LIPPINCOTT'S FARM MANUALS

PRODUCTIVE FEEDING OF FARM ANIMALS

BY F. W. WOLL PH. D.

"The first farmer was the first man, and all historic nobility rests on possession and use of land."
—EMERSON.

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EDITED BY
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PROFESSOR OF AGRICULTURE, SCHOOL OF COUNTRY LIFE
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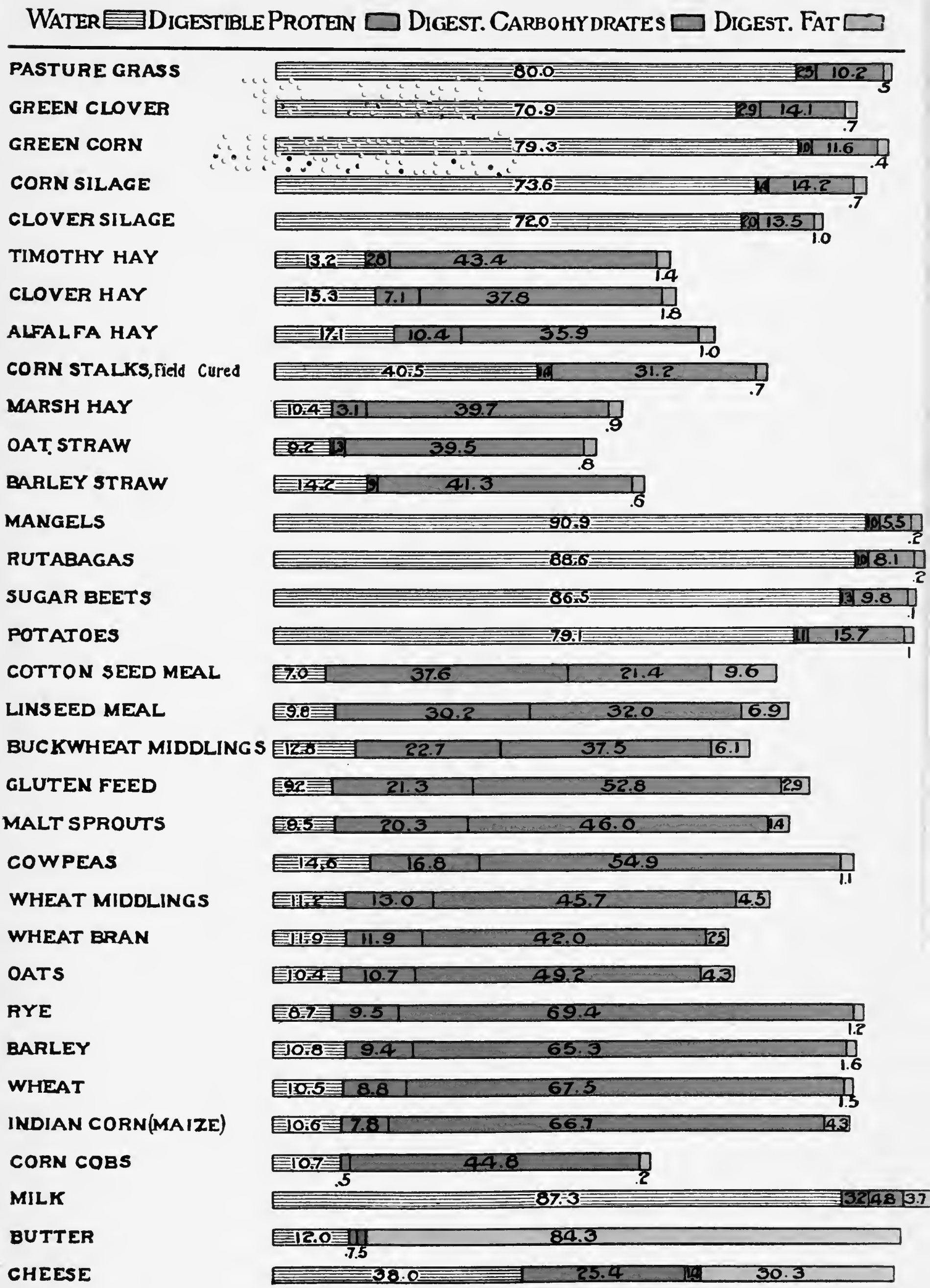

COMPOSITION OF FEEDING STUFFS

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105 ILLUSTRATIONS IN THE TEXT

SECOND EDITION REVISED

"If vain our toil,
We ought to blame the culture, not the soil."
POPE—*Essay on Man*

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PREFACE

The general interest in matters pertaining to the farm and farm life that has been evidenced in recent years is one of the wholesome signs of the times. Farm animals have shared in this increasing interest, and the love of fine stock, as well as the desire to surround the animals with conditions that will secure the best results for the care and labor bestowed upon them, has been a potent factor in the development of animal industry in this country during the last generation. For permanent and fruitful advance in agricultural matters, it is agreed that the boy must be interested; must learn about the realities and problems of farm life; must be taught how to meet these and how to adjust himself to changes in new conditions of farming that may arise. Hence we find that courses in agriculture are being introduced into more and more schools; the agricultural college no longer has a monopoly of teaching animal husbandry, field crops, horticulture, etc. County agricultural schools and agricultural high schools, as well as graded schools in a number of States, are giving their pupils an opportunity to study the underlying principles of farm operations.

Until recently there were no text-books that met the needs of these different classes of students. This want is now, however, gradually being filled, and in some cases there is already a choice of carefully-prepared books, well adapted for the purpose intended. This volume has been prepared with a view to furnishing students in agricultural schools and colleges, as well as practical farmers, with a concise discussion of the main principles relating to the feeding of farm animals and of the various feeding stuffs available to our stockmen. So far as possible, different feeding practices for the various classes of farm animals have also been given and discussed, pointing the way to profitable methods of stock feeding under the variety of conditions existing on American farms.

The treatment of this subject in text-book form presents peculiar difficulties. In view of the immense amount of research work that has accumulated and is being conducted and published every year, at public expense and otherwise, it would be easy to present a bewildering mass of detailed experimental evidence as to the merits of different feeds and methods of feeding. This would not, however, serve the purpose of either teacher or student. It has been the aim of the author to give a well-digested, systematic treatment of the subject. It is hoped that the presentation will commend itself to the judgment of educators and farmers, and that a study of this book will aid them to a clear understanding of the principles of productive feeding of farm animals.

Acknowledgment for loan of photographs or cuts is due to the Directors of the Agricultural Experiment Stations at Berkeley, Cal.; Ottawa, Canada; Ithaca, N. Y.; State College, Pa.; Burlington, Vt.; Madison, Wis., and U. S. Bureau of Animal Industry; Professors K. C. Davis, S. B. Doten, David Griffiths, I. D. Iddings, Frank L. Peterson, E. A. Trowbridge, and Gordon H. True; American Guernsey Cattle Club; W. J. Gillett, Rosendale, Wis.; A. W. Morris & Sons Corp., Woodland, Cal.; Publishers *Breeders' Gazette,* Chicago, and *Pacific Rural Press,* San Francisco, Cal., and Hog Motor Company, Minneapolis.

F. W. Woll.

Davis, Cal., January, 1915.

PREFACE TO SECOND EDITION

Minor changes and corrections have been made in the present edition, and a chapter on Feeding Poultry, prepared by Prof. J. E. Dougherty, of the University of California, has been incorporated, in order that students and farmers may learn the main principles of feeding this important class of livestock. It is believed that the usefulness of the book will be further increased by the addition and changes thus made in the text.

Davis, California, June, 1916.

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PRODUCTIVE FEEDING OF FARM ANIMALS

INTRODUCTION

PRODUCTIVE feeding of farm animals is only one of the factors on which successful animal husbandry depends; others are: Keeping the right kind of stock; giving it the necessary care and attention and maintaining the animals in a healthy condition. Each of these factors is of fundamental importance to the stockman. If one is not given due attention, the results secured will not be satisfactory, no matter how favorable the conditions with which the animals may be surrounded in other respects.

A clear understanding of the main principles underlying the nutrition of farm animals has never been more important to the stock farmer than at the present time, with prevailing high prices for feed and labor. In order to secure profitable returns, the farmer must be able to adapt these principles to the special conditions that surround him; these are likely to vary in different years, both as to prices and products. Modern industries supply immense quantities of by-products that serve as feed for farm stock, such as flour- and oil-mill feeds, starch and sugar-factory feeds, brewery and distillery feeds, and others. These differ much in nutritive values as well as in cost. Since better results may be obtained in feeding stock a combination of different feeds than from only one or two, it is important not only to understand the principles of stock feeding, but to become familiar with the different available feeding stuffs, their main characteristics and nutritive properties, as well as their relative values under changing market conditions. Only in this way can the stock farmer secure the best and most economical returns from his feeding operations and make stock raising pay; provided the other factors have received proper attention: Keeping animals adapted for the purpose in view, and giving them the care which they require in order to do well.

Animal husbandry is one of the most remunerative branches of agriculture when rightly conducted, and it makes permanent agriculture possible. The stock farmer is a manufacturer, converting the raw materials raised on the farm into valuable human food products. Generally speaking, the animal products sold contain only small amounts of fertility, and the stock farmer can, therefore, secure good crops from his land for an indefinite period with a relatively small outlay for fertilizers. He does not, like many grain farmers, rob the farm of its fertility until it will no longer produce paying crops, making it necessary to change the system of farming or to move on to some other section where the same method of selling the fertility of the land can be repeated. Stock farming can be pursued on the same land with excellent results from generation to generation, and for centuries, as is shown by conditions in the agricultural regions of the Old World.

The livestock farmer utilizes his own labor and that of his family throughout the year, and not only during the growing season. Stock raising in general leads to thrift and develops some of the best qualities in man. His children grow up with young stock and learn to enjoy and love them, and thus in turn acquire one of the fundamentals for successful animal husbandry, an appreciation of good stock and love of animals. Without these qualities, a farmer is not likely to give his stock the watchful care that they require for best results.

There are various reasons why animal husbandry will continue to be one of the best paying branches of agriculture in America. One is, that our population is increasing considerably faster than is the number of farm animals. This holds true of all classes of livestock, except horses; there has, in reality, been an actual decrease in the number of cattle, sheep, and swine in this country since the beginning of the present century, while our population increased over twenty per cent from 1900 to 1910.

Another reason why stock raising will prove a profitable business in the future is the fact that it is not likely to be overcrowded. Stock raising calls for a larger investment than grain farming, and many farmers do not have or cannot secure the necessary capital to engage in animal husbandry; this is true especially of the large and increasing class of tenant farmers in many of the States. Furthermore, it takes from nearly a year to three or four years, according to the system of stock raising adopted, before the investment will yield any revenue. Like people in other walks of life, many farmers lack the necessary business ability and foresight to plan ahead for such a period. If cattle, *e.g.*, are low, and produce little or no revenue one year, it is easy to get discouraged, and many cannot see that such a period is just the time when one should plan for cattle raising, since a shortage of cattle with resulting high prices is certain to follow a period of low prices.

The preceding considerations suggest the reasons for the belief held by those familiar with the situation, that the prospects for the livestock industry in this country are very bright. In spite of the high cost of feed and labor and the rise in land values during the last decade, the industry will furnish excellent opportunities for farmers that give their stock good care. But the changed conditions call for a higher type of farming and stock raising than that followed by the majority of farmers of earlier times.

Only improved stock, bred for the specific purpose in view, can give the results that must be reached to make stock raising profitable on high-priced land, and systems of feeding and management must be adopted that will secure such returns at a minimum cost. To be successful, the stock raiser must be a student and a business man, in addition to a farmer. He should secure all the technical knowledge relating to his profession that he can, and understand the leading principles of the livestock industry, so that he may be prepared to grapple successfully with the problems that confront the stockman.

PART I

PRINCIPLES OF FEEDING FARM ANIMALS

CHAPTER I

THE COMPOSITION OF FEEDING STUFFS

THE feeding stuffs used for the nutrition of farm animals are, as a general rule, of vegetable origin. They are either farm crops grown especially for this purpose, or are by-products from manufacturing processes in which farm crops furnish the raw materials. It will be well, therefore, to examine into the composition of plants at the outset, in order that the discussions given in the following pages relative to the feeding of farm animals and problems connected therewith may be clearly understood.

Chemical Elements.—Plants are composed of an immense number of different compounds; some of these are present in large proportions, others in only small amounts. When these compounds are separated into their ultimate constituents we find that they contain a relatively small number of substances which, according to our present knowledge, cannot be further subdivided. These substances are known as *elements*. About a dozen of the elements are absolutely necessary to plant life, and no plant can grow in the absence of one or more of them. These so-called *essential elements* are:

Carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, fluorin, and iodin.

A few other elements may not be essential to plant growth, but are always present in plants. These are:

Sodium, chlorin, silicon, and *manganese.*

The first group of elements, in fact the first six of them, make up the bulk of all plant materials; over 95 per cent of the weight of most plants and feeding stuffs is composed of these few elements. But the other essential elements, although present in small amounts, are equally important, since plants cannot grow to maturity if any of them be lacking in the soil or not available to the plant.

Group of Components in Feeds.—The elements given in the preceding paragraph are present in plants in chemical combinations with each other, forming in some cases very complex substances whose exact composition has not yet been ascertained. For our present purpose they may, however, be conveniently considered as belonging to a few groups of substances which can be readily determined by chemists. These groups of components are separated in the customary chemical analysis of feeding stuffs, and the percentage quantities present in each are ascertained. For the purposes of chemical analysis and for our discussions we may thus consider plant materials composed of—

I. Water.
II. Dry substance.

The dry substance of plants is of either (1) mineral or (2) so-called organic origin. The former components are known as mineral matter or ash; while the organic matter is composed of the following groups of substances: Protein, fat, nitrogen-free extract, and fiber. The last two belong to a group of substances known as carbohydrates.

The schedule given below will help to make clear these various groups of plant components:

Plants contain—		Composed of the elements
I. Water		Oxygen, hydrogen.
II. Dry substance:	1. Mineral matter (ash)	Potassium, sodium, calcium, magnesium, sulfur, chlorin, iron, phosphorus, silicon, etc.
	2. Protein	Carbon, oxygen, hydrogen, nitrogen, sulfur (and sometimes phosphorus).
	3. Fat 4. Nitrogen-free extract 5. Fiber	Carbon, oxygen, hydrogen.

COMPOSITION OF PLANTS

Water is found in all plants and plant materials, ranging in amount from 5 per cent to 95 per cent in extreme cases. Some factory by-products which have been artificially dried contain less than 10 per cent, in some cases as low as 5 per cent of water. Hay and dry coarse feeds generally contain from 10 to 20 per cent, while corn fodder (stover) and some kinds of hay, as alfalfa, will occasionally contain as much as 30 per cent of water when imperfectly cured or exposed to damp or rainy weather. The cereals and most concentrated feeds contain about 12 per cent water; green forage crops from 70 to 90 per cent; silage, 70 to 80 per cent; root crops, beet pulp, and wet brewers' grains, 80 to 90 per cent; in case of turnips and some vegetables, as pumpkins, the water content may reach even 93 to 95 per cent (Fig. 1).

