Experiments with Ruminants.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's		Fat	Authority
				Fiber	N-free extract		
CONCENTRATES.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Dent corn	12	91	76	58	93	86	K.
Corn meal	21	88	66	------	92	91	M.
Corn cob	2	59	17	65	60	50	M.
Corn-and-cob meal	3	79	52	45	88	84	M.
Gluten meal	8	87	88	------	88	93	M.
Gluten feed	15	87	85	76	89	82	M.
Germ oil meal	5	76	73	------	76	96	M.
Hominy meal	8	82	65	67	89	92	M.
Corn bran	5	70	54	57	76	77	M.
Wheat meal	4	87	74	------	93	71	M.
Wheat bran, average all trials	11	66	77	41	71	63	M.
Spring wheat bran	7	67	76	44	74	63	M.
Winter wheat bran	3	62	77	27	65	64	M.
Flour wheat middlings	4	82	88	36	88	86	M.
Standard wheat middlings (shorts)	6	------	77	30	78	88	M.
Wheat feed (bran and middlings)	4	73	78	62	77	87	M.
Rye meal	2	87	84	------	92	64	M.
Rye feed (bran and middlings)	3	82	80	------	88	90	M.
Barley	4	86	70	50	92	89	L.
Barley bran	1	77	85	20	86	87	----
Barley feed	4	86	83	57	92	74	M.
Emmer (speltz)	1	94	87	84	97	92	----
Oats	6	70	77	31	77	89	M.
Oat middlings, fine	2	90	81	49	96	94	M.
Oat feed	6	40	65	32	42	90	M.
Buckwheat	2	71	75	24	76	100	L.
Buckwheat bran	----	49	47	39	56	56	----
Buckwheat middlings	3	75	85	17	83	89	M.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's Fiber	Carbohydrat's N-free extract	Fat	Authority
CONCENTRATES—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Rice	2	98	86	------	100	90	L.
Rice meal	2	74	62	------	92	91	M.
Rice bran	4	62	64	21	78	72	M.
Rice polish	2	83	66	22	93	74	M.
Rice hulls	2	16	10	------	35	67	L.
Kafir corn	11	53	46	------	60	46	M.
Sorghum seed	2	78	49	68	85	77	L.
Millet seed	2	86	65	51	71	70	L.
Pea meal	2	87	83	26	94	55	M.
Cowpea meal	2	87	82	64	93	74	M.
Northern field beans	30	88	87	58	91	83	L.
Soybean meal	10	79	87	------	73	85	M.
Flax seed	7	77	91	60	55	86	L.
Linseed meal, old process	3	79	89	57	78	89	M.
Linseed meal, new process	12	82	84	74	80	89	M.
Cocoanut cake	5	80	78	63	83	97	L.
Palmnut cake	3	91	95	82	94	95	L.
Sunflower-seed cake	4	76	90	30	71	88	L.
Peanut kernel, without hulls	7	83	90	9	84	90	L.
Peanut cake	7	83	90	9	84	90	L.
Peanut feed	2	32	71	12	49	90	M.
Sesame cake	4	77	90	31	56	90	L.
Rape-seed cake	7	66	81	8	76	79	L.
Cotton seed	2	66	68	76	50	87	M.
Roasted cotton seed	2	56	47	66	51	72	M.
Cotton-seed meal	14	77	83	35	78	94	M.
Cotton-seed hulls	13	41	6	47	34	79	M.
Cotton-seed hulls, when fed with cotton-seed meal	11	45	------	46	51	76	M.
Cotton-seed feed	23	52	51	46	55	86	M.
Factory by-products							
Dried brewers' grains	6	62	80	50	60	90	M.
Wet brewers' grains	12	63	73	40	62	86	L.
Malt sprouts	4	78	77	83	81	90	M.
Dried distillers' grains, largely from corn	17	79	73	95	81	95	M.
Dried distillers' grains, largely from rye	2	58	59	------	67	84	M.
Fresh beet pulp	2	88	60	76	94	------	L.
Dried beet pulp	11	77	51	72	86	------	L.
Beet molasses	4	83	52	------	91	------	L.
Dried molasses beet pulp	1	------	66	86	79	9	----
Molasses feed (grains)	13	72	63	55	81	76	M.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's		Fat	Authority
				Fiber	N-free extract		
CONCENTRATES—con.							
Factory by-products—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Apple pomace	6	72	------	65	85	46	M.
Meat scraps	5	93	93	------	------	98	L.
Dried fish	5	93	93	------	------	98	L.
Blood meal	2	------	84	------	------	------	M.
ROUGHAGE							
Field-cured corn fodder (Corn forage with ears, if any)							
Dent and flint varieties, average	23	68	55	65	73	74	M.
Dent corn fodder, immature stage, average all trials	15	62	50	67	62	65	M.
Dent corn fodder, milk stage	11	63	50	64	66	75	M.
Dent corn fodder, mature stage	38	65	45	64	71	65	M.
B. & W. dent corn fodder, immature stage	4	57	27	59	61	76	M.
Flint corn fodder, ears forming	3	70	70	72	71	67	M.
Flint corn fodder, mature stage	11	70	64	76	71	71	M.
Sweet corn fodder, mature stage	6	67	64	74	68	74	M.
Field-cured corn stover (Corn forage with ears removed)							
Corn stover, average all trials	31	57	36	64	59	67	M.
Shredded corn stover, fed dry	2	57	40	65	56	72	M.
Shredded corn stover, fed wet	2	60	36	70	59	74	M.
Ground corn stover minus pith (Marsden's process)	3	63	60	61	66	83	M.
Corn stover, blades and husks	4	65	48	73	66	58	M.
Corn stover, tops and blades	2	60	55	71	62	71	M.
Corn stover, stalks below ears	2	67	21	74	69	80	M.
Corn stover, stalks above ears	2	55	22	71	54	64	----
Corn stover, leaves	4	61	46	70	64	60	M.
Corn stover, husks	2	72	30	80	75	33	M.
Kafir corn fodder	4	61	38	60	66	61	M.
Kafir corn stover	5	57	34	67	60	75	M.
Cured hay from the grasses, etc.							
Meadow hay, rich in protein	48	67	66	63	68	57	L.
Meadow hay, medium in protein	94	61	57	60	64	53	L.
Meadow hay, poor in protein	28	56	50	56	59	49	L.
Timothy, average all trials	64	55	48	50	62	50	M.
Timothy, in bloom	8	59	57	57	63	48	M.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's Fiber	Carbohydrat's N-free extract	Fat	Authority
ROUGHAGE—con.							
Cured hay from the grasses, etc.—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Timothy, past bloom	17	52	43	46	59	51	M.
Timothy and clover, poorly cured	2	55	38	53	60	58	M.
Orchard grass	3	56	60	61	55	55	M.
Red top	3	60	61	61	62	51	M.
Tall oat grass, *Arrhenatherum elatius*, late bloom	2	55	51	55	58	56	M.
Mixed grasses, rich in protein	60	60	57	60	61	50	M.
Mixed grasses, mostly timothy	10	55	47	65	59	45	M.
Rowen	16	------	69	66	64	47	M.
Pasture grass	3	73	73	76	74	67	M.
Prairie grass, *Sporobolus asper*	1	56	18	61	61	57	M.
Kentucky blue grass, *Poa pratensis*, bloom	1	56	57	63	53	43	M.
Canada blue grass, *Poa compressa*, bloom	2	62	43	71	63	37	M.
Blue-joint, in bloom	2	69	70	72	69	52	M.
Blue-joint, past bloom	1	40	57	37	43	37	M.
Native blue grass, *Poa sandbergii*	1	52	64	45	60	50	----
Western brome grass *Bromus marginatus*	1	60	68	53	67	16	----
Millet	12	59	53	65	58	50	M.
Cat-tail millet, *Pennesetum spicatum*	2	62	63	67	59	46	M.
Hungarian grass	2	65	60	68	67	64	M.
Johnson grass, *Andropogon halepensis*	3	57	40	68	57	38	M.
Witch grass (quack), *Agropyrum repens*	4	61	58	62	66	57	M.
Salt bush, *Atriplex argentea*	3	46	66	8	49	52	M.
Salt grasses	22	54	56	56	52	37	M.
Swale meadow (Swamp hay)	2	39	34	33	46	44	M.
Low meadow fox grass, *Spartina juncea*	2	53	57	51	52	24	M.
High-grown salt hay (largely *Spartina juncea*)	2	53	63	50	53	47	M.
Branch grass (*Spartina juncea* with *Spartina stricta*, var. *glabra*)	2	56	62	52	54	31	M.
Wild oat grass, *Danthonia spicata*	3	64	58	68	65	50	M.
Sorghum fodder	3	58	43	49	61	65	M.
Sorghum fodder, leaves	2	63	61	70	65	47	M.
Sorghum bagasse	1	61	14	64	65	46	M.
Barley	4	59	65	62	63	41	M.
Oat	20	54	53	51	55	60	M.
Wheat and sand vetch	6	66	74	65	68	64	M.
Oat and pea	7	61	73	58	61	59	M.
Oat and vetch	7	58	65	55	59	55	M.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's Fiber	Carbohydrat's N-free extract	Fat	Authority
ROUGHAGE—con.							
Cured hay from the grasses, etc.—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Buffalo grass *Bulbilis Dactyloides*	1	55	54	65	62	62	M.
Chess or cheat, *Bromus secalinus*	1	45	42	46	49	32	M.
Colorado upland hay, largely *Agropyrum tenerum*	6	56	62	59	57	34	M.
Ripe crab grass, *Eragrostis Neo Mexicanna*	8	53	58	60	53	43	M.
Meadow fescue, *Festuca elatior pratensis,* in bloom	2	61	52	67	59	54	M.
Buttercup, *Ranunculus acris*	2	56	56	41	67	70	M.
White weed (Ox-eye daisy), *Leucanthemum vulgare*	2	58	58	46	67	62	M.
Indian potato, *Ataenia gairdneri*	1	67	57	74	65	77	----
Common sunflower, *Wyethia mollis*	1	61	70	54	61	63	----
Balsam root, *Balsamorhiza sagittata*	1	66	77	59	75	74	----
Wild carrot, *Leptotaenia multifida*	1	69	71	47	83	81	----
Dandeloin, *Crepis intermedia*	1	62	63	36	78	33	----
Bitter brush, *Kunzia tridentata*	1	77	82	70	86	71	----
Little lupine, *Lupinus,* sp	1	68	75	56	75	75	----
Cured hay from the legumes							
Alfalfa, average all trials	39	62	72	47	72	43	M.
First crop alfalfa, budded to full bloom	17	63	71	49	72	41	M.
Second crop alfalfa, budded to full bloom	12	62	75	45	73	42	M.
Third crop alfalfa	2	58	69	34	71	42	M.
Red clover	18	57	58	54	64	55	M.
Red clover, in bloom	46	61	62	49	69	62	L.
Red clover, late bloom	2	55	55	46	64	53	M.
Alsike clover	9	59	66	50	66	38	M.
Crimson clover	9	62	69	45	62	44	M.
White clover	1	66	73	61	70	51	M.
Clover rowen	4	------	65	47	63	60	M.
Cowpea	2	59	65	43	71	50	M.
Soybean	2	62	71	61	69	29	M.
Peanut vine	2	60	63	52	70	66	M.
Spring vetch, *Vicia sativa*	2	66	70	58	72	71	M.
Winter or hairy vetch, *Vicia villosa*	6	69	82	61	73	70	M.
Sanfoin	2	62	70	36	74	66	L.
Serradella	2	62	75	50	63	65	L.
Straw and chaff							
Wheat	10	42	23	50	37	31	L.
Rye	----	46	23	55	39	36	L.
Oat	11	48	33	54	46	36	L.
Barley	7	52	25	54	53	39	L.
Rice	4	47	45	57	32	47	L.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's		Fat	Authority
				Fiber	N-free extract		
ROUGHAGE—con.							
Straw and chaff—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Horse bean	5	55	49	43	68	57	L.
Pea vine	2	59	60	52	64	46	L.
Soybean vine	4	55	50	38	66	60	L.
Wheat chaff	3	36	26	39	33	43	L.
Oat chaff	2	42	38	45	49	48	L.
Green corn forage and sorghum							
Dent corn fodder, immature stage	17	68	66	64	71	68	M.
Dent corn fodder, milk stage	9	70	61	64	76	78	M.
Dent corn fodder, glazing stage	9	67	54	51	75	78	M.
Dent corn fodder, mature stage	21	68	53	60	73	72	M.
Sweet corn fodder, milk stage	2	77	77	75	81	74	M.
Sweet corn fodder, roasting stage	12	------	62	60	77	74	M.
Sorghum fodder	9	64	45	58	70	69	M.
Green grasses							
Mixed pasture grass	4	71	70	76	73	63	M.
Meadow grass	2	70	68	76	73	58	M.
Timothy grass	3	64	48	56	66	52	M.
Timothy grass, rowen	2	------	72	64	68	52	M.
Barnyard millet, in bloom	6	70	65	73	71	58	M.
Japanese millet, bloom to early seed	3	------	50	62	67	68	M.
Hungarian grass, early to late bloom	8	66	63	70	67	62	M.
Oat fodder, bloom to early seed	5	------	73	55	62	69	M.
Rye fodder	2	74	79	80	71	74	M.
Barley fodder	6	------	71	58	72	56	M.
Green legumes, grasses and legumes combined							
Alfalfa	2	61	74	43	72	39	M.
Red clover	5	66	66	49	71	61	M.
Crimson clover, late bloom	3	------	77	56	74	66	M.
Clover rowen, late bloom	2	61	62	52	65	61	M.
Soybean	18	65	77	45	75	54	M.
Soybean, before bloom	2	66	79	50	72	54	M.
Soybean, seed half grown	2	62	69	41	73	54	M.
Cowpeas, ready for soiling	4	68	76	60	81	59	M.
Canada field peas	8	65	81	49	75	54	M.
Spring vetch, *Vicia sativa*	2	62	71	44	76	59	M.
Winter or hairy vetch, *Vicia villosa*, in bloom	14	71	83	63	77	71	M.
Barley and pea, in bloom	4	------	75	52	68	59	M.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's		Fat	Authority
				Fiber	N-free extract		
ROUGHAGE—con.							
Green legumes, grasses and legumes combined—con.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Oats and spring vetch, in bloom	3	67	75	68	68	47	M.
Oats and peas	10	70	74	60	68	64	M.
Winter wheat and hairy vetch	5	69	75	68	73	57	M.
Dent corn, mature stage	25	66	50	64	71	82	M.
Dent corn, immature stage	17	64	53	68	66	71	M.
Flint corn, mature stage, small varieties	11	75	65	77	79	82	M.
Large white flint corn, partly eared	2	70	56	72	76	73	M.
Sweet corn, mature stage	2	68	54	71	72	83	M.
Clover	5	44	35	48	45	45	M.
Soybean	7	56	66	53	65	57	M.
Soybean and barnyard millet	4	59	57	69	59	72	M.
Soybean and corn	8	69	63	62	78	83	M.
Cowpea	4	60	57	52	72	63	M.
Sorghum, well matured	3	57	13	58	64	------	M.
Corn, sunflower heads and horse beans	2	66	63	60	72	77	M.
Corn, sunflowers and horse beans	2	65	58	65	74	74	M.
Kafir corn, well matured	3	55	28	57	62	50	M.
Oat and pea	2	65	75	61	67	75	M.
Roots and tubers.							
Potato	30	83	51	------	90	------	L.
Rutabaga	2	87	80	74	95	84	L.
Mangel	22	87	70	37	95	------	L.
Sugar beet	30	92	72	34	97	------	L.
Turnip	10	87	73	51	92	------	L.
MISCELLANEOUS							
Dwarf Essex rape, average	4	85	89	87	92	48	M.
Acorns	2	88	83	62	91	88	L.
Pumpkin	----	------	77	65	90	50	----
Sugar beet leaves	4	77	74	70	80	55	L.