A knowledge of the amount of water in a feeding stuff is important, both because its value for the nutrition of farm animals is dependent thereon and because its keeping quality is affected thereby. An excessive water content renders plant materials liable to decomposition through the growth of bacteria and molds.

Water is the vehicle by which nutrients in both plants and animals are transported from one part to another. Plants absorb it from the soil through their roots, and with it take up mineral matter held in solution in the soil water. The quantity of water

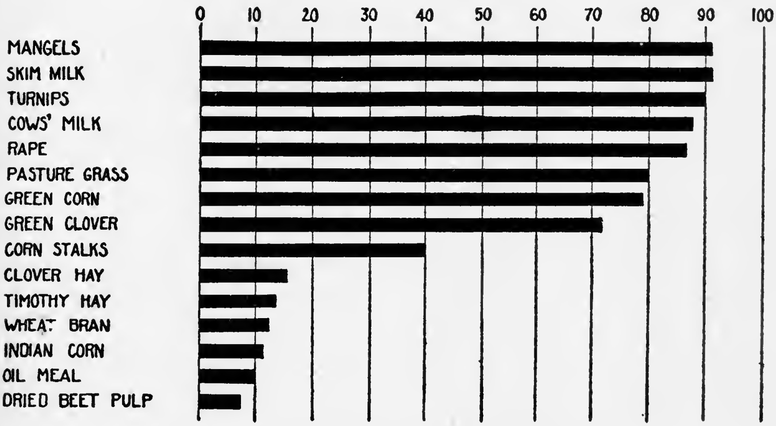

FIG. 1.—Water in common feeding stuffs, in per cent.

thus taken up by plants is very large, and this is partly retained in the cells and the sap of the plants, and partly again evaporated through the leaves. For every pound of dry substance in the plant it has been found that about 400 pounds of water are required, on the average, the exact figure varying from below 300 to over 1000 pounds, according to the character of the soil and the crop.

Dry Substance.—The components of the dry substance of plants considered in the following pages are: Mineral matter or ash, protein, fat, nitrogen-free extract, and fiber.

Mineral matter in plants is derived from the soil through the root system. This is the portion of the plants which remains as ashes after combustion. It is composed of the elements already given and, in addition, of many elements that happen to be present in the soil where the plant grew. The elements found in the mineral matter are present in one or two forms: Either in inorganic form, in combinations of two or more of the elements, as sulfates, phosphates, nitrates, chlorides, or silicates, combined with bases, as potassium, sodium, calcium, magnesium, and iron; or in organic form, as constituents of organic compounds. Especially in the case of seeds of plants the ash materials are present largely in the latter form.

Ordinary feeding stuffs contain, as a rule, only relatively small amounts of mineral matter, viz.: Less than 5 per cent, except in the case of some factory by-products and dry forage, in which the ash content may go even above 10 per cent. Leafy plants con-

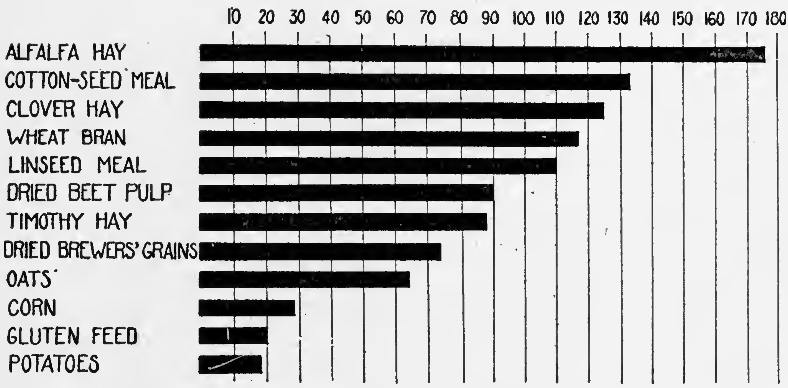

FIG. 2.—Mineral matter in a ton of common feeds, in pounds.

tain relatively large percentages of ash, like all parts of plants in which a considerable evaporation of water takes place. On the other hand, by-products in manufacturing processes where the raw materials are treated with large quantities of water, as gluten feed, brewers' grains, etc., have comparatively small ash contents (Fig. 2).

Protein is a general name for nitrogenous organic compounds of a very complex chemical structure. They contain carbon, oxygen, hydrogen, and nitrogen, with a small percentage of sulfur and, in some cases, phosphorus. The name protein was given to these substances by Mulder, a German chemist, and means the first or the most important. This term is justified from a physiological point of view, inasmuch as protein is absolutely essential to animal life.

The protein substances are characterized by the fact that all contain the element nitrogen, which is not found in the other groups of organic plant substances. It was formerly believed that all proteins contain about 16 per cent nitrogen, and, since this element can be readily determined by the chemist, the content of protein in a substance was obtained by multiplying the nitrogen content by $\frac{100}{16}$, or 6.25. Later investigations showed that the different protein substances vary considerably in chemical composition, and that the percentage of nitrogen they contain may range from 15 to over 19 per cent. Hence, the factor 6.25 is often not correct, but it is generally applied, since our knowledge of the composition of pure proteins from different sources is still incomplete. We shall, therefore, continue the use of the factor 6.25 in this book until chemists have agreed on specific factors to be used in the case of plant materials and feeding stuffs of different origin.

Besides nitrogen, proteins contain between 50 and 55 per cent of carbon, 6 to 7 per cent hydrogen, 20 to 24 per cent oxygen, 0.3 to 2.3 per cent sulfur; the phosphorus content of the proteins in which this element is present ranges between 0.4 and 0.9 per cent. The average composition of protein substances may be given as follows:

Carbon, 53 per cent.
Hydrogen, 7 per cent.
Oxygen, 22 per cent.
Nitrogen, 16 per cent.
Sulfur, 2 per cent.

The proteins form a most important group of nutrients, since they furnish the materials for building up body tissues and fluids; other nutrients cannot take their place for this purpose. We shall see, however, that protein may also serve other purposes than to furnish material for tissue building when necessary, viz.: To supply energy that may be used for maintaining body heat, for performing work, or for storage as body fat.

Classification of Proteins.—Protein substances are generally classified as (1) simple, (2) conjugated, and (3) derived proteins.

1. *Simple Proteins.*—The most important compounds in this group are given below.

a. Albumins.—These are soluble in pure water and are coagulated and rendered insoluble by heat. They are present in small amounts in the sap and seeds of plants. The main proteins found in the animal body belong to this class, viz.: Those of the muscle, blood, milk, and eggs. Leucosin found in the cereals, legumelin found in leguminous seeds, ricin in castor bean, and tuberin in potatoes, belong to this class.

b. Globulins are insoluble in water, but soluble in a 10 per cent sodium chloride solution. The globulins are abundant in plant materials and have been identified in many seeds of plants. The following are present in the cereals and other common seeds: Maysin in corn kernels, edestin in corn, wheat, cotton seed, and flaxseed, avenalin in oats, legumin and vicilin in leguminous seeds (peas, lentils, horse beans), glycin in soybeans, and conglutin in lupines.

c. *Alcohol-soluble proteins* are insoluble in water and soluble in 70 to 80 per cent. alcohol. To this class belong gliadin found in wheat and rye grain, hordein in barley, and zein in Indian corn.

d. *Glutelins* are insoluble in water, salt solutions and alcohol, and soluble in dilute acids and alkali. Glutenin belonging to this group, with gliadin, forms the gluten of flour; bread dough owes its stickiness to the gluten found therein; grains like rice which contain no gliadin cannot be used for bread making.

Other simple proteins are *albuminoids, histones* and *protamines;* the first substances form the organic basis of bone; tendon and ligament; hair, hoof and nails, etc. These are the most resistant groups of protein substances, being insoluble in ordinary chemical solvents, like water, alcohol, salt solutions, etc.

2. *Conjugated Proteins.*—These substances have been modified so as to possess different chemical and physical properties from the simple proteins, either through combination with other compounds or through the action of ferments, heat or chemicals. The nucleo-proteins belong to this group of which the best known is casein of milk. They contain phosphorus in addition to the elements that are always found in protein substances.

3. *Derived Proteins.*—These are intermediate substances formed in the process of digestion by cleavage of the naturally-occurring proteins; they are diffusible and are assimilated by the living cell for use in the building-up (synthesis) of true proteins. Proteose and peptones are the first representatives of this class that are formed, when protein is acted upon by enzymes of the digestive juices (pepsin, trypsin, erepsin). On further cleavage these substances are changed into amino-acids, the final decomposition products formed in the digestion of protein substances.

The **amino-acids** are the primary building materials out of which the proteins of the animal body are formed. The different protein substances vary greatly in the kinds of amino-acids which they contain, and the proportion in which these occur in the protein molecule. The differences in the nutritive value of proteins of different origin that have been observed, appear to be intimately connected with this fact.

There are eighteen different amino-acids known at present, all of which differ in their chemical constitution and the proportions in which they occur in different proteins. About one-half of this number are found in plants and plant materials. Among the more important amino-acids may be mentioned: glycine, leucine, glutamic acid, tyrosine, arginine, tryptophane, lysine and cystine. Zein (the main protein of Indian corn) has been found to contain no glycine, tryptophane or lysine. Glycine is also absent in albumins and in gliadin. The vegetable proteins contain large amounts of glutamic acid, while the animal proteins are high in leucine and also contain appreciable amounts of glutamic acid. The amino-acids found in feeding stuffs other than the cereals and other seeds have not yet been systematically studied, although a large amount of research work of these substances and their physiological value has been done during late years.

Amides are a common name for soluble crystallizable protein substances of simpler molecular structure than that of the protein substances and even some of the amino-acids. While the latter usually occur in only small amounts in free form in plants, amides are found in abundance in the sap of green and young plants, especially after sprouting, as well as in all immature plant materials. The best known amides are asparagin, found in young asparagus, peas and beans; glutamin and betain, found in the beet root, etc. The amides are intermediate products formed in the living plant from inorganic materials (nitric acid or ammonia), and are later changed into complex protein substances. They are also formed in the decomposition of proteins through the action of bacteria and molds, hence are always present in silage and other fermented feeds.

In contradistinction to total or crude protein (*i.e.,* total nitrogen multiplied by 6.25), the protein substances other than amides and amino-acids are called true proteins.

The amides are considered of inferior value in feeding farm animals by some authorities, but it has been shown that they will save body protein from decomposition, and, in some cases at least, they can be utilized for the building up of protein tissues in the animal body. Amides are also present in small amounts in dry feeds and in most concentrates. The average proportion of non-protein ("amide") nitrogen in various feeds is as follows: Green forage crops, 20 to 40 per cent of the total nitrogen content, according to the stage when cut; corn silage, 30 to 40 per cent; mangels, 60 per cent; potatoes, 40 per cent; malt sprouts, 30 per cent; small grains, 3 to 11 per cent; mill feeds, 10 per cent, and oil meals, 4 per cent.

High- and Low-protein Feeds.—Feeds rich in protein substances are spoken of as high-protein feeds, or simply protein feeds or nitrogenous feeds, and those low in protein are called low-protein or starchy feeds. Among the former class (*high-protein feeds*) may be mentioned:

Concentrates.—Peanut cake meal, containing about 48 per cent protein; cotton-seed meal and soybean meal, 40 to 45 per cent; gluten meal, soybeans and linseed meal, 34 to 36 per cent; dried distillers' grains, 32 per cent; malt sprouts and dried brewers' grains, 26 per cent.

Coarse Feeds.—Pea hay, 22.9 per cent; vetch and sweet clover, 18 per cent; alfalfa hay, white and crimson clover, 15 per cent.

As examples of *low-protein feeds* may be given:

Concentrates.—Cereal grains, 10 to 12 per cent; dried beet pulp, and corn and cob meal, 8 to 9 per cent; rice, 7.4 per cent.

Coarse Feeds.—Timothy hay, 5.9 per cent; hay from mixed grasses and Hungarian grass, 6 to 8 per cent; barley hay and oat hay, 8 to 9 per cent; straw from the cereals, 3 to 4 per cent; corn stover, 1 to 2 per cent; corn silage, 2.7 per cent (see Fig. 8, p. 42).

Fats are organic compounds consisting largely of mixtures of fatty acids, combined with glycerine (so-called *glycerides*). The more common fats are stearin, palmitin, and olein. The last-mentioned glyceride is liquid at ordinary temperatures, and, if present in large quantities, renders the mixed fat liquid or very soft. Linoleic and linolenic acids are also found in the seeds of some plants, like flaxseed and soybeans; on exposure to the air in a thin layer, they

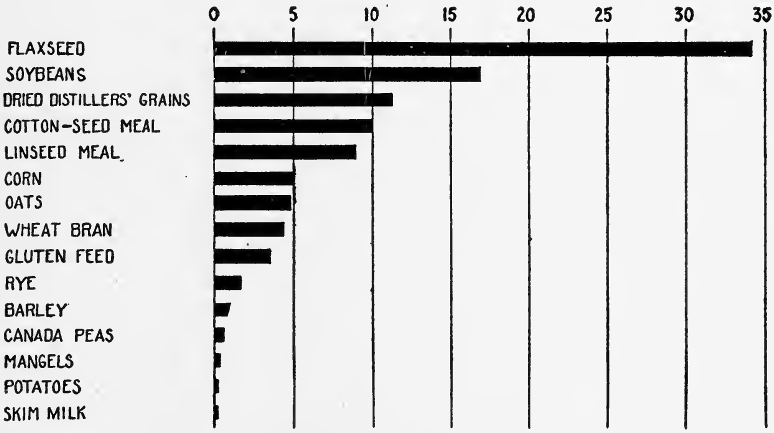

Fig. 3.—Fats in common feeding stuffs, in per cent.

take up oxygen and "set," *i.e.,* they dry and harden. This difference in the behavior on exposure to the air is characteristic of drying and non-drying oils.

Some seeds contain large proportions of fat (oil), while others, *e.g.,* some of the cereals, are low in fat (Fig. 3). The coarse feeds contain other materials than fat which are soluble in ether, the solvent for fat used in chemical analysis, viz., chlorophyl and various resinous substances. The ether extract, in the case of these feeds, is, therefore, not as pure fat as that from concentrated feeds. The following figures show the average percentages of fat present in various feeds:

Concentrates	Per cent	Coarse feeds	Per cent
Rice	0.4	Soiling crops	0.3 to 2.1
Wheat, barley, buckwheat	1.8 to 2.2	Hays	1.7 to 3.6
Indian corn and oats	5.0 to 5.4	Straws	1.2 to 2.3
Soybeans	17.2	Roots	0.1 to 0.4
Flaxseed	33.7	Corn silage	0.9
Cotton seed	36.6		

Fat contains more carbon and less hydrogen than the group known as carbohydrates, viz., on the average,

Carbon, ...	76	per cent
Hydrogen, ...	12	per cent
Oxygen, ...	11.5	per cent

They, therefore, furnish more energy on combustion and are more valuable as heat-producing substances than are the carbohydrates (for which see below).

Nitrogen-free extract is a general name for all non-nitrogenous organic substances in plants and plant materials besides fat and fiber. It includes a large number of substances of different properties and value for feeding purposes, such as starch, sugar, pentosans, pectin, organic acids, and other compounds that are present in plants in small amounts and are of minor importance. The name "nitrogen-free extract" is in reality a misnomer, as but few of the substances included under this group name are soluble in water or other liquids; it has come into general use, however, since the early days of agricultural chemical analysis, and no better name for this group of substances has so far been suggested.