B. *Experiments with Horses.*

Corn	2	74	58	------	88	48	M.
Corn meal	2	88	76	------	96	73	M.
Oats	4	74	84	22	82	81	M.
Timothy hay	2	44	21	43	47	47	M.
Ground corn stover minus pith (Marsden's process)	2	50	68	55	47	60	M.

TABLE II. Average digestibility of American feeding stuffs—*continued.*

C. *Experiments with Calves.*

Feeding stuffs	No. of trials	Dry matter	Protein	Carbohydrat's		Fat	Authority
				Fiber	N-free extract		
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Whole milk	8	------	95	------	100*	97	M.
Pasteurized whole milk	9	------	93	------	100*	95	M.
Cooked whole milk	3	------	87	------	100*	95	M.
Skim milk	3	------	95	------	100*	------	M.

D. *Experiments with Swine.*

Feeding stuffs	No. of trials	Dry matter	Protein	Fiber	N-free extract	Fat	Authority
Corn	1	83	69	38	89	46	M.
Corn meal	2	90	88	39	94	80	M.
Corn-and-cob meal	1	76	76	29	84	82	M.
Whole wheat	----	83	80	60	83	70	L.
Cracked wheat	----	82	80	60	83	70	M.
Wheat shorts	2	77	73	37	87	------	M.
Wheat bran	2	66	75	34	66	72	M.
Rye bran	2	67	66	9	75	58	L.
Barley meal	8	82	76	15	90	65	L.
Barley meal	1	80	81	49	87	57	M.
Pea meal	1	90	89	78	95	50	M.
Linseed meal, old process	4	77	86	12	85	80	M.
Hog millet seed, *Panicum miliaceum*	1	73	68	33	92	59	M.
Potato	4	97	84	------	98	------	M.
Dried blood	1	72	72	------	92	------	L.
Flesh meal	8	92	97	------	------	87	L.
Sour milk	1	95	96	------	98	95	L.

*Assumed.

TABLE III. AVERAGE DIGESTIBLE NUTRIENTS AND FERTILIZING CONSTITUENTS IN AMERICAN FEEDING STUFFS.

The data for the digestible nutrients in this table are derived, for the most part, by combining the data in the two preceding tables. Where no digestion factors are available in Table II for a given feed, the digestion factor of a similar feed has been used and that fact indicated by an asterisk.

The fertilizing constituents given are mostly from the extensive tables compiled by Roberts in *The Fertility of the Land*, and by Voorhees in *Forage Crops*.

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
CONCENTRATES.							
Grains, seeds, and their parts	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dent corn	89.4	7.8	66.8	4.3	16.5	7.1	5.7
Flint corn*	88.7	8.0	66.2	4.3	16.8	7.1	5.7
Sweet corn*	91.2	8.8	63.7	7.0	18.6	7.1	5.7
Corn meal	85.0	6.1	64.3	3.5	14.7	6.3	4.7
Corn cob	89.3	0.5	44.8	------	3.9	0.6	6.0
Corn-and-cob meal	84.9	4.4	60.0	2.9	13.6	5.7	4.7
Gluten meal	90.5	29.7	42.5	6.1	54.8	3.3	0.5
Gluten feed	90.8	21.3	52.8	2.9	40.0	3.7	0.4
Hominy feed (chop)	90.4	6.8	60.5	7.4	16.8	9.8	4.9
Germ oil meal	91.4	15.8	38.8	10.8	34.7	3.9	2.1
Corn bran	90.6	6.0	52.5	4.8	17.9	10.1	6.2
Wheat	89.5	8.8	67.5	1.5	19.0	5.5	8.7
High grade flour*	87.6	10.6	65.1	1.0	19.2	5.7	5.4
Red dog flour*	90.1	16.2	57.0	3.4	29.4	------	----
Flour wheat middlings	90.0	16.9	53.6	4.1	30.7	12.2	9.6
Standard wheat middlings (shorts)	88.8	13.0	45.7	4.5	27.0	26.3	15.3
Wheat bran, all analyses	88.1	11.9	42.0	2.5	24.6	26.9	15.2
Winter wheat bran	88.5	12.1	37.1	2.8	25.1	------	----
Spring wheat bran	88.0	11.9	43.1	3.1	25.1	------	----
Wheat feed	89.1	12.7	47.1	4.0	26.1	20.4	5.4
Wheat screenings	88.4	9.6	48.2	1.9	20.0	11.7	8.4
Rye*	91.3	9.5	69.4	1.2	18.1	8.6	5.8
Rye flour*	86.9	5.6	72.2	0.5	10.7	8.2	6.5
Rye middlings*	88.2	11.0	52.9	2.6	22.9	12.3	9.6
Rye bran*	88.4	11.2	46.8	1.8	23.3	22.8	14.0
Rye feed	87.6	12.6	56.6	2.8	25.1	7.7	4.7
Barley	89.2	8.4	65.3	1.6	19.2	7.9	4.8
Barley screenings*	87.8	9.5	49.9	2.5	19.7	------	----
Barley feed*	91.1	11.5	60.3	2.9	22.1	6.6	3.4
Emmer (speltz)	92.0	10.0	70.3	2.0	18.4	7.6	5.7

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
CONCENTRATES—con.							
Grains, seeds, and their parts—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Oats	89.6	8.8	49.2	4.3	18.2	7.8	4.8
Ground oats	88.0	10.1	52.5	3.7	19.7	7.6	5.0
Oat meal*	92.1	11.9	65.1	6.7	23.5	------	----
Oat middlings	91.2	13.1	57.7	6.5	25.9	22.5	15.3
Oat feed	93.0	5.2	30.1	2.6	12.8	6.1	7.2
Oat dust*	93.5	5.1	32.8	2.3	21.6	------	----
Oat hulls*	92.6	1.3	38.5	0.6	5.3	1.6	4.9
Buckwheat	86.6	8.1	48.2	2.4	17.3	6.9	3.0
Buckwheat flour*	85.4	5.9	63.0	1.2	11.0	6.8	3.4
Buckwheat middlings	87.2	22.7	37.5	6.1	42.7	12.3	11.4
Buckwheat bran*	91.8	5.9	34.0	2.0	20.2	4.2	12.7
Buckwheat feed*	88.4	15.6	38.2	4.4	29.3	15.8	10.5
Buckwheat hulls*	86.8	1.2	28.6	0.5	7.3	4.3	14.7
Rice	87.6	6.4	79.2	0.4	11.8	1.8	0.9
Rice meal	89.8	7.4	48.3	11.9	19.2	------	----
Rice polish	89.2	7.9	58.6	5.3	19.0	26.7	7.1
Rice bran	90.3	7.6	38.8	7.3	19.0	2.9	2.4
Rice hulls	91.2	0.3	19.9	0.7	5.1	1.7	1.4
Canada field pea	85.0	19.7	49.3	0.4	37.9	8.4	10.1
Canada field pea meal	89.5	16.8	51.7	0.7	32.3	8.2	9.9
Canada field pea bran*	89.0	7.7	41.6	0.6	16.0	3.1	10.3
Table bean meal*	89.1	20.2	42.3	1.3	37.1	12.0	12.9
Cowpea	85.4	16.8	54.9	1.1	32.8	10.1	12.0
Soybean	88.3	29.1	23.3	14.6	53.6	10.4	12.6
Horse bean*	88.7	23.1	49.8	0.8	42.6	12.0	12.9
Kafir corn	90.1	5.2	44.3	1.4	17.9	------	----
Ground kafir corn heads*	86.4	4.2	42.4	1.2	14.7	------	----
Sorghum seed*	87.2	4.5	61.1	2.8	14.6	8.4	3.4
Milo maize seed*	91.0	4.9	44.8	1.3	17.1	------	----
Ground milo maize heads*	90.3	4.2	45.0	1.1	14.7	------	----
Broom-corn seed*	87.2	4.6	42.2	1.5	15.8	7.2	5.2
Millet seed	87.9	7.1	48.5	2.5	17.4	6.5	3.3
Hungarian grass seed*	90.5	6.4	48.8	3.3	15.8	4.7	3.8
Flax seed	90.8	20.6	17.1	29.0	36.2	13.9	10.3
Linseed meal, old process	90.2	30.2	32.0	6.9	54.2	16.6	13.7
Linseed meal, new process	91.0	31.5	35.7	2.4	60.0	17.4	13.4
Cotton seed	89.7	12.5	30.0	17.3	29.4	10.5	10.9
Cotton seed, roasted	93.9	7.9	25.5	19.9	26.9	------	----
Cotton-seed meal	93.0	37.6	21.4	9.6	72.5	30.4	15.8
Cotton-seed hulls	88.9	0.3	33.2	1.7	6.7	4.3	10.4
Palmnut cake	89.6	16.0	52.6	9.0	26.9	11.0	5.0

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
CONCENTRATES—con.							
Grains, seeds, and their parts—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Cocoanut cake	89.7	15.4	41.2	10.7	31.5	16.0	24.0
Sunflower seed	91.4	14.8	29.7	18.2	26.1	12.2	5.6
Sunflower-seed cake	89.2	29.5	23.3	8.0	52.5	21.5	11.7
Peanut kernels, without hulls	92.5	25.1	13.7	35.6	44.6	12.4	12.7
Peanut cake	89.3	42.8	20.4	7.2	76.2	20.0	15.0
Rape-seed cake	90.0	25.3	23.7	7.6	49.9	20.0	13.0
Sesame oil cake	92.6	33.0	10.9	23.4	58.7	32.7	14.5
Factory by-products							
Dried brewers' grains	91.3	20.0	32.2	6.0	40.0	16.1	2.0
Wet brewers' grains	23.0	4.9	9.4	1.7	10.7	4.2	0.5
Malt sprouts	90.5	20.3	46.0	1.4	42.1	17.4	19.9
Dried distillers' grains	92.4	22.8	39.7	11.6	49.9	6.0	1.7
Apple pomace	17.0	0.6	13.1	0.5	1.6	0.1	0.3
Cassava starch refuse*	88.0	0.4	74.0	0.6	1.2	0.6	2.8
Starch refuse*	88.0	2.4	70.6	1.1	7.6	2.9	1.5
Wet starch feed	31.2	3.7	12.4	2.6	8.0	0.5	0.2
Potato pomace	7.3	0.4	6.8	0.1	0.9	0.2	0.9
Bakery refuse*	87.0	7.0	55.5	4.8	12.8	----	----
Wet beet pulp	10.2	0.5	7.7	----	1.4	0.3	11.4
Dried beet pulp	91.6	4.1	64.9	----	12.9	2.2	3.1
Sugar beet molasses	79.2	4.7	54.1	----	14.5	0.5	56.3
Porto Rico molasses*	74.1	1.4	59.2	----	4.3	1.2	36.8
Dried molasses beet pulp	92.0	6.1	68.7	----	15.4	1.5	18.1
Molasses grains	89.6	10.8	48.0	2.2	27.4	8.5	21.1
Alfalmo*	90.9	9.8	40.8	0.9	20.9	----	----
Cow's milk	12.8	3.4	4.8	3.7	5.8	1.9	1.7
Cow's milk, colostrum	25.4	17.6	2.7	3.6	28.2	6.6	1.1
Skim milk	9.4	2.9	5.3	0.3	5.0	2.1	2.0
Buttermilk	9.9	3.8	3.9	1.0	6.4	1.7	1.6
Whey*	6.2	0.6	5.0	0.2	1.0	1.1	2.0
Meat scrap	89.3	66.2	----	13.4	114.0	81.1	----
Meat and bone meal*	94.0	36.7	5.5	10.6	63.2	146.8	----
Dried blood	91.5	70.9	----	2.5	135.0	13.5	7.7
Tankage*	93.0	50.1	----	11.6	86.2	139.0	3.0
Dried fish	89.2	45.0	----	11.4	77.4	140.0	3.0
DRIED ROUGHAGE							
Field-cured corn forage							
Fodder corn, ears, if any, remaining	57.8	2.5	34.6	1.2	7.2	5.4	8.9
Corn stover, ears removed	59.5	1.4	31.2	0.7	6.1	3.8	10.9
Corn husks	49.1	0.8	33.8	0.2	4.0	----	----
Corn leaves	70.0	2.8	37.8	0.8	9.8	----	----
Sweet corn forage	60.0	3.4	36.2	1.1	9.8	4.0	----