Carbohydrates.—The nitrogen-free extract and fiber form the group called *carbohydrates.* These include substances widely distributed in plants and of the greatest importance to the feeder. They are, in general, characterized by the fact that they contain the elements carbon, oxygen, and hydrogen, the latter two being present in the same ratio as in water, one molecule of which contains two atoms of hydrogen and one atom of oxygen (H_2O). The more important substances of this group are briefly considered below.

Starch is one of the first organic substances formed in the living plant from the carbon-dioxide of the air and water. It is changed to sugar in the transfer of carbohydrates from one part of the plant to another, and accumulates as such in large quantities as reserve material in some plants, as the beet root and sugar cane. In others it is changed into oil or fat, as in the so-called oil-bearing seeds, flax, sunflower, castor bean, etc. In still others, which most frequently happens, there is an accumulation of starch in the seeds, as in the case of the cereals and legumes.

On boiling with dilute acid or through the action of diastatic ferments (diastase, ptyalin, etc.), starch is changed to sugar. This process forms the basis for the manufacture of corn or glucose syrup from Indian corn.

The starch of many plants can be identified by their characteristic microscopic structure, but from the feeder's point of view there is no difference in the value of starch from different sources.

The average percentages of starch found in some plants are as follows:

Rice, 79; corn, 71; wheat, 69; rye, 67; barley, 65; potatoes, 63; oats, 53; beans and peas, 39. Starch is found only in small amounts in coarse feeds or in stems and leaves of plants.

When subjected to ultimate chemical analysis, the percentage composition of starch is shown to be as follows:

44.4 per cent carbon,
6.2 per cent hydrogen,
49.4 per cent oxygen.

Sugar is found in many farm crops during the immature stage of the plant, but it is as a rule changed back to starch in the mature plant. There are a number of different sugars found in plant materials, classified as mono-, di,- or poly-saccharides.

The following statement shows the more important sugars in each of these classes:

a. *Mono-saccharides.*—Dextrose (or glucose), levulose (or fructose), and galactose. They occur in unripe plants and in fruits. Like other carbohydrates, they are composed of carbon, oxygen, and hydrogen, with six atoms of carbon in the molecule; hence are also called hexoses.

b. *Di-saccharides.*—Sucrose (cane-sugar), maltose (malt-sugar), and lactose (milk-sugar). These contain twelve atoms of carbon in the molecule, combined with a corresponding number of atoms of oxygen and hydrogen (p. 13). Sucrose is found in large quantities in sugar beets and sugar cane; when ripe both of these plants contain 12 to 18 per cent of this sugar, according to the character of the seed used, method of cultivation, season, soil, etc. These crops are the two great sugar plants of the world, all other sources of sugar, like sugar maple, sorghum, etc., being of minor importance.

c. *Poly-saccharides* or amyloses, containing a multiple of six carbon atoms in the molecule. To these belong starch, dextrine, cellulose, and glycogen. The substances in both this and the preceding group are readily changed into mono-saccharides (glucose) through hydrolysis (boiling with dilute acids), or through the action of ferments, as already stated under starch.

The pentosans and pentoses stand close to starch and sugar, respectively, being the corresponding compounds with only five atoms of carbon in the molecule. The pentosans are readily changed to pentoses on boiling with acids. They have an important nutritive value, almost equal to that of starch, and well merit the attention which they have received from chemists during late years. The pentosans are widely distributed in plants, and make up a considerable proportion of the nitrogen-free extract of many plants. Hay from grasses contains about 20 per cent of pentosans; gluten feed, 17 per cent; dried brewers' grains and wheat bran, 24 per cent; clover, 10 per cent; cereal straw, 22 per cent; oil meal and dried distillers' grains, 13 per cent.

The best known substances of this group are *araban,* found in beet pulp, cherrygum, etc., and *xylan* or wood gum, found in wood and straw.

The pectin bodies occur especially in unripe fruits; these substances are responsible for the jellying of fruit juices, which depends upon pectin taking up water during the boiling of the fruit,

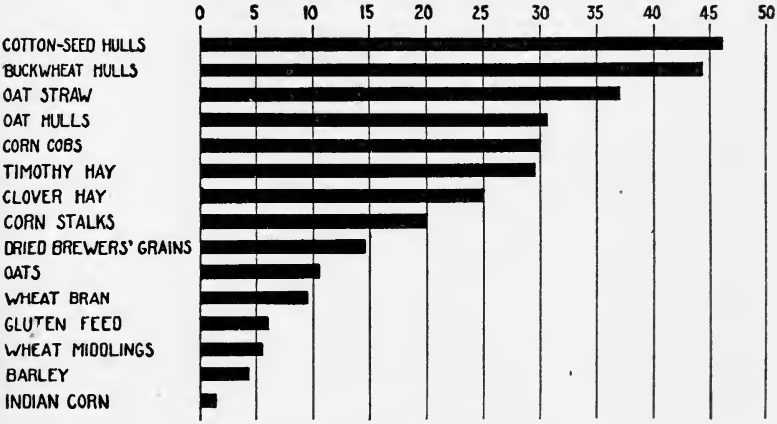

FIG. 4.—Fiber in plant materials, in per cent.

gelatinous substances being formed known as pectoses or pectic acids. The mucilaginous substances of flaxseed and seeds or roots of some other plants belong to this group; these substances do not, however, possess the importance that is attached to the preceding three groups of compounds, starch, sugar and pentosans.

Fiber (called crude fiber or woody fiber by some authors) makes up the cell walls of the plants and is largely composed of cellulose. So-called incrusting substances (lignin and cutin) are always present, especially in tough, woody plant materials, like husk, hulls, seed-coats, overripe hay and straw, which contain considerable proportions of these substances in the fiber. Fiber is more resistant to the action of solvents and digestive fluids than other groups of plant materials. It is attacked by bacteria and possibly by special ferments in the intestinal tract of herbivorous animals. By this decomposition marsh gas and other gases are formed, and also organic acids, like acetic and butyric acids. Since straw is very high in fiber, and ruminants, like steers, sheep, and goats, can subsist for a long time on coarse straw only, we are justified in concluding that this substance possesses a certain nutritive value, although authorities differ as to how much value shall be ascribed to the digestible portion of cellulose.

Plants increase in their contents of fiber toward maturity as the stems become coarse and tough; hence their digestibility decreases during the latter stages of plant growth (p. 58). The following approximate amounts of fiber are found in different classes of feeding stuffs:

Buckwheat hulls, buckwheat straw, and flax shives, 45 per cent; straw of cereals, 40 per cent; hay from different grasses or legumes, 20 to 35 per cent; cereals, 0.2 per cent (rice) to 10.8 per cent (oats); roots and tubers, 0.4 to 2.2 per cent; concentrated feeds, 0.9 to 30 per cent, generally, however, less than 20 per cent (Fig. 4).

A high fiber content indicates that a feed is of relatively low value for stock feeding, and *vice versa.* The figures for this component, with those for protein and fat, are, therefore, of the greatest assistance to feed buyers in judging the value of manufactured and other feeds.

Chemical Analyses of Feeding Stuffs.—The following components are determined by the chemist in the ordinary analysis of feeding stuffs: Water (often called *moisture*), protein, fat, fiber, and ash; the difference between 100 and the sum of percentages of these various components obtained in the analysis is known as nitrogen-free extract (starch, sugar, pentosans, organic acids, etc.).

Methods of Chemical Analysis.—The outline of the common method adopted in chemical laboratories in the analysis of feeding stuffs given below will be of value to students by enabling them to better understand data and discussions relating to the chemical composition of feeding stuffs (Fig. 5).

a. Moisture (water) is determined by heating a small portion (generally 2 grams)[1] of the carefully-sampled and finely-divided feeding stuff in a steam-bath or water oven at 100° C. for two to five hours, till it no longer loses weight. After cooling in a desiccator, it is weighed carefully on a chemical balance and the percentage loss calculated on the original weight is taken to represent moisture. Volatile organic substances sometimes present in minute amounts in plant materials would also be included in this loss. In the case of some feeding stuffs containing fats that take up oxygen, as corn. flaxseed, and other oil-bearing seeds, the material must be heated in a current of hydrogen or other inert gas, so as to prevent oxidation and a resulting increase in weight during the drying, which would give too low a moisture content.

[1] $\frac{1}{14}$ of an ounce. 1 ounce equals 28.35 grams.

b. Fat.—The residue from the preceding determination is extracted with anhydrous sulfuric ether in a suitable apparatus for a considerable period of time, generally 16 hours, till the fat has been completely dissolved. The ether is distilled off and the residue dried at 100 ° C. and weighed. As previously stated, the ether extract, in the case of roughage and some other feeds, contains considerable impurities, as chlorophyl, wax, and resins.

c. Protein is obtained by multiplying the total nitrogen by 6.25 (see p. 9), the nitrogen being determined by the Kjeldahl method, so called after the inventor, a Danish chemist. In this method a small portion of the feed (generally 1 gram) is heated with 20 c.c. sulfuric acid till the organic matter has been completely decomposed and the nitrogen has been changed into ammonium sulfate. This is dissolved in distilled water,

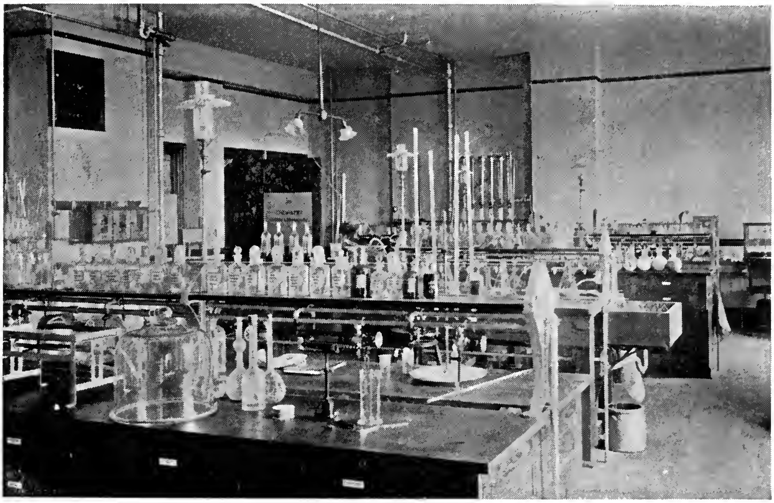

Fig. 5.—View of a chemical laboratory for analysis of feeding stuffs and other agricultural products. (Wisconsin Station.)

and 50 c.c. of a concentrated soda solution are added, the flask being connected with a distillation apparatus and heat applied. A certain quantity of standard hydrochloric acid solution, more than sufficient to neutralize the ammonia obtained in the oxidation of the protein, has been previously added in the receiving flask, and the distillation is now continued till all ammonia has been distilled over. The excess of acid in the receiving flask is then accurately titrated back (neutralized), and from the volume of acid used the amount of nitrogen in the sample is obtained. This is calculated in percentage of the amount of sample weighed out, and by multiplying by 6.25 the percentage of protein contained in the sample is obtained.

d. Fiber is determined in the residue from the fat extraction by boiling first with 200 c.c. of a 1.25 per cent sulfuric acid solution and then with 200 c.c. of a soda solution of the same strength. After filtering, drying, and weighing, the residue is ignited, and the loss in weight, calculated on the amount of the sample originally weighed out, shows the percentage of fiber in the feed. This method, which is known as the Weende method gives pure cellulose or woody fiber, with some impurities like pentosans, incrusting substances (lignin, cutin), and certain insoluble proteins. The method does not give very satisfactory results, and is only used for want of some better method of arriving at the amount of fiber present in feeding stuffs.

e. Ash or mineral matter is obtained by igniting at a low red heat 2 grams of the sample and weighing the residue after cooling in a desiccator. The crude ash thus obtained generally contains some free carbon, as well as carbonates and sulfates formed by oxidation of organic components of plant materials. It is sometimes purified by treatment with distilled water, and the amount thus found is given as pure ash.

f. Nitrogen-free extract is obtained by subtracting the sum of the percentages of the preceding components from 100. It includes chiefly starch, sugar, pentosans, and organic acids (p. 13). The amounts of the first three components are also sometimes determined separately by well-known methods of analysis that are of interest mainly to chemists.[2]

The example given below will show the customary form of reporting analyses of feeding stuffs.

Chemical Analysis of Timothy Hay

	Per cent
Moisture	13.2
Crude protein	5.9
Fat	2.5
Fiber	29.0
Nitrogen-free extract	45.0
Ash	4.4
	100.0

QUESTIONS

1. Name the elements essential to plant growth; also some others that are always present in plants.
2. What are the groups of plant components determined in ordinary chemical analyses?
3. Give the main characteristics of each one of these components.
4. What is protein, nitrogen-free extract, carbohydrates?
5. State the difference in the chemical composition of these substances.
6. Give the ordinary form of reporting a chemical analysis of a feeding stuff.

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[2] For complete directions for making chemical analyses of feeding stuffs and other agricultural products, see Official and Provisional Methods of Analysis, Association of Official Agricultural Chemists, Bureau of Chemistry, U. S. Department of Agriculture, Bulletin 107 (Revised), Washington, 1912.

CHAPTER II

THE COMPOSITION OF ANIMALS

WE find, in general, similar substances in the animal body as in plants, but the relation between the different groups of components differs, and some substances found in animals do not exist in plants, or differ in their properties from the corresponding plant constituents. Animals are composed of water, protein bodies, fat and mineral matter; the protein, or protein and fat, make up the largest proportions of the dry matter of animals, while carbohydrates are present in only small amounts. We have seen that the dry matter of plants, on the other hand, is largely composed of carbohydrates, and that protein is, as a rule, present in relatively small amounts.

The composition of different farm animals varies according to their body condition, especially the amount of fat which they carry. The classic experiments of Lawes and Gilbert which were conducted about 1850 at the Rothamsted Experiment Station, England, furnished the first accurate information on this point; their findings have been corroborated during later years by investigations at the Maine and Missouri Experiment Stations and elsewhere. The following summary table shows the percentage composition of live animals, less contents of stomach and intestines:

Composition of Live Animals, in Per Cent. (Lawes and Gilbert.)