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—con.							
Cured hay from the grasses, etc.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
English hay	86.0	4.5	44.0	1.2	12.6	3.2	16.1
Hay from mixed grasses	84.7	4.2	42.0	1.3	11.9	2.7	15.5
Timothy, all analyses	86.8	2.8	42.4	1.3	9.4	3.3	14.2
Timothy, cut in full bloom	85.0	3.4	43.3	1.4	9.6	5.0	14.1
Timothy, cut soon after bloom	85.8	2.5	39.2	1.5	9.1	----	----
Timothy, cut nearly ripe	85.9	2.1	40.1	1.1	8.0	----	----
Meadow foxtail	93.4	5.3	41.0	1.3	14.9	----	----
Orchard grass	90.1	4.9	42.4	1.4	12.9	3.7	16.9
Red top	91.1	4.8	46.9	1.0	12.6	3.6	10.2
White top	86.0	6.8	40.6	1.5	17.9	----	----
Meadow fescue*	80.0	4.2	36.9	1.5	11.2	4.0	21.0
Kentucky blue grass	86.0	4.4	40.2	0.7	12.5	4.0	15.7
Tall oat	86.0	3.3	41.4	1.1	10.3	----	----
Italian rye grass*	91.5	4.5	43.4	0.9	12.0	7.6	24.6
Perennial rye grass*	86.0	6.1	37.8	1.2	16.2	7.4	24.1
Rowen hay	86.0	7.9	42.2	1.4	18.2	4.3	14.9
Bermuda grass*	92.9	6.4	44.9	1.6	17.1	----	----
Johnson grass	89.8	2.9	45.6	0.8	11.5	----	----
Macaroni wheat	93.0	4.4	48.7	0.8	10.9	----	----
Barley	85.0	5.7	43.6	1.0	14.1	----	----
Oat	86.0	4.7	36.7	1.7	14.2	6.7	25.4
Emmer (speltz)	93.4	7.0	43.9	0.6	17.1	----	----
Barnyard millet	86.0	5.2	38.6	0.8	16.9	4.3	28.8
Cat-tail millet	89.0	7.2	41.6	1.0	18.5	----	----
Hungarian grass	86.0	5.0	46.9	1.1	12.1	4.3	15.4
Wild oat grass	85.7	2.9	48.7	1.7	8.0	----	----
Prairie grass	90.8	3.0	42.9	1.6	9.9	----	----
Buffalo grass	85.0	3.0	42.0	1.6	7.1	----	----
Gama grass	85.7	4.2	39.9	0.9	11.8	----	----
Texas blue grass	85.7	5.1	36.3	1.4	14.6	----	----
Guinea grass*	----	3.3	47.2	0.5	8.8	----	----
Para grass*	----	5.5	45.6	0.6	14.6	----	----
Swamp grass	88.4	4.0	38.9	0.7	11.5	----	----
Salt marsh grass	89.6	3.1	39.7	0.9	8.8	2.5	7.2
Buttercups*	90.7	4.8	40.7	1.8	15.9	----	----
Ox-eye daisy*	89.7	3.7	41.0	1.7	12.3	4.4	12.5
Australian salt bush	93.0	3.8	28.8	0.7	18.6	5.9	21.3

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
DRIED ROUGHAGE—con.							
Cured hay from legumes and mixed legumes and grasses	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Red clover	84.7	7.1	37.8	1.8	19.7	5.5	18.7
Red clover in bloom	79.2	7.7	34.0	2.8	19.9	------	----
Mammoth red clover*	78.8	6.2	34.7	2.1	17.1	5.2	11.6
Alsike clover	90.3	8.4	39.7	1.1	20.5	5.0	13.9
White clover	90.3	11.5	42.2	1.5	25.1	7.8	13.2
Crimson clover	90.4	10.5	34.9	1.2	24.3	4.0	13.1
Japan clover*	89.0	9.1	37.7	1.4	22.1	------	----
Sweet clover	92.1	11.9	36.7	0.5	28.8	5.6	18.3
Soybean	88.2	10.6	40.9	1.2	23.8	------	----
Cowpea	89.5	9.2	39.3	1.3	14.3	5.2	14.7
Alfalfa	91.9	10.5	40.5	0.9	23.4	6.1	17.9
Alfalfa leaves	95.1	16.8	35.9	1.3	37.3	------	----
Bur clover	91.0	8.2	39.0	2.1	21.8	------	----
Hairy (winter) vetch	88.7	11.9	40.7	1.6	27.2	9.7	24.4
Serradella	90.8	11.4	38.6	1.7	24.3	7.4	26.3
Peanut vine	92.4	6.7	42.2	3.0	17.1	3.2	11.6
Velvet bean	90.0	9.6	52.5	1.4	22.4	------	----
Beggar weed	90.8	6.8	42.8	1.6	18.9	------	----
Sanfoin	85.0	10.4	36.5	2.0	23.7	5.0	14.7
Wheat and vetch*	85.0	10.6	36.8	1.2	23.2	------	----
Oat and pea	89.5	7.6	41.5	1.5	16.5	6.1	18.1
Oat and vetch	85.0	8.3	35.8	1.3	20.5	6.0	12.7
Mixed grasses and clover	87.1	5.8	41.8	1.3	16.2	------	----
Mixed rowen	83.4	8.0	40.1	1.5	18.6	------	----
Straw and chaff							
Wheat	90.4	0.8	35.2	0.4	5.0	2.2	6.3
Rye	92.9	0.7	39.6	0.4	5.0	2.5	8.6
Oat	90.8	1.3	39.5	0.8	5.8	3.0	17.7
Barley	85.8	0.9	40.1	0.6	7.0	2.0	10.6
Millet*	85.0	0.9	34.3	0.6	6.5	1.8	17.3
Buckwheat*	90.1	1.2	37.4	0.5	8.0	1.3	11.4
Field bean	95.0	3.6	39.7	------	------	------	----
Soybean	89.9	2.3	40.1	1.0	6.8	2.5	10.4
Horse bean	90.8	4.3	39.5	0.8	14.1	------	----
Wheat chaff	85.7	1.2	25.4	0.6	7.2	3.8	8.2
Oat chaff	85.7	1.5	33.0	0.7	6.4	1.4	4.5
Flax shives	90.0	1.2	34.4	1.0	8.1	------	----
Sorghum bagasse	88.8	0.5	52.2	0.7	5.5	------	----