	Water	Fat	Protein	Ash
Fat calf	64.6	14.1	16.5	4.8
Steer, well fed	66.2	8.7	19.2	5.9
half fat	59.0	17.5	18.3	5.2
fat	49.5	30.5	15.6	4.4
Sheep, lean	67.5	10.2	18.3	4.0
well fed	63.2	15.5	17.4	3.9
half fed	58.9	21.3	16.0	3.8
fat	50.9	31.9	13.9	3.3
very fat	43.3	41.4	12.2	3.1
Swine, well fed	57.9	24.2	15.0	2.9
fat	43.9	42.3	11.9	1.9

The figures given in the table show that the fatter an animal is, the less water, protein, and ash will it contain; also, that the percentage of fat in the body of a steer may range from at least 8 to 30 per cent, that in a sheep from 10 to 41 per cent, and that in a hog from 24 to 42 per cent. As these percentages increase, those for the other components decrease; *e.g.,* the water contents in the body of a steer decrease from 66 to 49 per cent, in sheep from 67 to 43 per cent, and in swine from 58 to 44 per cent. In all cases except where the animals are very fat, their bodies consist of more than one-half water; the body of a lean animal or a fat calf (as of all young animals) is made up of nearly two-thirds water. As the animal grows toward maturity, and especially during fattening, the proportion of water in its body tissue becomes generally smaller, and that of fat increases. This is because the increase in body

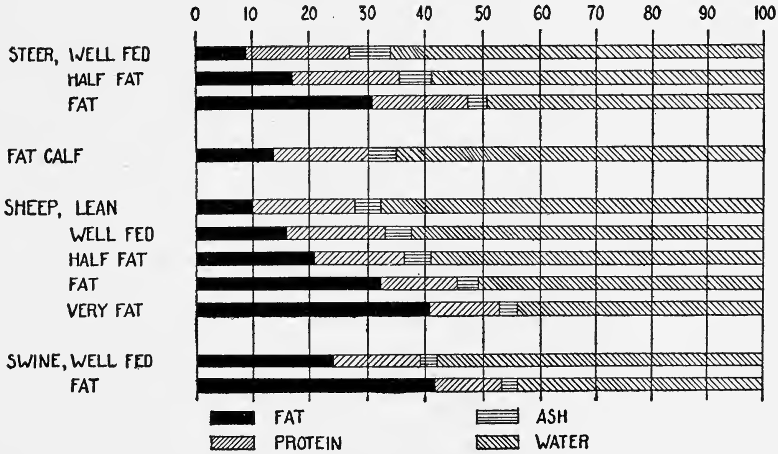

FIG. 6.—Composition of live animals less contents of stomach and intestines, in per cent.

weight of animals with increasing age or during fattening is composed of more dry matter and less water than when the animal is young or has not been fattened, and not because the fat replaces the water in the body tissues (Fig. 6).

The composition of the increase of live weight in fattening has been calculated by Lawes and Gilbert for steers, sheep, and hogs. They found that if a steer, for example, gained 100 pounds during fattening, these 100 pounds would be composed, on the average, as follows:

Water, 23.8 pounds, and total dry matter, 76.2 pounds, made up of:
Fat, 67.8 pounds,
Protein, 7.3 pounds,
Ash, 1.1 pounds.

While lean animals consist of nearly two-thirds water and less than one-tenth fat, the increase in body substance during fattening is over two-thirds fat and less than one-fourth water, and protein makes up only about 7 per cent of the increase. It is easy to understand, in view of these figures, why fat and older animals can command higher prices than young or lean animals, and why the percentage dressed weight of cattle, for example, is higher in the case of the former kind of animals than with the latter.[1]

Components of the Animal Body.—We shall now briefly consider the chemical composition and main characteristics of the various groups of components found in the animal body.

Protein.—Protein substances are found in all parts of the animal body, in the blood, lymph, muscles, connective tissues, milk, etc.

The blood is the vehicle by which the digested and absorbed nutrients are distributed throughout the body, and which supplies its different parts with the substances necessary for growth and the exercise of vital functions. Blood makes up about 8 per cent of the body weight of horses, cattle, and sheep, and less than 5 per cent of that of the pig. It is composed of a liquid portion called plasma, in which the blood-cells or corpuscles are suspended. The plasma makes up about two-thirds of the blood; it contains three protein substances in solution, viz., fibrinogen, serum globulin, and serum albumen. On clotting of the blood or when it is whipped, the fibrinogen is changed, through a special ferment called thrombin, into fibrin, which entangles the blood-corpuscles and holds them in a solid clot. The liquid that separates from clotted blood on standing is called blood-serum.

There are two kinds of blood-corpuscles, red and white. The red corpuscles are minute, round discs, that vary in shape and size in different animals. They are composed of a spongy albuminoid substance which holds in its meshes the red coloring matter called hæmoglobin. This is a very complex protein substance and contains about one-half of one per cent of iron, in addition to the ordinary components of protein. Hæmoglobin is a dark, purplish red, crystalline substance which has great affinity for oxygen. It absorbs oxygen in the lungs, forming oxyhæmoglobin; this again readily gives up its oxygen in the cells of the different body tissues when the oxidation (combustion) of nutrients takes place. The chemical changes that occur in the cells and are necessary for the continuance of life and for growth are dependent on this supply of oxygen and on the nutrients which are carried to the different parts of the body by the blood.

[1] See live weight and dressed weight of steers of different breeds and ages, Woll, "Handbook for Farmers and Dairymen," 6th ed., p. 206.

The white blood-corpuscles (so-called leucocytes) are of larger size than the red ones, and are found in only small numbers compared with red corpuscles. The leucocytes have the power of going through the walls of the capillaries (p. 31), and can pass with the lymph in between the cells of the tissues. In case some part of the body is injured or diseased, they collect there in large numbers, and on breaking down form pus. Their main function appears to be to destroy disease germs.

The muscular tissues in animals consist approximately of 75 per cent water, 20 per cent protein, largely myosinogen (myosin), belonging to the globulin group 3 per cent fat, less than 1 per cent carbohydrates (glycogen and dextrose), 0.2 per cent nitrogenous waste products (so-called extractives), and 1.0 to 1.5 per cent salts. The extractives are mainly creatin, with xanthine, uric acid, urea, and other waste products that are present in small quantities. The mineral matter in the muscle consists largely of potassium phosphates; small amounts of salts of sodium, calcium, magnesium, and iron are also present.

Connective tissues form another class of nitrogenous organic substances in the animal body. To this group belong tendons, ligaments, cartilage, skin, horns, hoofs, etc. They are all insoluble in water or salt solutions, and are only slightly attacked by acids or alkalies. Among the substances of this group that have been identified only two need be mentioned here, collagen and keratin. The former is the main organic component of cartilage and bone, and also makes up a large proportion of tendons and ligaments. On long boiling with water, collagen is dissolved and forms gelatin, which solidifies on cooling. Keratin is the main component of skin, hoofs, horns, wool, hair, and feathers, all substances that offer the greatest resistance to the action of solvents. Keratin contains 4 to 5 per cent sulfur in addition to the elements ordinarily found in protein compounds. On treatment with steam under pressure it is rendered soluble and forms glue. The manufacture of this material is an important side-line of the large packing houses.

Milk contains two important protein substances, casein and albumen. Casein belongs to the so-called nucleoproteins, combinations of albumen and phosphoric acid. It is suspended in a colloidal state in milk, and is not in perfect solution, hence may be separated out by means of centrifugal force. On addition of an acid to the milk, or through the action of enzymes, like rennin or pepsin, casein is precipitated, and the milk "curdles." The manufacture of cheese from milk depends on this property of casein. Milk albumen is soluble in water, and, like other albumens, is coagulated on heating above 80° C. (176° F.). Milk contains about 3.2 per cent casein and albumen, the content ranging between 2.5 per cent and 4.6 per cent, according to the quality of the milk; about 80 per cent of the total milk proteins is composed of casein; the rest is largely albumen.

Fats may be present in animals as body fat, in the marrow of bones, and in milk. They occur in the former two as oval or round cells that are composed of a nitrogenous membrane filled with fluid fat in live animals. The body fat is similar in composition to the vegetable fats, being largely composed of glycerides of the fatty acids, stearic, palmitic, and oleic acids, but the proportions of the different glycerides vary from that of plant fats, and there are also characteristic components of animal fat which are not found in the vegetable kingdom. Milk fat is composed of the three glycerides mentioned and, in addition, of about 8 per cent of glycerides of volatile fatty acids (mainly butyric acid), which give the characteristic fine flavor to fresh butter and, on decomposition, a rancid flavor to old butter. On account of the presence of these volatile fatty acids in butter it is possible to distinguish, by means of chemical analysis, between natural pure butter and artificial or adulterated butter.

Body fat may be deposited in animals receiving an abundant supply of feed; it is stored either between the layers of muscular tissue, about the internal organs, or directly beneath the skin, especially on the backs of animals. The body fat makes a reserve material that the animal can draw upon in time of a scarcity of feed. Through systematic liberal feeding and other favorable conditions the faculty to lay on body fat has been greatly developed in fattening animals, especially pigs. Adipose tissue of pigs consists of about 92 per cent of pure fat, the balance being 6.4 per cent water and 1.35 per cent nitrogenous substances (membrane).

Lipoids form a group of bodies that stand close to the fats. They are mixed with fats in various tissues and organs of the body. Only two of these substances will be mentioned here, lecithin and cholesterin. The former consists of glycerin and stearic and phosphoric acids, with a nitrogenous base known as cholin. It is found in the nerve tissues, cellular structures, and in the bile. Cholesterin is likewise found in the nerve tissues and cells of the body, and also in the liver, brain, eggs, and in wool fat. It is composed of carbon, hydrogen, and oxygen, and does not contain either nitrogen or phosphorus. In spite of relatively small quantities in which the lipoids occur in the animal body, they appear to be of the greatest importance in the nutrition of animals, especially in the case of growing animals.

Ash Materials.—The animal body contains the same ash materials as are found in plants, and it holds true, as a general proposition, that the elements which are essential to the life of plants are also essential to animal life. In the case of two elements, sodium and chlorin, the evidence at hand is not sufficient to show that they are absolutely essential to plants, but, since they are present in all soils, plants always contain an ample supply of both elements. It is definitely known, however, that both sodium and chlorin are essential to the growth of animals and to the continued exercise of their vital functions. We shall see that gastric juice, one of the digestive fluids of the body, contains free hydrochloric acid; this acid comes from the sodium chloride (common salt) found in the feed of the animals or eaten directly by them. Animals fed largely coarse feeds receive a sufficient amount of salt in the feed to supply their wants, but when fed much grain or other concentrates low in mineral matter, they need more salt than that contained in the feed; all farm animals relish salt greatly, and the practice of "salting" livestock has, therefore, become quite general.

Salt improves the appetite of the animals and increases the flow of digestive juices; it promotes and regulates digestion and should, therefore, be furnished in ample amounts. In the case of milch cows at least, a supply of salt in addition to that in the feed is essential to their continued health, both because of their large feed consumption, especially grain feed, and because of the amount of chlorin that is daily removed in the milk. The general practice among dairy farmers is to supply about an ounce of salt daily per cow, placing it before them in the mangers or giving them access to salt in the yard. Unless milch cows have access to salt, abnormal conditions will soon appear which will result in a general breakdown after a period varying with different cows from a month to more than a year. The gradual reduction in vitality of the animals which is brought about by a lack of salt, as shown by Babcock, is evidenced by "loss of appetite, a generally haggard appearance, lusterless eye, a rough coat, and a very rapid decline in both weight and yield of milk." [2]

Phosphate of Lime.—The mineral components present in the animal body in the largest quantities are lime and phosphoric acid. They make up the skeleton of the body and form about 80 per

[2] Wisconsin Report 22, p. 154.

cent of its entire ash content. In the case of suckling or young growing animals it is important that the feed shall contain a sufficient amount of lime and phosphoric acid. A deficiency of these components in the feed will give rise to serious disorders in the bone structure of the young, as is shown in the case of pigs fed wholly or largely on Indian corn (pp. 300–301). Under ordinary conditions, when mixed rations are fed, there is generally little danger of not furnishing enough of these two ingredients. The matter should, however, receive attention in feeding pregnant or nursing animals, or young growing animals, and heavy feeding of materials low in calcium or phosphorus should be avoided.

Among the feeds low in lime (calcium) may be mentioned: Straw and chaff, the cereals and their by-products, as gluten meal and shorts, malt sprouts, dried brewers' and distillers' grains, roots, and molasses. Feeds high in lime, on the other hand, are: Hay from grasses and legumes, and many leguminous seeds. Straw, distillery feeds, molasses, mangels, and potatoes are deficient in phosphoric acid, while the small grains, wheat bran, malt sprouts, brewers' grains, and oil meal, are high in phosphoric acid. If the rations fed are rather low in either or both of the ash materials mentioned, the deficiency may be made up by an addition to the feed of small amounts of bone meal, calcium phosphate or floats (ground phosphate rock).

Potassium and Iron.—Of other essential mineral elements in the animal body, we shall mention only potassium, which is found especially in the cell walls, muscles, and blood; and iron, mainly found in the red coloring matter of the blood (hæmoglobin, p. 21). There is no danger that the rations fed farm stock will be deficient in these or other physiologically important elements, like fluorin and silicon, since only very small amounts of them are required and an ample supply is always present in the feeds.

QUESTIONS

1. Name the various groups of substances in the animal body and describe their main properties.
2. How much water, fat, and protein are contained in the body of a calf, a lean and a fat steer, a fat sheep, and a fat hog?
3. What is the composition of the increase in live weight during fattening?
4. Name the different forms in which protein occurs in the animal body.
5. What is hæmoglobin?
6. What are leucocytes, connective tissues, keratin?
7. What protein substances are found in the milk?
8. In what forms is fat found in the animal body? What are the lipoids?
9. What are the main mineral substances found in the animal body?
10. Give the office of common salt in the digestion of feeds and in animal nutrition.

CHAPTER III

THE DIGESTION OF FEEDS

THE farm animals that chew their feed a second time are known as ruminants. Cattle, sheep, and goats belong to this class. The non-ruminants, on the other hand, are represented among the farm animals by the horse and the pig. The two kinds of animals differ radically in the anatomy of their digestive apparatus; the stomach of the ruminants consists of four divisions or sacs, of which the first three are mainly reservoirs for softening and holding the feed till it is returned to the mouth to be chewed again, while the fourth one is the true stomach, where a digestive fluid is secreted. The non-ruminating animals have only one stomach, into which the feed passes directly from the mouth and the gullet (œsophagus), and is acted upon by the digestive fluid secreted there. We shall consider separately the digestive apparatus of ruminants and non-ruminants.

The digestive apparatus of ruminants consists, as already stated, of four separate compartments that are connected with one another, viz.:

a. The rumen or paunch.
b. The reticulum or honeycomb.
c. The omasum or manyplies.
d. The abomasum or the true stomach (Fig. 7).

The first three stomachs are mainly enlargements of the alimentary canal and serve as reservoirs for the feed before it is chewed the second time. The rumen or paunch is by far the largest one of the four stomachs and, in the case of grown cattle, holds about nine-tenths of the total capacity of them all. The abomasum, or fourth stomach, corresponds to the single stomach of the non-ruminants, and, like this, contains a digestive fluid which acts upon the feed. When the cow swallows her feed, which is partly chewed and well mixed with saliva, it passes down the gullet and partly into the paunch through a slit in the gullet, partly into the second stomach (honeycomb). It remains here for a time and is softened by the saliva and the watery secretions of the paunch wall. The contents of the paunch are given a churning motion which gradually forces it toward the funnel-shaped orifice of the gullet through compression of the paunch by the diaphragm and the abdominal muscles. A portion of the softened mass is pressed at a time and conveyed into the mouth by a reverse, so-called peristaltic motion of the gullet. In the mouth it is chewed a second time and swallowed again. By the second chewing the cud or "bolus" is reduced to a pasty pulp, and it now passes directly through the œsophagus groove into the third stomach, the manyplies, without opening the slit in the gullet leading into the paunch. The manyplies has numerous hard, fleshy leaves, between

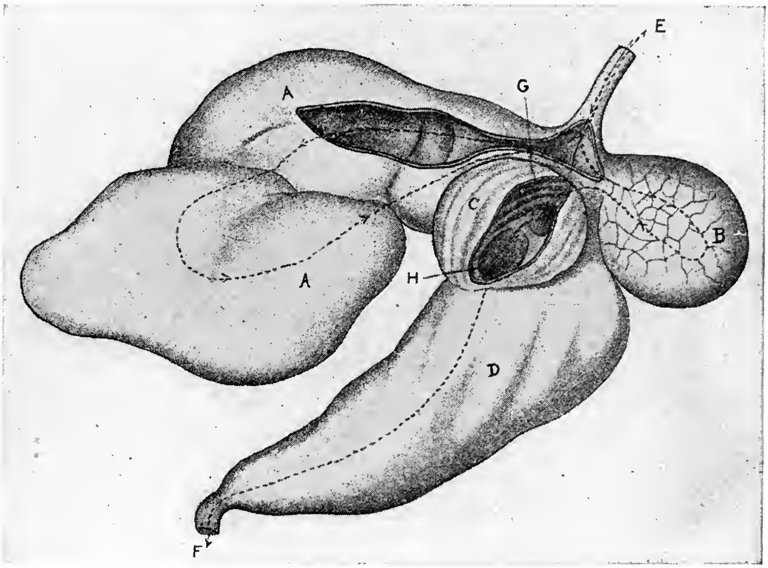

FIG. 7.—The digestive apparatus of ruminants (a full-grown sheep): *A*, Rumen or paunch; *B*, reticulum or honeycomb; *C*, omasum or manyplies; *D*, abomasum or rennet stomach (fourth stomach); *E*, œsophagus or gullet, opening into first and second stomachs; *F*, opening of fourth stomach into small intestines; *G*, opening of second stomach into third; *H*, opening of third stomach into fourth. The lines indicate the course of the feed in the stomachs. (U. S. Department of Agriculture.)

which the soft mass is pressed, allowing the liquid portion to pass into the fourth stomach, and the balance of the mass is likewise gradually emptied into this stomach.

The Non-ruminants.—In the case of the non-ruminating animals the feed passes directly from the œsophagus into the single stomach. In the horse this has two divisions: The lining of the left one does not secrete any digestive fluid, but the action of the saliva swallowed with the feed is continued here, and the ferments found in the feed itself (*e.g.*, in the case of oats) may also act on the starch. In the lining of the right side, on the other hand, there are numerous glands which secrete gastric juice, as in the case of the fourth stomach of ruminants. From this point on, the digestion of the feed takes place in essentially the same manner in non-ruminants as in ruminants.

The Digestion of Feed.—The various digestive fluids which act on the feed during its passage through the body are (1) saliva, (2) gastric juice, (3) pancreatic juice and the bile, and (4) intestinal juice.

Saliva.—The first step in the digestion of feed occurs in the mouth. When an animal is eating, the feed is crushed and ground by the teeth, and at the same time mixed with saliva. This is a digestive fluid secreted by several glands located beneath or at the base of the tongue. The secretion of saliva is stimulated by the presence of feed in the mouth, and the saliva is intimately mixed with the feed in the process of mastication, especially in the case of coarse and dry feeds.

This insalivation of the feed serves two purposes: *First,* it moistens and softens the feed so that it may be readily swallowed. *Second,* saliva contains a digestive ferment, called ptyalin, which acts upon the starch of the feed, changing it to sugar (maltose, the same sugar as is found in malted barley). Saliva is an alkaline, viscous fluid which is secreted in immense quantities in the case of the large farm animals. A horse fed on hay has been found to secrete over 10 pounds of saliva per hour. Oats require a little more than their own weight of saliva, and dry, coarse feed requires four times its weight. As a horse or cow will consume at least 24 pounds of dry feed in a day, it follows that the quantity of saliva secreted daily by these animals may reach or even go beyond 100 pounds (over 12 gallons).

The Gastric Juice.—The digestion of the protein substances of the feed is commenced in the true stomach (abomasum) of the ruminants, or in the single stomach of the non-ruminants, where the feed comes into contact with the gastric juice, which is secreted here. This digestive fluid contains two ferments, pepsin and rennin, and also an appreciable quantity of free hydrochloric acid (about 0.5 per cent). Both rennin and pepsin have the faculty of coagulating the casein of milk, a wonderful provision of nature which insures that milk will remain in the stomach long enough to be acted upon by the stomach ferments, and its nutrients thus fully utilized by the animal. In young calves and other young ruminants the first three stomachs are not much developed, and the milk passes directly into the fourth stomach, where it is curdled by the rennin and subjected to the action of pepsin. The latter ferment acts only in an acid medium and on protein substances, which it causes to break up into soluble compounds, known as proteoses and peptones. Since the ptyalin of the saliva acts only in an alkaline solution, its action on the starch of the feed is stopped when the feed reaches the fourth stomach and is mixed with the gastric juice.

From the fourth stomach the feed passes through a valve, called the pylorus, into the small intestine. This is a long, tortuous tract, about 120 feet long in cattle, in which three different digestive fluids are secreted or emptied: The pancreatic juice, the bile, and the intestinal juice.

The pancreatic juice is secreted by the large gland called pancreas (or sweetbread) and is emptied into the small intestine near its upper end, through a duct leading from the pancreas. This digestive fluid contains three specific ferments: Trypsin, amylopsin, and lipase. Trypsin converts protein into soluble compounds, mainly peptones, but also compounds of simpler molecular structure than those resulting from pepsin digestion, viz., amino acids. Amylopsin changes starch into sugar, and lipase (formerly called steapsin) acts upon the fats, splitting these up into their component parts, free fatty acids and glycerin (see p. 23).

The bile plays an important part in the digestion of fats. It is a strongly alkaline, yellowish-green digestive fluid secreted by the liver and stored in the gall-bladder attached to the same. The bile acts upon the fats of the feed that are still unchanged, emulsifying these; *i.e.,* separating them into very minute drops or globules that may be either absorbed through the intestinal wall or readily acted upon by the fat-splitting ferment lipase of the pancreatic juice. It also aids in the absorption of the fatty acids. The bile contains a number of characteristic components whose importance in the digestion of feeds is not clearly understood, but it has several regulative and digestive functions besides those mentioned; it acts as a natural laxative and prevents an accumulation of waste materials in the intestines, changing poisonous decomposition products of protein into harmless compounds that are excreted through the kidneys.

The intestinal juice is secreted by numerous small glands in the mucous lining of the intestines, especially in the lower part of the tract.

It contains three different ferments: (1) *Erepsin*, which acts upon the decomposition products of the proteins, albumose and peptones, in the same way as trypsin; (2) an *amylolytic ferment* which converts starch to sugar (maltose), and (3) *invertases* (sucrase, maltase, and lactase), changing the di-saccharides, cane-, malt-, and milk-sugar, into mono-saccharides (dextrose or glucose, see p. 14).

From the small intestines the undigested material passes into the large intestine, where the formation of the solid excrements takes place. The ferments and bacteria, present here in immense numbers, continue their action until the mass has assumed the consistency peculiar to each species and is voided as fæces.

Summarizing the various steps in the digestion of the different components of feed, we note that—

Starch is changed into sugar (maltose) by the ptyalin of the saliva, the amylopsin of the pancreatic juice, and an amylolytic ferment in the intestinal juice.

Fats are changed into free fatty acids and glycerin by the lipase of the pancreatic juice, and by the bile into emulsified fats or soaps.

Proteins are changed into proteose and peptones by the pepsin of the gastric juice, and into amino bodies by the trypsin of the pancreatic juice and the erepsin of the intestinal juice.

In addition to the action of these various digestive ferments the feed is subjected to bacterial action in the paunch and the intestines. Through the fermentation processes caused by bacteria, the cellulose and considerable quantities of other carbohydrates are decomposed and converted into gaseous products, like marsh gas, carbon-dioxide, and free hydrogen, which are of no value to the animals except incidentally through the heat generated in these processes; this may be of benefit in aiding to maintain the body temperature of the animals.

Digestion of Feed by Non-ruminants.—The digestion of feed by the non-ruminating farm animals takes place, as previously suggested, in much the same way as in the case of the ruminants.

The same digestive fluids act on the feed of the horse and other animals of this class as in the case of the ruminants, viz., saliva, gastric juice, pancreatic juice, bile, and intestinal juice. These differ from the corresponding fluids secreted by ruminants mainly in point of concentration. The protein compounds are broken up into simple soluble substances, like peptones and amino acids; the starch is changed into maltose, and the fats into free fatty acids, emulsified fats, or soaps. The stomach of the horse has a capacity of 12 to 15 quarts, while the paunch of a cow or steer holds over 100 quarts. The horses cannot, therefore, eat as much of bulky feeds at a time as cattle, nor can they digest coarse feeds containing considerable cellulose (fiber) so completely as the ruminants.

To make up in a measure for its small stomach, the horse has a large sac, *cæcum,* which is about a yard long and corresponds to the vermiform appendix in man. The large intestine is also of considerable size and has several enlargements. The entire length of the alimentary canal of the horse is about twelve times the length of the body, that of the pig fourteen times and that of cattle and sheep twenty times or more the length of the body. The length of time during which the feed remains in the alimentary canal and is exposed to the action of the digestive enzymes (or to bacterial action in the intestines) will, therefore, vary in different animals. In cattle and sheep the undigested part of the feed is voided in three to four days, and in horses and pigs in one and one-half to two days.

Absorption of Digested Materials.—The soluble materials and those that have been broken down into simpler, largely soluble compounds through the various processes of digestion are absorbed to some extent by the mucous membrane of the stomach, but for the most part pass through the walls of the intestines. The intestines are lined with innumerable fine projections called *villi,* inside of which are found microscopic branches of two systems of vessels, the *capillaries* of the blood-vessels, and the *lacteals* belonging to the so-called lymphatic system. The digested materials in the form of sugar, salts, soluble proteose and peptones, and similar compounds pass over into the capillaries by the process of osmosis. The capillaries are exceedingly fine blood-vessels that converge to a large vein called the portal vein, through which the materials absorbed by the blood are taken into the liver. They are here distributed through a second set of capillaries and then reunited, passing into the hepatic vein which leads to the heart.

The emulsified fats and free fatty acids, or combinations of these with alkali (soaps), on the other hand, are taken up by the lacteals in the villi of the intestines. From these they pass into the lymphatic system and are later emptied into the thoracic duct which leads to one of the large veins before this enters the heart.

The nutrients thus taken into the blood circulation come into contact with the oxidizing agent of the blood, the oxyhæmoglobin, and are either directly oxidized in the blood or carried to the body tissues to repair waste and supply materials for the formation of new tissues. Very likely, both these processes occur simultaneously. Some of the digested and assimilated nutrients, especially sugar and lactic acid, soon disappear from the blood through oxidation, and the carbon-dioxide and water formed in the process of oxidation are excreted through the lungs and skin. Other nutrients, like the mineral salts and soluble protein compounds, pass into circulation and are brought to the parts of the body where they are needed for building materials. The proteins are decomposed chiefly into amino-acids in the process of digestion, and pass through the intestinal wall as such, or possibly in part, as groups of amino-acids; they appear to be synthesized through the action of the living cell walls into more complex substances, from which the body is able to build its various protein tissues or fluids. In the same way the free fatty acids, and the soaps formed from these in the digestion of fats, are changed in their passage through the intestinal wall into neutral fats which enter the lacteals and pass into the circulation through the lymphatics.

The carbohydrates of the feed, as we have seen, are changed to sugar in the process of digestion and enter the capillaries as such; from these the sugar passes into the blood circulation and enters the liver, along with all other nutrients except the fats. In the liver the sugar is changed into a carbohydrate of the same composition as starch, called *glycogen* or animal starch, and is deposited as such in the cells of the liver. By this provision an accumulation of sugar in the blood is prevented, and the body has a base of supply of a readily available and oxidizable carbohydrate which can be drawn upon as needed. The liver normally contains only about 2 per cent of glycogen, but after heavy feeding with starchy feeds the content may rise as high as 10 per cent. Aside from furnishing material for production of heat and muscular energy, glycogen may also serve as supply material for the formation of body fat and butter fat, in the case of fattening animals and milch cows, respectively.

The fats may be stored between the muscular fibers or deposited as adipose tissue, or, in the case of females giving milk, may be changed into butter fat. We have seen that the muscular tissues of the body consist largely of protein substances, and that they are the form in which protein is stored in the animal's body. This can take place only in the growing animal. Oxidation of body tissues continues in the animal cells so long as life exists. The final oxidation products of protein substances in the body are carbon-dioxide and water (as in the case of carbohydrates and fat), and, in addition, urea, which is excreted through the kidneys in the urine. As there are no gaseous nitrogenous decomposition products formed, and urea represents the most important and, practically speaking, the only nitrogenous decomposition product in the oxidation of protein substances in the body, it becomes a measure of the protein decomposition in the body. By determining the amount of urea excreted in the urine, say during a day, we are able to ascertain the amount of protein substances in the feed or of body tissues that have been decomposed during the day (see p. 44).

Metabolism.—The chemical changes that occur within the body incident to the exercise of vital functions and to growth are included under the general term *metabolism.* Metabolic processes in the animal body are of two kinds: *Katabolic* or destructive, those by which the food materials are broken into compounds of simpler structure, and *anabolic* or constructive, by which these simpler compounds are again built up into complex substances. The formation of peptones and amino acids from the proteins is a katabolic process, while the reverse change, the building up of these simpler compounds into body protein, albumen, globulin, etc., is a constructive process. Both kinds of processes take place continuously in the living body, as we have seen; they are essential to life, and are discontinued only when life ceases.

QUESTIONS

1. Give the various groups of substances found in the animal body and state their main characteristics.
2. Why is it necessary to give salt to farm animals?
3. Name the various digestive fluids in the animal body, and state the changes which different components of feed undergo in the process of digestion.
4. What is the difference between ruminants and non-ruminants?
5. Name the American farm animals that belong to each group.
6. Describe the difference between the digestive apparatus of ruminants and non-ruminants.
7. Describe the process of absorption of the digested protein substances, carbohydrates and fat.

CHAPTER IV

USES OF FEED BY ANIMALS

We have seen that the animals, through their various digestive fluids, are able to dissolve certain feed components from the feeding stuffs which they eat, and that these components are used for maintaining the vital functions of the animals, and for the production of work, meat, milk, wool, etc., in the case of different farm animals. When only sufficient feed is supplied to maintain the body weight of the animal, no production is possible, except in the case of milk-producing animals. Even when the supply of feed is not sufficient to prevent a loss of body weight, these animals will continue to produce milk, and the interests of their young are thus safeguarded. But this is done at the expense of the flesh (or body fat) of the mother. Good milch cows with highly-developed dairy qualities will lose considerable weight under these conditions; this is especially apt to occur shortly after freshening, although a rather liberal supply of feed may be given, and it is often necessary to counteract this tendency to loss of flesh at this period by supplying special fattening feeds.

Maintenance Requirements.—The amounts of feed required to maintain farm animals at an even body weight have been studied by a number of scientists since the middle of the last century, and the maintenance requirements of different classes of farm animals are now definitely known. This subject has both a theoretical and practical interest, and is of fundamental importance in the study of the uses of feed by animals, since about 50 per cent of the feed they eat is used for body maintenance.