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE							
Green corn and sorghum forage	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Fodder corn, all varieties	20.7	1.0	11.9	0.4	2.9	1.1	3.9
Dent varieties	21.0	0.9	12.2	0.4	2.7	------	----
Dent, kernels glazed	26.6	1.1	15.0	0.7	3.2	------	----
Flint varieties*	20.2	1.1	11.4	0.5	3.2	1.3	3.1
Flint, kernels glazed	22.9	1.5	13.2	0.6	4.3	------	----
Sweet varieties	20.9	1.2	12.6	0.4	3.4	1.4	3.8
Sweet corn, without ears	20.0	0.7	11.6	0.4	2.2	------	----
Red kafir corn*	18.4	0.8	9.7	0.4	2.9	1.3	4.5
White kafir corn*	16.6	0.9	8.3	0.5	3.0	1.2	5.0
Teosinte*	9.9	0.9	4.9	0.2	2.2	0.6	9.2
Yellow milo maize*	16.8	1.1	9.3	0.3	2.7	1.1	5.7
Sorghum fodder	20.6	0.6	11.6	0.3	2.1	0.7	3.4
Sugar cane	15.8	0.5	9.5	0.3	1.9	0.9	4.4
Fresh green grasses							
Pasture grass	20.0	2.5	10.1	0.5	5.6	2.6	7.4
Kentucky blue grass*	31.9	2.8	19.7	0.8	6.6	------	----
Timothy	38.4	1.5	19.9	0.6	5.0	2.6	7.6
Orchard grass*	27.0	1.2	13.4	0.5	4.2	1.6	7.6
Red top, in bloom*	34.7	1.9	21.3	0.5	4.5	------	----
Wheat forage	22.7	1.7	12.0	0.4	3.8	1.6	6.0
Rye forage	23.4	2.1	14.1	0.4	4.2	2.5	7.1
Oat forage, stage uncertain	25.0	2.6	11.0	0.6	5.6	------	----
Oat forage, in milk	37.8	2.5	18.2	1.0	5.4	1.3	3.8
Oat forage, in bloom	25.0	1.1	12.4	0.5	2.6	------	----
Barley forage	21.0	1.9	10.4	0.3	4.3	------	----
Meadow fescue*	30.1	1.6	18.6	0.5	3.8	------	----
Italian rye grass*	26.8	1.5	12.6	0.7	5.0	2.9	11.4
Tall oat grass*	30.5	1.2	15.7	0.5	3.8	------	----
Johnson grass*	25.0	0.6	13.7	0.2	1.9	------	----
Bermuda grass	28.3	1.3	13.4	0.4	3.5	------	----
Hungarian grass	28.9	2.0	15.9	0.4	5.0	1.2	4.2
Japanese millet	25.0	1.1	13.6	0.3	3.4	2.0	3.4
Barnyard millet	25.0	1.6	14.4	0.3	3.8	1.1	5.8
Pearl millet*	18.5	0.6	10.0	0.2	1.9	1.5	7.1
Common millet*	20.0	0.8	11.0	0.2	2.4	0.7	4.7
Hog millet*	20.0	0.8	10.8	0.3	2.4	------	----
Fresh green legumes, grasses and legumes combined							
Red clover	29.2	2.9	13.6	0.7	7.0	1.5	4.8
Mammoth red clover*	20.0	2.0	9.1	0.2	4.8	------	----
Alsike clover*	25.2	2.6	11.4	0.5	6.2	1.1	2.0
Crimson clover	19.1	2.4	9.1	0.5	5.0	1.2	4.0
Sweet clover*	20.0	2.5	8.4	0.4	6.1	2.4	6.7

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
FRESH GREEN ROUGHAGE—con.							
Fresh green legumes, grasses and legumes combined—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Alfalfa	28.2	3.6	12.1	0.4	7.7	1.3	5.6
Spring vetch	15.0	1.9	6.6	0.2	4.3	1.0	4.5
Cowpea	16.4	1.8	8.7	0.2	3.8	1.3	4.6
Hairy vetch, winter	15.0	2.8	6.4	0.3	5.8	1.4	5.2
Hairy vetch, in bloom	18.0	3.5	7.7	0.3	6.7	----	----
Soybean	24.9	3.1	11.0	0.5	6.4	1.4	5.6
Serradella*	20.5	2.1	8.9	0.4	4.3	1.6	5.5
Horse bean*	15.8	2.3	7.3	0.2	4.5	0.5	2.1
Velvet bean	17.8	2.7	8.4	0.4	5.6	----	----
Sanfoin	25.0	2.9	11.1	0.5	7.0	1.4	5.7
Canada field pea	15.3	1.8	6.9	0.3	4.5	1.6	5.0
Canada field pea, in bud	15.0	2.6	6.8	0.3	5.0	1.1	4.4
Canada field pea, in bloom	13.0	2.3	5.3	0.2	4.5	1.1	3.2
Canada field pea, in pod	16.0	1.9	7.0	0.2	3.7	1.3	3.7
Barley and vetch	20.0	2.1	6.5	0.3	4.5	2.0	5.7
Barley and peas	20.0	2.1	9.1	0.4	4.5	----	----
Oats and peas	20.3	1.8	10.2	0.4	3.8	1.5	5.0
Oats and vetch*	20.0	2.3	10.0	0.2	4.8	1.4	3.0
Wheat and vetch*	20.0	2.6	10.3	0.3	5.4	----	----
Mixed grasses and clover	25.0	2.3	14.6	0.5	4.6	----	----
Roots and tubers							
Potato	20.9	1.1	15.7	0.1	3.4	1.6	5.8
Common beet*	11.5	1.2	7.9	0.1	2.4	0.8	4.8
Mangel	9.1	1.0	5.5	0.2	2.2	0.9	3.8
Sugar beet	13.5	1.3	9.8	0.1	2.9	0.8	3.7
Flat turnip	9.9	0.9	6.4	0.1	2.1	0.9	3.4
Carrot*	11.4	0.8	7.7	0.3	1.8	0.9	2.6
Rutabaga	11.4	1.0	8.1	0.2	1.9	1.2	4.9
Parsnip*	11.7	1.1	10.1	0.2	2.6	2.0	4.4
Artichoke*	20.5	1.3	14.7	0.2	4.2	1.4	4.7
Sweet potato*	28.9	0.8	22.9	0.3	2.4	0.8	3.7
Chufa	20.5	0.6	9.1	5.6	----	----	----
Cassava	34.0	0.8	28.9	0.2	2.0	1.0	4.0
MISCELLANEOUS							
Acorns*	44.7	2.1	34.4	1.7	4.0	----	----
Apples	22.2	0.8	16.5	0.2	1.2	0.1	1.7
Dwarf Essex rape	14.3	2.0	8.2	0.2	3.5	1.2	3.5
Dwarf Essex rape, summer, southern states	15.0	1.9	8.6	0.2	3.4	----	----
Dwarf Essex rape, winter, southern states	15.0	2.0	8.1	0.2	3.7	----	----
Cabbage*	10.0	2.3	5.9	0.1	4.2	1.1	4.3