The earliest statements as to the maintenance requirements of farm animals came to us from Germany. Wolff's maintenance standard for cattle, for instance, called for a supply in the feed of the following digestible components: 0.7 pound protein, 8 pounds carbohydrates, and 0.1 pound fat per 1000 pounds body weight and per day. Later investigations by Sanborn, Caldwell, Haecker, and others showed, however, that this is a larger allowance than necessary. The Haecker maintenance standard for barren dry cows is now generally accepted; this calls for 0.7 pound protein, 7 pounds digestible carbohydrates, and 0.1 pound digestible fat per 1000 pounds body weight.

Of late years the amount of chemical energy which different feed components and feeding stuffs supply is generally taken to represent their value for feeding purposes, as will be shown presently (p. 44). This has come largely through the studies of Stohmann, Rubner, and Kellner in Germany, and Armsby in this country.

The maintenance rations for different animals per thousand pounds or one hundred pounds body weight formulated by Armsby are as follows:[1]

Armsby Standard Maintenance Rations

	Live weight	Digestible true protein	Energy value, therms
Cattle	1000 pounds	0.50 pound	6.0
Horses	1000 pounds	1.00 pound	7.0
Sheep	100 pounds	0.10 pound	1.0
Swine*	100 pounds	0.10 pound	1.12

* Illinois Bulletin 163. The amount of digestible protein is crude, and not true protein (p. 11).

The figures given for the amounts of digestible protein and energy values for maintaining swine at an even weight are derived from recent investigations by Professor Wm. Dietrich, formerly of the Illinois Experiment Station.

There are a number of factors that influence the maintenance requirements of animals; among these may be mentioned: The muscular activity of the animals (whether standing or lying), temperament, external conditions tending to affect the degree of muscular activity, condition or amount of fat tissue carried, and external temperatures.[2] It is believed, however, that the feeding standards show with a considerable degree of accuracy the average amounts of digestible true protein and energy values required by the different classes of farm animals given for the maintenance of an even body weight.

It is generally assumed that the maintenance requirements of animals are proportional to their live weights; *i.e.*, a cow weighing 1200 pounds will require 50 per cent more feed for the maintenance of her body weight than an 800-pound cow. This is not correct, however, although sufficiently so for most practical purposes. The maintenance requirements increase with the surface of the animal, and this is approximately proportional to the squares of the cube-roots of the weights of similar animals. If a cow weighing 800 pounds requires, say, 8 pounds of digestible nutrients for maintenance, a 1200-pound cow would require $8 \times \sqrt[3]{(\frac{1200}{800})^2}$ or 10.48 pounds, and a 1600-pound cow, 12.7 pounds.

[1] Farmers' Bulletin 346.
[2] Pennsylvania Bulletin 111.

Uses of Feed.—It has been shown that the digested and assimilated feed is oxidized in the cells and tissues of the body; the chemical energy thus set free is utilized in one or more of three different ways: As *kinetic energy,* for the maintenance of the body heat, or as *mechanical energy,* for the production of internal work in the body of the animal or for mechanical labor (horses, mules, and oxen), or as *chemical energy* stored in the form of animal products. If the energy supplied in the feed is more than sufficient to cover the demands for the first two purposes given, the excess may be stored up in the body in the form of animal products, like meat, fat, milk, eggs, etc., which may later serve to supply energy to man or other animals when used in their feed.

The functions of the different components of feed are, briefly stated, as follows:

Protein.—Flesh-forming substances. Essential for the production of lean meat, muscles, skin, ligaments, horns, hair, wool, milk, etc. When present in excess in the feed, used for production of body fat or as fuel, to give warmth and energy. Of general value in stimulating nutritive processes in the body.

Fats.—Furnish fuel to keep the animal warm and produce energy. Aid in the production of fatty tissue. For the production of heat, 2.25 times as valuable as carbohydrates.

Carbohydrates.—Supply fuel to keep the animal warm and produce energy for muscular work. They are transformed into fats for the production of fatty tissue.[3]

Feed for Production.—The portion of the ration fed an animal over and above maintenance requirements is the productive part of the ration; the higher this can be increased up to the capacity of the animal for digestion and absorption of feed, the better are the returns obtained and the more economical is the production, so far as feed consumption is concerned. The amounts of nutrients required by the different farm animals for productive purposes have been determined in similar ways as in the case of the maintenance standards. The first attempts to formulate general standards for farm animals were made by the German scientist Grouven in 1858. He gave the quantities of total dry substance, protein, and fat which an animal of a certain age would require daily in its feed ration. A somewhat later effort in this direction is represented by the standards proposed by Wolff, in which the amounts of digestible components required by different classes of farm animals under varying conditions are given.

[3] North Carolina Bulletin 106.

Feeding Standards.—The Wolff standards were brought to the attention of American farmers in the seventies, and, mainly through the publication of Armsby's "Manual of Cattle Feeding," in 1880, they became quite generally known here as "the German feeding standards." They were modified in 1897 by Lehmann, another German scientist, and ten years later Kellner proposed a new set of standards, based on contents of digestible protein and "starch values"; *i.e.*, the amounts of different nutrients or feeds equivalent to one pound of starch for the production of body fat by mature fattening steers. These and similar standards suggested by Armsby are the latest contributions to this subject. In order that students may become familiar with the two methods of determining the requirements of different farm animals, we shall give in this book both sets of standards, known as the Wolff-Lehmann and the Armsby standards, based respectively upon digestible components of feeds and the digestible true protein and energy values, measured in therms.[4]

Wolff-Lehmann Standards.—The feed requirements for different farm animals of average body weights, according to these standards, are as follows:

Feed Requirements per 1000 Pounds Live Weight.—Wolff-Lehmann

	Dry matter, pounds	Digestible			Nutritive ratio, 1:
		Protein, pounds	Carbohydrates, pounds	Fat, pounds	
Fattening steers, first period	30	2.5	15.0	.5	6.5
Milch cows, yielding 22 pounds milk daily	29	2.5	13.0	.5	5.7
Fattening sheep, first period	30	3.0	15.0	.5	5.4
Horses, medium work	24	2.0	11.0	.6	6.2
Fattening swine, first period	36	4.5	25.0	.7	5.9

As all the main feeding stuffs in this country, like corn and corn products, oats, mill feeds, oil meal, hay, etc., are relatively high in fat, there is no danger that the rations will not contain sufficient amounts of this component; it does not, therefore, call for special consideration, and has generally been merged with the carbohydrates in this book, according to its carbohydrate equivalent (by multiplying with 2.25, see p. 46). Stated in this manner, the Wolff-Leh-

[4] One therm is the amount of heat required to raise the temperature of 1000 kilograms of water 1 degree C. (see p. 45).

mann standards become very simple and are as easily applied as any standard so far proposed for farm animals.

The nutritive ratio of a feed (or a ration) is the proportion between the digestible protein and the sum of the digestible carbohydrates and fat contained therein. The fat is changed to its carbohydrate equivalent by multiplying with 2.25, because it has 2.25 times as high heat value as similar amounts of carbohydrates. For example, the nutritive ratio is expressed as 1 : 6.5, meaning that there are 6.5 pounds digestible carbohydrates and fat combined for every pound of digestible protein. The nutritive ratio is calculated as follows, *e.g.*, in the case of the first ratio given above:

0.5 (digestible fat) $\times$ 2.25 = 1.13;

15.0 (digestible carbohydrates) + 1.13 (the carbohydrate equivalent of the digestible fat) = 16.13;

16.13 $\div$ 2.5 (digestible protein) = 6.5.

The nutritive ratio of the ration for milch cows given is figured in the same way, as follows:

$$.5 \times 2.25 = 1.13;$$
$$13.0 + 1.13 = 14.13;$$
$$14.13 \div 2.5 = 5.7;$$ the nutritive ratio is, therefore, 1 : 5.7.

The Armsby Standards.—The estimated feed requirements for different classes of farm animals according to Armsby are given in the following table; the figures show the amounts of digestible true protein and energy values, expressed in therms, that should be supplied daily to growing cattle and sheep at different ages. These figures in all cases include the maintenance requirements for the various animals.[5]

Estimated Feed Requirements per Day and per Head (including the Maintenance Requirements).—Armsby.

Age, months	Growing cattle			Growing sheep		
	Live weight, pounds	Digestible protein, pounds	Energy values, therms	Live weight, pounds	Digestible protein, pounds	Energy values, therms
3	275	1.10	5.0	...	...	....
6	425	1.30	6.0	70	.30	1.30
9	....	....	....	90	.25	1.40
12	650	1.65	7.0	110	.23	1.40
15	....	....	....	130	.23	1.50
18	850	1.70	7.5	145	.22	1.60
24	1000	1.75	8.0	...	...	....
30	1100	1.65	8.0	...	...	....

[5] Farmers' Bulletin 346.

For fairly mature fattening animals (*e.g.*, two- to three-year-old steers) 3.5 therms per pound of gain in live weight are believed to be sufficient, and a similar amount of digestible protein is recommended as in feeding for normal growth.

Requirements for Milk Production.—For the production of a pound of average milk containing about 13 per cent solids and 4 per cent fat, 0.05 pound of digestible protein and 0.3 therm of energy value are considered ample, milk rich in fat and in total solids requiring more nutriment than milk containing more water or a lower percentage of fat. Recent work by Haecker and by Eckles has furnished additional data on this point. The results obtained by these investigators are important contributions to the subject of feed requirements of dairy cows. The tentative statement of the requirements for the production of milk containing different percentages of butter fat given by Eckles is as follows:[6]

Feed Requirements for Different Grades of Milk

Per cent fat in milk	Per pound of milk	
	Digestible protein, pounds	Energy values, therms
3.0	.050	.26
4.0	.055	.30
5.0	.062	.36
6.0	.070	.45

The method of calculating rations according to the Wolff-Lehmann and Armsby standards will be explained fully when the uses of nutrients by different animals and the various feeding stuffs available for farm animals have been discussed.

QUESTIONS

1. What do you understand by the maintenance requirements of animals?
2. Give maintenance ration for a 1000-pound cow according to (*a*) the Wolff-Lehmann standard, (*b*) the Armsby standard.
3. Give the feed requirements for fattening swine according to the Wolff-Lehmann standard.
4. What is meant by nutritive ratio? Give an example.
5. Show how the feed requirements for a dairy cow are calculated according to the Armsby standard.

[6] Missouri Research Bulletin 7.

CHAPTER V

DETERMINATION OF THE NUTRITIVE VALUE OF FEEDING STUFFS

THE nutritive value of different feeding stuffs may be determined by two different methods: First, by chemical analysis and digestion trials with farm animals; second, by trials with animals in a respiration apparatus or respiration calorimeter. The first method shows the proportions of the feeds that are dissolved in the digestive processes, while the second method furnishes direct information as to the nutritive effect of the feeds or rations and shows the uses which an animal makes of the feed eaten.

Digestion Trials.—The digestibility of feeding stuffs is determined in so-called digestion trials with animals. Numerous such trials have been conducted with ruminants during the past half-century in this country and abroad, and a number of trials have also been conducted with horses, pigs, and poultry. In these trials the animals experimented with are fed the feeding stuff whose digestibility is to be determined, for a period of about a week, and the solid excrements voided by the animal are then collected for another week. Samples of both the feed eaten and of the fæces are taken for chemical analysis, and by a comparison of the total amounts of feed components in each the proportion of each component retained or digested by the animal may be determined and calculated on a basis of percentage digestibility. An example will readily explain the method of calculation.

In an experiment by the author, in which the digestibility of corn silage was to be determined, a cow was fed, on the average, 55.0 pounds of silage per day; a small amount, 0.71 pound, was refused. She voided 58.8 pounds of dung daily during the trial. Chemical analyses were made of both the silage fed and that refused, as well as of the dung voided. The digestion coefficients for the silage were then calculated as shown below:

Digestion Trial with Corn Silage

	Dry matter, pounds	Protein, pounds	Fat, pounds	Fiber, pounds	Nitrogen-free extract, pounds	Ash, pounds
In 54.3 pounds of silage..	20.55	1.52	.67	4.25	13.23	.88
In 58.8 pounds of dung..	7.62	.68	.12	2.29	3.73	.72
Digested...............	12.93	.84	.55	1.96	9.50	.16
Digested in per cent.....	62.9	55.3	82.1	45.4	71.8	18.2

The results show that the dry matter of the corn silage was found to be 62.9 per cent digestible, the protein 55.3 per cent, the fat 82.1 per cent; *i.e.,* the digestion coefficients for the different components in the feed were as follows (leaving off fractions): Dry matter, 63; protein, 55; fat, 82; fiber, 45; nitrogen-free extract, 72, and ash, 18.

If the digestion coefficients for the organic matter in silage is wanted, it is readily obtained by calculating the amount of this component in the feed and fæces, as follows: In silage, 20.55 (dry matter) minus 0.88 pound (ash) equals 19.67 pounds (organic matter); in fæces, 7.62 less 0.72 equals 6.90; 19.67 less 6.90 equals 12.77; percentage digestible, 12.77 divided by 19.67 equals 64.4. It was found, therefore, that 64 per cent of the organic matter of the silage was digestible.

In the case of feeding stuffs that cannot be fed alone (*i.e.,* a grain feed for ruminants) it is necessary to feed it along with some feed of known digestibility that will supplement it so that when fed together they will make at least a fairly normal ration. The calculated amounts of digestible components in the second feed are then deducted from the total digestible amounts of the various components in the ration fed, and the difference is calculated on a percentage basis of the total amounts present in the feed whose digestibility was to be determined (Fig. 8).

Interpretation of Results.—The figures obtained in digestion trials show the proportion of the components of the feed that have been dissolved by the digestive fluids of the body and retained for the uses of the animal. This is true only in a general way, for various factors render the matter much more complicated. There reappears in the dung not only the undigested matter of the feed, but small amounts of residues of the digestive juices, waste products in the activity of the digestive organs, and intestinal mucus. A correction can be made, however, for the presence of these in the dung by determining the amounts of these waste products. This is done by means of artificial digestion of the dung with a pepsin-hydrochloric-acid solution (Kühn's method), and making proper deductions for these in the calculations. Another and more serious source of error is introduced by the fact that the feed is subjected to the action of bacteria and ferments in the paunch and intestines, through which gaseous products are formed, as previously stated (p. 30). These attack especially the fiber of plant materials, and the figures obtained for the digestibility of these components, therefore, include a portion which has not been dissolved by the digestive fluids of the animals and taken into circulation. This portion does not contribute to the maintenance or the growth of the body, and is of value to the animal only in so far as the heat generated by the fermentation processes helps to maintain an even body temperature. In spite of these errors to which digestion trials

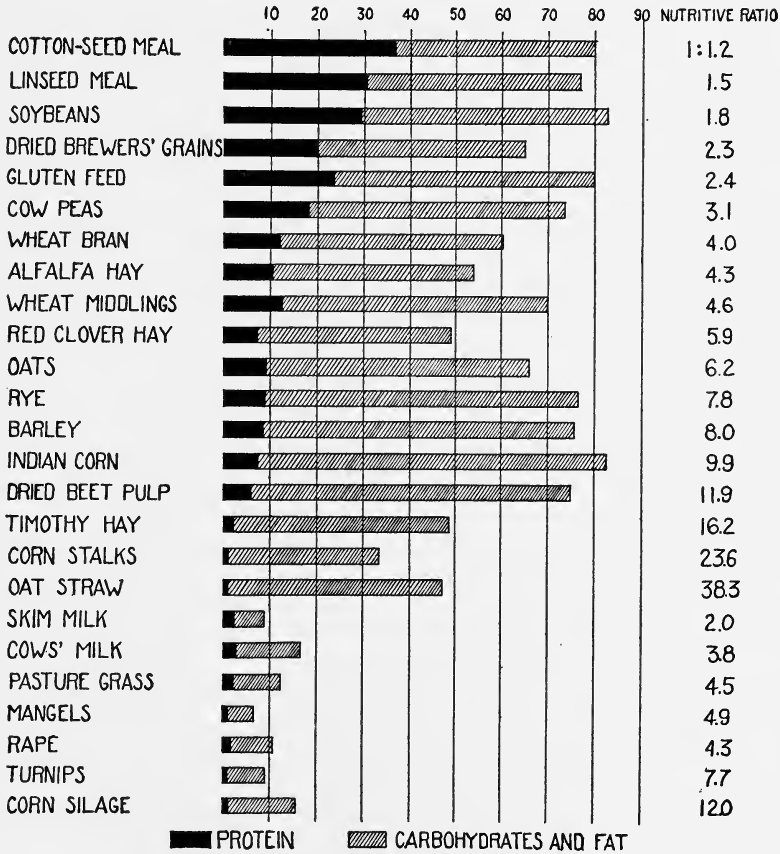

Fig. 8.—Digestible components and nutritive ratios of common feeds, in per cent.

are subject, the results obtained by them are of the greatest value to both the feeder and the student of nutrition problems. Until the latter part of the last century, our theories of these problems and the science of animal nutrition rested almost wholly on the knowledge of the feeding stuffs gained through chemical analysis and digestion trials.

Coefficients of Digestibility.—The average digestion coefficients for a number of important feeding stuffs are given in the following table. Complete compilations of digestion coefficients determined for American feeding stuffs will be found in several U. S. Department of Agriculture and State publications, as well as in standard reference books on the subject; these compilations also give the number of separate trials conducted and the number of animals experimented with in each case, as well as the variations in the results of the separate trials.[1]

Digestion Coefficients for Ruminants

	Dry matter	Protein	Fat	Fiber	Nitrogen-free extract
Pasture grass	71	70	63	76	73
Green alfalfa	61	74	39	43	72
Timothy hay	55	48	50	50	62
Meadow hay	61	57	53	60	64
Indian corn fodder	68	55	74	65	73
Corn stover	57	36	67	64	59
Corn silage	66	50	82	64	71
Corn meal	88	66	91	—	92
Oats	70	77	89	31	77
Wheat bran	66	77	63	41	71
Wheat middlings	82	88	86	36	88
Pea meal	87	83	55	26	94
Linseed meal (old process)	79	89	89	57	78
Cotton-seed meal	77	83	94	35	78
Mangels	87	70	—	37	95
Sugar beets	92	72	—	34	97

Respiration Studies.—The second method by which the nutritive effect of feeding stuffs may be studied is by respiration experiments, involving the use of either a respiration apparatus or a so-called respiration calorimeter.

The Respiration Apparatus.—The first apparatus of this kind was constructed by Pettenkofer, the great Munich chemist. It consists of a large air-tight chamber, through which a measured current of air is maintained. The animal experimented with is kept in this chamber for a given period, 24 hours or longer. By weighings and analyses of the feed, water, and air taken in by the animal, as well as of the gaseous and solid products given off, the intake and outgo of carbon, nitrogen, oxygen, and other ele-

[1] Bulletin 77, Office of Experiment Stations; Massachusetts Report, 1912; Henry, "Feeds and Feeding," p. 574; Jordan, "The Feeding of Animals," p. 427.

ments from the body can be determined with great accuracy. The effect of a given ration on the nutritive processes in the animal body is thus ascertained, and it is possible to determine whether the animal lost or gained in flesh or body fat on the ration fed, and also the exact amount of the gain or loss. An example will illustrate how this information is obtained.

A steer received daily the following amounts of nitrogen and carbon in the feed, water, and air: 0.44 pound nitrogen and 13.25 pounds carbon; he excreted in the urine, dung, vapor, and gases given off during the 24 hours 0.35 pound nitrogen and 12.10 pounds carbon, or there remained in the body 0.09 pound nitrogen and 1.15 pounds carbon.

Pure muscular tissue (lean meat) contains, on the average, 16.67 per cent nitrogen and 52.54 per cent carbon. The addition of 0.09 pound nitrogen, therefore, equals 0.09 multiplied by 100/16.67, or 0.54 pound of dry lean meat; this amount contains 0.28 pound carbon (0.54 pound multiplied by 52.54/100). The difference between this amount of carbon and that remaining in the body is 0.87 pound. As only very small amounts of other non-nitrogenous components than fat are found in the body, we are safe in assuming that the excess of the carbon was used for the formation of body fat; as this contains, on the average, 67.5 per cent carbon, the difference of 0.87 pound equals 1.14 pounds of fatty tissue which was added during the day. The steer gained 0.54 pound of dry lean meat and 1.14 pounds body fat during the day. If the increase was 2.50 pounds a day on the average throughout the experimental period, the difference, amounting to 0.82 pound, was composed of water and a small amount of mineral matter, both of which can be readily determined.

Calorimetry.—The value of a feeding stuff for the nutrition of animals depends, to a large extent, on the amount of chemical energy that is set free when it is oxidized. This energy may be utilized for the production of body heat, work, or animal tissues. The burning of a material in a stove and the oxidation of the digested nutrients in the animal body are similar chemical processes differing mainly in the intensity with which they run their course. In either case organic substances unite with the oxygen of the air or of the blood, respectively, and form carbon-dioxide and water (also urea in the case of protein substances oxidized in the body). The same amount of heat is given off whether the oxidation takes place in the body or outside of it. The heat evolved on combustion is a measure of the chemical energy which is stored up in the feeding stuff, and may be used by animals for maintenance and production.

Various units have been employed for measuring the heat of combustion. The common unit is a *Calorie,* which represents the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade, or that of a pound of water very nearly four degrees Fahrenheit. A *therm,* as proposed by Armsby, means 1000 Calories, the amount of heat required to raise the temperature of 1000 kilograms of water (or 2204.6 pounds) one degree Centigrade. This unit has been quite generally adopted of late and will be used in the following pages.

The various components of feeding stuffs contain certain amounts of oxygen and are, therefore, partially oxidized. Carbohydrates thus contain about 50 per cent of oxygen, fats 10 to 12 per cent, protein 22 per cent (pp. 9, 12, 14). The amount of heat evolved in the combustion of any organic material depends on the proportion of oxygen it requires for complete oxidation of the carbon, hydrogen, nitrogen, and other chemical elements contained therein. This amount can be calculated in the case of substances of known composition, and directly determined in a so-called *calorimeter.*

The Calorimeter.—This apparatus consists of a well-insulated, double-walled compartment, into which a platinum shell or bomb is introduced and submerged in water. A weighed small amount of the substance whose heat of combustion is to be determined is introduced into this shell with compressed oxygen, and ignited by means of an electric spark. By noting the rise in temperature in the surrounding water the amount of heat given off by the substance on complete combustion can be calculated.

Chemical Energy.—It has been found by direct experiments that the chemical energy of different classes of nutrients and feeding stuffs is as follows:

Chemical Energy in 100 Pounds, in Therms

Pure nutrients			
Protein:		Carbohydrates:	
Wheat gluten	272	Starch, cellulose	190
Gliadin, serum albumen	268	Glucose	170
Egg albumen, pure lean meat	259	Sucrose, lactose, maltose	179
Blood fibrin	256	Fats:	
		Steers and swine	425
		Sheep	427
		Corn oil	421
Common feeding stuffs			
Flaxseed meal	267	Alfalfa hay, mixed hay and oat straw	173
Linseed oil meal	194	Rice meal	170
Corn meal	171		

The figures given in the table show the amounts of chemical energy (in therm units) which are set free when 100 pounds of different pure nutrients and common feeding stuffs are completely burned. We note that the figures range for protein from 256 to 272 therms, for carbohydrates from 170 to 190, and for fats from 421 to 427, while those for feeding stuffs vary from 170 (rice meal) to 267 (flaxseed meal). Fats yield about 2.25 times as much energy on combustion as starch, and this factor has been commonly

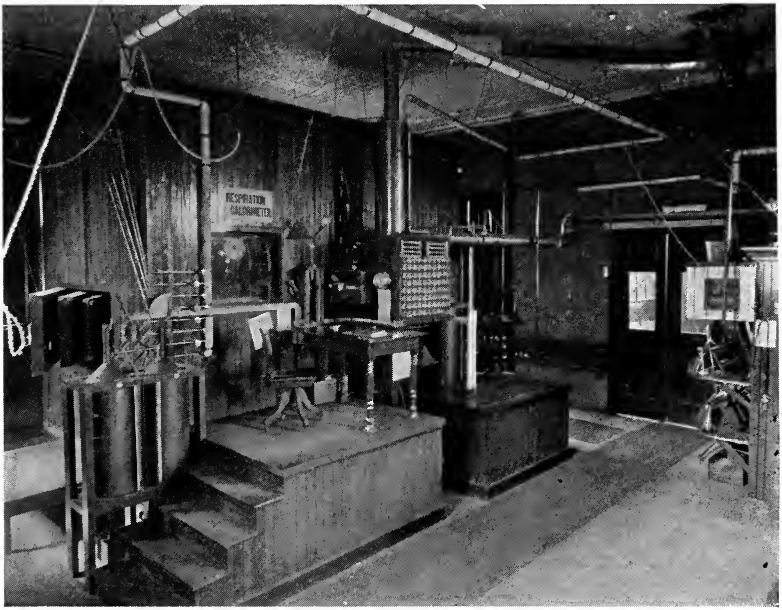

Fig. 9.—A view of the respiration calorimeter at the Pennsylvania Experiment Station. The calorimeter chamber in which the animal on the experiment is kept, to the left. (Armsby.)

adopted for the heat-producing value of fats as compared with that of starch and of carbohydrates in general.

The figures given represent the total potential energy that is locked up in the materials, but they do not show the energy that is available to animals fed the different feeding stuffs or nutrients. The reason for this is three-fold:

First, feeding stuffs are never completely digested by animals, as has been shown; only the digestible portions furnish energy for physiological uses: the rest is inert matter, passing through the animals and of no direct value to them, except possibly in regulating the bowels. The less digestible matter in a feed, the lower is, therefore, its value to animals.

Second, there are certain losses through fermentations in the paunch and intestines which result in the evolution of incompletely oxidized gases that escape from the alimentary tract (p. 30).

Third, incompletely oxidized protein substances are excreted as urea, and the fuel value which they represent is, therefore, of no value to animals. The total energy less that lost through these three sources furnishes the available energy, or so-called fuel value of the feed. This may be determined by means of the respiration apparatus, or its improved form, the respiration calorimeter.

The Respiration Calorimeter.—The Pettenkofer respiration apparatus was greatly improved by Atwater and Rosa by making the respiration chamber into a calorimeter. The original apparatus built at Wesleyan University, Connecticut, has been further modified by Armsby and associates at the Pennsylvania station, where an apparatus was built in 1898 by the Pennsylvania station, in coöperation with the U. S. Department of Agriculture. This apparatus is sufficiently large to allow of investigations with mature cattle, and it is possible to continue the experiments for a considerable length of time, if desired (Fig. 9).

"The apparatus consists of a Pettenkofer respiration apparatus provided with special devices for the accurate measurement, sampling, and analysis of the air-current. A current of cold water is led through copper-absorbing pipes near the top of the respiration chamber and takes up the heat given off by the subject. The volume of water used being measured, and its temperature when entering and leaving being taken at frequent intervals, the amount of heat brought out in the water-current is readily calculated. To this is added the latent heat of the water-vapor brought out in the ventilating air-current. By means of ingenious electrical devices, . . . the temperature of the interior of the apparatus is kept constant, and any loss of heat by radiation through the walls or in the air-current is prevented."[2]

Trials with this apparatus have been conducted since about 1901, and the results have greatly enlarged our knowledge of nutritive processes and the value of different feeding stuffs. The conduct of such trials involves an immense amount of chemical work and calculations; during the actual experiments alone the services of at least seven men are required, exclusive of the assistants in charge of the feeding and collection of excreta.[3]

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[2] Armsby, "Principles of Animal Nutrition," p. 248.

[3] For a description of the Pennsylvania respiration calorimeter, see U. S. Department of Agriculture Year Book, 1910, pp. 307 to 318; Experiment Station Record, vol. 15, p. 1037.

By means of the respiration calorimeter the amount of heat produced by the oxidation of the digested nutrients in the animal body is determined. The distribution of the losses of energy to the animal in the dung, urine, and marsh gas, as well as the net energy contained in the different feeding stuffs, is also shown by the results obtained in trials with this apparatus.

The following table shows the distribution in therm units in the case of three common feeds, as determined by Armsby:

Energy in Different Feeding Stuffs per 100 Pounds, in Therms

	Clover hay	Corn meal		Wheat straw	
Total energy............	172.1		170.9		171.4
Losses in dung..73.6		15.7		93.9	
Losses in urine..11.5		6.5		4.3	
Losses in marsh gas.........12.3		15.9		15.5	
Total losses........	97.4		38.1		113.7
Available energy, balance	74.7		132.8		57.7
Available in per cent....	43		78		34

We note that, while clover hay and corn meal contain nearly the same amount of total energy, only 43 per cent of this is available to animals in the case of clover hay, against 78 per cent in the case of corn meal.

Available Energy.—These figures and others similarly obtained do not, however, tell the whole story. Clover hay and other rough feeds are bulky and call for a large amount of work in mastication and moving it through the alimentary canal, and also necessitate the secretion of larger amounts of digestive fluids than do corn meal and other concentrates. The energy required for these purposes is likewise lost to the animal, so far as production or work is concerned, and can be provided only through that supplied in the feed. The balance, which is known as net available energy or *net energy,* represents that available to animals for maintaining the vital functions or for productive purposes.

The results obtained in respiration experiments with steers show that a larger percentage of the energy value of concentrated feeds is available for maintenance or for production than in the case of the rough feeds. In the poorest of these, as wheat straw, only small amounts of the energy value are obtained for productive purposes. Animals that have to subsist on only such feeds for any length of time will lose flesh, since there is not a sufficient amount of energy left to meet the needs of the body after that required for the digestion of the feed is taken out.

The weak point in the old system of basing the nutritive values of different feeding stuffs on their contents of total digestible components is that it does not take into account the differences in the amount of energy required for the work of digestion and assimilation of feeds of different kinds. Where this work does not differ greatly, however, as between different feeds of the same kind, either green feeds, dry roughage, or concentrates, the error introduced is not, generally speaking, of much importance. The immense amount of work done in the study of the composition and digestibility of different feeding stuffs makes the data obtained along these lines most valuable and fully justifies their continued use in practice and for the study of the comparative value of feeding stuffs.