TABLE III. Digestible nutrients and fertilizing constituents—*con.*

Name of feed	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.			Fertilizing constituents in 1,000 lbs.		
		Crude protein	Carbohydrates	Fat	Nitrogen	Phosphoric acid	Potash
MISCELLANEOUS—con.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Sugar beet leaves	12.0	1.9	5.0	0.2	4.2	1.5	6.2
Field pumpkin	9.1	1.0	5.8	0.2	2.1	----	----
Garden pumpkin	19.2	1.4	8.3	0.4	2.9	1.6	0.9
Prickly pear*	15.8	0.4	6.2	0.2	1.1	0.2	3.7
Cane cacti	21.5	0.9	11.1	0.4	2.3	0.6	3.5
Dried banana tops*	----	4.4	36.6	0.8	21.1	----	----
Dried banana butts*	----	2.1	37.1	0.9	10.2	----	----
Spurry	20.0	1.5	9.8	0.3	3.8	2.5	5.9
Prickly comfrey	13.0	1.7	5.1	0.2	3.7	1.2	7.6
Purslane	9.0	2.0	4.5	0.1	3.7	----	----
Dandelions*	15.7	1.1	7.5	2.0	1.9	----	----
Greasewood	95.5	10.9	40.9	1.8	----	----	----
Common little sage*	65.0	3.2	19.7	0.9	21.9	----	----
Common sage	50.4	1.2	14.1	3.8	7.4	----	----
Australian salt bush	22.0	2.0	8.5	0.3	4.4	1.4	5.0
Dried oak leaves, gathered in July*	95.1	3.2	34.6	1.6	15.2	----	----
Dried mixed tree leaves, gathered in July*	84.0	3.5	30.4	1.1	16.8	----	----
Dried beech twigs, gathered in winter*	84.7	0.9	21.8	0.6	6.4	----	----
SILAGE							
Corn, early analyses	20.9	0.9	11.4	0.6	2.7	1.1	3.7
Corn, recent analyses	26.4	1.4	14.2	0.7	4.3	1.1	3.7
Corn, ears removed*	26.3	1.1	14.9	0.7	3.5	----	----
Sorghum	23.9	0.1	13.5	0.2	1.3	1.5	1.9
Millet*	26.0	0.2	13.1	0.6	2.7	1.4	6.2
Rye*	19.2	0.7	9.0	0.2	3.8	----	----
Red clover	28.0	1.5	9.2	0.5	6.7	----	----
Canada field pea*	49.9	3.4	25.5	1.0	9.4	----	----
Soybean	25.8	2.7	9.6	1.3	6.6	1.6	7.5
Cowpea vine	20.7	1.5	8.6	0.9	4.3	1.5	4.6
Brewers' grains*	29.7	4.6	11.5	1.8	10.1	4.2	0.5
Apple pomace*	15.0	0.7	9.6	0.5	1.9	1.5	4.0
Corn cannery refuse, husk*	16.2	0.4	10.1	0.4	2.2	----	----
Corn cannery refuse, cobs*	25.9	0.3	13.7	0.9	2.4	----	----
Pea cannery refuse*	23.2	2.1	13.1	0.8	4.5	----	----
Cowpea and soy bean*	30.2	2.2	12.9	0.8	6.1	----	----
Corn and soy bean	24.0	1.6	13.2	0.7	4.0	1.5	3.6
Barnyard millet and soy bean	21.0	1.6	9.2	0.7	4.5	1.1	4.4

Table IV. The Wolff Feeding Standards for Farm Animals.

In 1864 Dr. Emil von Wolff, the great German scientist, presented in the Mentzel & von Lengerke Agricultural Calendar, published annually by Paul Parey, Berlin, Germany, a table of feeding standards for farm animals based on the digestible nutrients in feeding stuffs. This marked an era in the history of efforts toward the rational feeding of farm animals. The last appearance of the table under the directorship of Dr. Wolff was in 1896. From 1896 to 1906 the table was annually presented by Dr. C. Lehmann, of the Berlin Agricultural High School. The table which follows is a copy of the last presentation by Dr. Lehmann.

The table is given because historically it is worthy of a place in any book on the feeding of farm animals, and further because no matter what line one may ultimately follow in these matters, he should know and understand the teachings of Wolff.

The table has been for the most part fully considered in Chapter VIII, to which the student is referred for further explanation as to its purpose and manner of use. It only remains to say that the figures given in the column headed "Sum of nutrients" were written into the table by Lehmann in a primitive effort toward expressing the energy value of feeding stuffs. Having been superseded by later work, (**69-73, 141-6**) no explanation of how the figures the column contains were derived is necessary in this work. The following explanations accompany the table:

In considering the fattening standards the student should bear in mind that the most rapid fattening is usually the most economical, so that the standards given may often be profitably increased.

Standards for milch cows are given for the middle of the lactation period with animals yielding milk of average composition.

The standards for growing animals contemplate only a moderate amount of exercise; if much is taken, add 15 per cent.—mostly non-nitrogenous nutrients—to the ration. If no exercise is taken, deduct 15 per cent. from the standard.

The standards are for animals of normal size. Those of small breeds will require somewhat more nutrients, amounting in some cases to 0.3 of a pound of nitrogenous and 1.5 pounds of non-nitrogenous digestible nutrients daily for 1,000 pounds of live weight of animals.

Narrowing the nutritive ratio in feeding full-grown animals is for the purpose of lessening the depression of digestibility, to enliven the temperament, or to increase the production of milk at the expense of laying on fat.

The different standards given for the same class of animals according to performance illustrate the manner and direction in which desirable changes should be made.

Animal	Per day per 1,000 lbs. live weight					
	Dry matter	Digestible nutrients				
		Crude protein	Carbohydrates	Fat	Sum of nutrients	Nutritive ratio, 1:
1. *Oxen*	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
At rest in stall	18	0.7	8.0	0.1	7.5	11.8
At light work	22	1.4	10.0	0.3	9.7	7.7
At medium work	25	2.0	11.5	0.5	12.0	6.5
At heavy work	28	2.8	13.0	0.8	15.0	5.3
2. *Fattening cattle*						
First period	30	2.5	15.0	0.5	15.6	6.5
Second period	30	3.0	14.5	0.7	17.0	5.4
Third period	26	2.7	15.0	0.7	17.2	6.2
3. *Milch cows*						
When yielding daily—						
11.0 pounds of milk	25	1.6	10.0	0.3	10.2	6.7
16.6 pounds of milk	27	2.0	11.0	0.4	12.2	6.0
22.0 pounds of milk	29	2.5	13.0	0.5	14.4	5.7
27.5 pounds of milk	32	3.3	13.0	0.8	16.0	4.5
4. *Sheep*						
Coarse wool	20	1.2	10.5	0.2	9.1	9.1
Fine wool	23	1.5	12.0	0.3	10.5	8.5
5. *Breeding ewes*						
With lambs	25	2.9	15.0	0.5	16.3	5.6
6. *Fattening sheep*						
First period	30	3.0	15.0	0.5	16.5	5.4
Second period	28	3.5	14.5	0.6	16.9	4.5
7. *Horses*						
Light work	20	1.5	9.5	0.4	10.0	7.0
Medium work	24	2.0	11.0	0.6	12.8	6.2
Heavy work	26	2.5	13.3	0.8	15.5	6.0
8. *Brood sows*	22	2.5	15.5	0.4	19.0	6.6
9. *Fattening swine*						
First period	36	4.5	25.0	0.7	31.2	5.9
Second period	32	4.0	24.0	0.5	29.2	6.3
Third period	25	2.7	18.0	0.4	22.0	7.0

TABLE IV. Feeding standards for farm animals—*continued.*

Animal		Per day per 1,000 lbs. live weight					
		Dry matter	Digestible nutrients				
			Crude protein	Carbohydrates	Fat	Sum of nutrients	Nutritive ratio, 1:
10. Growing cattle							
Dairy breeds							
Age in months	Av. live wt. per head, lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
2–3	150	23	4.0	13.0	2.0	21.0	4.5
3–6	300	24	3.0	12.8	1.0	17.0	5.1
6–12	500	27	2.0	12.5	0.5	13.7	6.8
12–18	700	26	1.8	12.5	0.4	12.8	7.5
18–24	900	26	1.5	12.0	0.3	11.8	8.5
11. Growing cattle							
Beef breeds							
2–3	160	23	4.2	13.0	2.0	21.5	4.2
3–6	330	24	3.5	12.8	1.5	19.0	4.7
6–12	550	25	2.5	13.2	0.7	15.8	6.0
12–18	750	24	2.0	12.5	0.5	13.9	6.8
18–24	950	24	1.8	12.0	0.4	13.2	7.2
12. Growing sheep							
Wool breeds							
4–6	60	25	3.4	15.4	0.7	18.4	5.0
6–8	75	25	2.8	13.8	0.6	15.8	5.4
8–11	80	23	2.1	11.5	0.5	12.8	6.0
11–15	90	22	1.8	11.2	0.4	12.0	7.0
15–20	100	22	1.5	10.8	0.3	11.0	7.7
13. Growing sheep							
Mutton breeds							
4–6	60	26	4.4	15.5	0.9	20.9	4.0
6–8	80	26	3.5	15.0	0.7	17.8	4.8
8–11	100	24	3.0	14.3	0.5	16.3	5.2
11–15	120	23	2.2	12.6	0.5	13.8	6.3
15–20	150	22	2.0	12.0	0.4	12.8	6.5
14. Growing swine							
Breeding stock							
2–3	50	44	7.6	28.0	1.0	38.0	4.0
3–5	100	35	4.8	22.5	0.7	29.0	5.0
5–6	120	32	3.7	21.3	0.4	26.0	6.0
6–8	200	28	2.8	18.7	0.3	22.2	7.0
8–12	250	25	2.1	15.3	0.2	17.9	7.5
15. Growing, fattening swine							
2–3	50	44	7.6	28.0	1.0	38.0	4.0
3–5	100	35	5.0	23.1	0.8	30.0	5.0
5–6	150	33	4.3	22.3	0.6	28.0	5.5
6–8	200	30	3.6	20.5	0.4	25.1	6.0
9–12	300	26	3.0	18.3	0.3	22.0	6.4

TABLE V. MINERAL MATTER IN 1,000 LBS. OF REPRESENTATIVE FEEDING STUFFS.

The data presented in the following table are compiled from analyses by the American Experiment Stations, supplemented by others taken from Wolff's *Ash Analyses.* The older determinations of sulphur in feeding stuffs are too low on account of faulty methods of analysis. The figures here given for sulphur are the result of recent work at the Wisconsin Station.

Name of feed	Total ash	Pot-ash K_2O	Soda Na_2O	Lime CaO	Mag-nesia MgO	Iron oxide Fe_2O_3	Sul-ph'ric acid SO_3	Phos-ph'ric acid P_2O_5	Silica SiO_2	Chlo-rin Cl
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Corn	15.0	5.7	0.2	0.3	2.3	0.11	3.9	7.1	0.31	0.14
Wheat, winter	18.0	8.7	0.4	0.6	2.2	0.23	4.3	5.5	0.35	0.06
Oats	32.0	4.8	0.5	1.2	2.3	0.38	4.7	7.8	12.54	0.30
Barley	25.0	4.8	0.6	0.7	2.2	0.30	3.8	7.9	6.48	0.26
Wheat bran	58.0	15.2	0.4	1.7	9.7	0.34	5.0	26.9	0.26	-----
Linseed meal, o. p.	55.0	13.7	0.8	4.6	8.7	1.44	10.1	16.6	6.88	0.39
Cotton-seed meal	66.0	15.8	-----	2.9	10.0	0.84	12.2	30.4	5.48	0.03
Pea meal	26.0	9.9	0.3	1.3	2.1	0.22	-----	8.2	0.24	0.41
Dried brewers' grains	37.0	2.0	0.2	5.2	3.7	0.39	-----	16.1	12.27	-----
Malt sprouts	61.0	19.9	1.1	1.7	1.7	0.95	-----	17.4	13.46	4.23
Corn stover	34.0	10.9	6.5	4.3	2.1	0.71	3.2	3.8	9.10	0.41
Timothy hay	44.0	14.2	0.8	3.5	1.4	0.37	4.8	3.3	14.15	2.28
Red clover hay	62.0	18.7	1.2	21.6	6.8	0.67	4.1	5.5	1.67	2.34
Alfalfa hay	106.0	17.9	1.9	43.1	5.2	1.97	7.2	6.1	10.11	3.19
Cowpea hay	142.2	14.7	2.5	12.7	4.2	-----	-----	5.2	-----	-----
Wheat straw	42.0	6.3	0.6	2.4	1.0	0.26	3.0	2.2	28.35	0.71
Oat straw	51.0	17.7	1.7	3.6	1.9	0.59	4.9	3.0	23.81	2.23
Corn silage	21.0	3.7	1.0	2.8	2.2	-----	1.3	1.1	-----	1.01
Mangel	11.0	3.8	0.4	1.8	0.5	0.08	0.3	0.9	0.22	1.10
Rutabaga	12.0	4.9	0.7	1.4	0.4	0.07	2.6	1.2	0.13	0.79

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