Kellner's Starch Values.—The system of comparison of different feeding stuffs elaborated during the early part of the century by the German agricultural chemist, Kellner, is based on the results of extensive feeding and respiration trials with mature fattening steers. Kellner fed such steers basal rations barely sufficient to maintain them at an even body weight, and added to these either pure nutrients, like starch, sugar, oil, etc., fed separately or combined, or different feeding stuffs whose nutritive effect was studied. He thus found that one pound of digestible components was capable of producing the following amounts of body fat:

1 pound pure starch or digestible fiber, 0.248 pound body fat.
1 pound sucrose, 0.188 pound body fat.
1 pound protein, 0.235 pound body fat.
1 pound fat or oil, 0.474 to 0.598 pound, according to its origin.

A large number of trials were made to determine whether the digestible components of ordinary feeding stuffs gave similar results as corresponding amounts of the various groups of nutrients fed in pure form. In the case of a number of feeding stuffs this was actually found to hold true; *e.g.*, for many oil meals, corn, rice polish, red dog flour, potatoes, buckwheat middlings, and animal feeds. With most feeds, however, the amount of fat which they produced fell considerably short of what the same amounts of digestible components contained therein would have produced, if fed separately.

In the case of these feeds the work of mastication and digestion reduced their nutritive effect, and they were given lower valuation numbers as a result. The following method of comparison of the production values of feeding stuffs was accordingly adopted by Kellner. The starch values were determined on a basis of the amount of fat produced by the different digestible components, viz.:

1 part digestible protein, 0.94 starch value.
1 part digestible fat from oil-bearing seeds and oil meals, 2.41 starch value.
from cereals and their by-products, 2.12 starch value.
from hay and straw, roots and their by-products, 1.91 starch value.
1 part digestible carbohydrates and fiber, 1.0 starch value.

If the nutrients of the particular feed can be regarded as of full value, it is only necessary to add starch values of the three groups of nutrients as shown above, which gives the total starch values of the feed. If they were given lower values, the total valuation obtained according to the preceding equivalent figures is reduced by the respective valuation values.[4] The starch values thus obtained have been calculated for all kinds of European feeding stuffs, and are published in standard German reference books. The starch or "production values" for American feeding stuffs which have been published by Armsby are given in the Appendix.

Kellner also formulated feeding standards for the various classes of farm animals, which give the amounts of dry matter, digestible true protein, and starch equivalents required for maintenance and production in each case. These follow rather closely the Wolff-Lehmann standards, except for the introduction of the starch equivalents.

Critique of the Starch Values.—The Kellner starch values and standards are the latest contributions to our knowledge of the relative values of feeding stuffs and the feed requirements of farm animals. They have been accepted by some European writers and students of animal nutrition, while others, and good authorities among them, consider that we are not, at the present stage of our knowledge, warranted in applying the data obtained to other

[4] The valuation figures for the various feeding stuffs are given in Kellner's two books, "Ernährung d. Landw. Nutztiere" and "Fütterungslehre," and in the English translation of the latter book, "The Scientific Feeding of Animals" (London, 1909).

classes of farm animals than steers,[5] nor indeed to other conditions of fattening steers than where these are fed moderate rations, at the early stage of the fattening period.[6]

The starch values very likely furnish substantially correct information for the study of rations and the feed requirements for fattening cattle, and may be safely adopted for this purpose. They are less reliable for growing animals and, especially, for milch cows, and due credit is not given to high-protein feeds and rations when these values are applied to the feeding of these animals.

A comparison of the figures, *e.g.*, for Indian corn (starch value, 88.8 therms),[7] oil meal (78.9), pea meal (71.8), dried brewers' grains (60.0), wheat bran (48.2), and malt sprouts (46.3), will at once show that the figures do not express the true relative nutritive values of these feeds for the purposes stated. The explanation of the apparent discrepancies very likely is to be sought in the fact that in case of milk-producing and growing animals the protein of the feed possesses a higher value than for fattening. In the latter case the animal utilizes only the difference between the total energy of the digestible protein and that of the solids in the urine, while in the former a considerable proportion of the protein is changed directly into milk and flesh proteins. Instead of calculating the starch values on the basis of one pound protein equals 0.94 starch value, it has been proposed by Hansson[8] to allow the full energy value of protein, viz., 1.43; this method appears to make the starch value system applicable also to milch cows.

The Kellner-Armsby's standards for feeding farm animals are given in Part III, under the respective classes of animals.

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[5] Zuntz, Mo. Bulletin International Institute of Agriculture, v (1914), No. 4, p. 440; Landw. Jahrb., 44, p. 761; Pott, "Handb. tier. Ernährung," vol. 3, ii, p. iv. The following quotation from Farmers' Bulletin 346 by Armsby is also of interest in this connection: "The Kellner production values . . . show primarily the value of these different feeding stuffs for the production of gain in mature fattening cattle. Even for this purpose many of them are confessedly approximate estimates, and still less can they be regarded as strictly accurate for other kinds of animals and other purposes of feeding. Nevertheless, there seems to be reason for believing that they also represent fairly well the relative values of feeding stuffs for sheep at least, and probably for horses, and for growth and milk production as well as for fattening. . . . As regards swine, the matter is far less certain, and it may perhaps be questioned whether the values given in the table are any more satisfactory for this animal than the older ones." See also Armsby, Cycl. Amer. Agr., vol. iii, p. 67, and Murray, "Chemistry of Cattle Feeding and Dairying," p. 222.

[6] Wood and Yule, *Journal Agr. Science*, v, 1914, p. 248.

[7] Table IV in Appendix.

[8] *Centralanst. Ber.*, Stockholm, No. 85.

QUESTIONS

1. Give an outline of the method of conducting digestion trials.
2. What is a coefficient of digestibility?
3. Describe the respiration apparatus.
4. How is a gain in muscular tissue and in body fat in the animal body determined?
5. What is a Calorie? A therm?
6. Describe a calorimeter.
7. Describe the respiration calorimeter.
8. What is meant by the potential energy of a feeding stuff?
9. What is the difference between potential and available energy?
10. Why are coarse feeds less valuable to farm animals than concentrates?
11. What are energy values, and how have they been obtained?
12. For which class of farm animals are the energy values especially applicable, and what are the weak points in applying these to other classes of farm animals?

CHAPTER VI

VARIATIONS IN THE CHEMICAL COMPOSITION OF FEEDING STUFFS

We have seen that plants manufacture more or less complex organic substances and ash materials from carbon-dioxide, water, and mineral components, and that the energy thus stored up in the plants is utilized by the animals feeding on these materials. Different plants vary considerably in the amount of energy that they supply, and the same plants vary according to their stage of growth and other conditions. The main factors that influence the chemical composition of plants will be considered in the following pages.

The soil is an important factor in determining the quality as well as the yield of the crops grown; in a fertile soil, plants reach their highest development, and maximum crops are secured. It is possible to modify appreciably the percentage of different plant constituents by special fertilization; an increase in the protein content, *e.g.*, may be secured by applications of a general fertilizer that is high in nitrogen. By increasing the nitrogen content of the soil in this manner the percentage of protein in barley was increased from 13.77 to over 19 per cent. German scientists found the protein content of wheat grown on different kinds of soil as follows: On unfertilized soil, 16.25 per cent; fertilized with nitrogen, 21.43 per cent, and fertilized with nitrogen and phosphoric acid, 22.37 per cent. Differences are likely to occur in the composition of the whole plant as well as, to a smaller extent, in the kernels, and it is therefore as important for the stockman as for the general farmer to adopt a good system of crop rotation that will secure the best possible growing conditions for the different crops. Plants grown in a soil rich in lime or phosphoric acid will contain a higher percentage of these constituents than those grown in a poor soil, and will, therefore, be of superior value for feeding milk-producing and growing animals, which require a liberal supply of these mineral constituents.

Climatic Environment.—It would be wrong to assume, however, that the soil exerts the chief influence in determining the physical properties or the chemical composition of a crop. In a study of the influence of environment on wheat, which was continued for a series of years, LeClerc found that the climatic environment (*i.e.*, temperature, rainfall, and sunlight) is the most important factor that influences the physical and chemical characteristics of a crop,[1] and the results obtained by Wiley with sugar beets and sweet corn lead to the same conclusion.[2]

The length of the growing periods of plants is another factor that influences the quality of the crop grown. Spring grains are higher in protein and lower in starch than winter grains, because their growing period is shortened by the higher average temperature during the summer. Plants grown in the South are richer in protein than northern-grown plants, for the same reasons.[3]

The Variety and Quality of Seed.—The sowing time and the method of seeding or planting are other factors that have a bearing on the quality of the crops grown. The stage of development when a crop is harvested is another factor that influences profoundly both the crop yields secured and their chemical composition and feeding value. We select as illustrations data obtained with two of the most important single fodder crops in our country, Indian corn and alfalfa.

Indian Corn.—Like all other plants, Indian corn is higher in water, ash, protein, amides, and fat, and lower in starch and fiber, during early vegetative stages than later during the growing period. In experiments conducted by Hornberger, a field of Indian corn was sampled and analyzed once every week, from June 18, when the plants were only six to seven inches high, until September 10, when the corn was nearly ripe. The results of the analyses show that the water contents of the samples decreased with the advance of the growing period from 90.3 per cent to 80.5 per cent, and that the ranges in composition of the dry matter were as follows:

Ash from 9.5 to 4.3 per cent.
Protein from 30.8 to 9.7 per cent.
Amides from 9.8 to 2.8 per cent.
Fiber from 17.8 to 22.6 per cent (with a maximum of over 26 per cent, August 6 to 13).
Nitrogen-free extract from 41.7 to 61.5 per cent.
Fat from 3.2 to 1.6 per cent.

Considering the total yields of feed components on the different dates, the following results are worthy of special note:[4]

[1] *Journal Agricultural Research*, i, p. 275.
[2] Bulletins 96 and 127, Bureau of Chemistry, U. S. Department of Agriculture. See also Shaw, "Studies upon the Influences Affecting the Protein Content of Wheat," Univ. of Cal. Pub. in Agricultural Sciences, No. 5.
[3] Haselhoff, "Landw. Futtermittel," p. 13.
[4] See Woll, "A Book on Silage," Rev. Ed., p. 14.

*Yield of Ingredients in Corn Plants, in Grams**

Date	Green weight of one plant	Dry matter	1000 plants contained					
			Ash	Crude protein	Fiber	Sugar, starch, etc.	Crude fat	Amides
June 25...	5	0.5	43	142	90	210	16	41
July 2...	21	2.1	161	566	438	847	63	186
9...	39	4.1	342	1020	933	1681	94	385
16...	78	8.3	674	1898	1896	3585	187	677
23...	161	18.8	1190	3249	4581	9301	380	1136
30...	276	32.8	1978	4972	8194	16884	679	1727
August 6...	468	55.0	3069	7215	14420	29266	851	2780
13...	565	67.4	3576	8192	17692	36746	865	2735
20...	591	82.6	3991	8848	21164	47357	974	3369
27...	...	108.7	5131	11369	27394	63232	1143	4970
September 3...	...	121.2	5215	12218	28311	73247	1729	4722
10...	611	119.4	5120	11554	27023	73473	1906	3245

* 1000 grams equal 2.2 pounds avoirdupois.

Similar results were obtained at Geneva (N. Y.), Maine, and other stations in studies of the development of the corn plant from tasselling to maturity.[5]

Chemical Changes in the Corn Crop toward Maturity

Yield per acre	Tasselled	Silked	Milk	Glazed	Ripe
Gross weight, tons	9.0	12.9	16.3	16.1	14.2
Dry matter, pounds	1619	3078	4643	7202	7918
Ash, pounds	139	201	232	303	364
Crude protein, pounds	240	437	479	644	678
Fiber, pounds	514	873	1262	1756	1734
Nitrogen-free extract, pounds	654	1399	2441	4240	4828
Fat, pounds	72	168	229	260	314

The data given in the table show how rapidly the yields of feed materials increase with the advancing age of the corn plant and also how the increase during the latter stages of growth comes mainly on the nitrogen-free extract (largely starch). Between tasselling and maturity the corn plant will increase an average of about 200 per cent in dry matter and toward 300 per cent in carbohydrate content, according to the results of experiments conducted at five different stations. The largest amounts of feed materials in the corn crop are not obtained until the corn is well ripened; when the plants have reached their total growth in height they contain only one-third to one-half of the weight of dry matter which they will gain if left to mature.

[5] Geneva, N. Y., Report, 1899; Maine Report, 1895.

The preceding remarks refer to total feed components in the corn plant, and not to its digestible components. Digestion trials trials have shown that the digestibility of plants in general decreases as they grow older. The following table of results obtained in American trials will show the average digestion coefficients of green dent corn fodder cut at different stages of growth: [6]

Digestion Coefficients for Green Dent Fodder Corn

Stage of growth	No. of trials	Dry matter	Crude protein	Fiber	Nitrogen-free extract	Fat
Immature.....	14	68	66	65	71	86
In milk........	17	70	62	64	77	76
Glazing........	9	67	54	51	75	78
Mature........	23	69	54	59	75	75

While there was no material change in the digestibility of the dry matter of the corn, a marked decrease is noticeable in the digestibility of the crude protein, fiber, and fat with the greater maturity of the fodder. The digestibility of the nitrogen-free extract, on the other hand, remains nearly stationary at the different stages of the growth, and the main increase in feed components falls on this constituent. In general, the decrease in the digestibility of the feed components given is not sufficiently marked to affect the large increase in the yield of the components with the advancing age of the plant, so that the yields of total digestible components will be greater at maturity or directly before that time than at any earlier stage of growth. Hence we find that the general practice of cutting corn for forage or for the silo at the time when it is in the roasting-ear stage or beginning to harden is in accord with our best knowledge of the subject.

Alfalfa.—The changes in the composition of alfalfa during its growing period have been studied by several stations. The average results obtained for three cuttings at the Ontario Agricultural College are given below.

Composition of Alfalfa Cut at Different Stages of Growth, in Per Cent

	Moisture	Composition of water-free substance					
		Ash	Protein	Fiber	Nitrogen-free extract	Fat	Amides
Buds forming...	81.53	11.63	18.46	27.56	39.36	3.06	4.09
Medium bloom.	78.48	9.60	15.44	33.58	39.08	2.40	2.23
Full bloom.....	74.50	8.35	13.12	37.64	39.36	1.94	1.86

[6] Compilation by Lindsey and Smith, Massachusetts Report, 1911.

The results show a decrease in the percentage of water and, therefore, in the succulence of the crop. In order to show the changes in chemical composition, the analyses have been calculated to water-free substance, and it is seen that as the plant matures the percentages of ash, crude protein, amides, and fat decrease; as the stems grow hard and woody, the fiber contents of the plant increase, and the percentages of valuable feed components decrease in proportion, except that of nitrogen-free extract, which does not change materially. If we now consider the digestibility of the different cuttings of alfalfa, we have the following average figures obtained in digestion experiments conducted at Ontario Agricultural College: [7]

Digestion Coefficients for Alfalfa

	Dry matter	Crude protein	Fat	Nitrogen-free extract	Fiber
First cutting	59	73	49	72	39
Second cutting	56	73	50	70	38
Third cutting	51	64	44	64	37

There is a decided decrease in the digestibility of the total dry matter and of all components as the plant approaches maturity; the decrease is especially marked between the second and third cuttings. If the total digestible matter obtained in the three crops be calculated on the basis of the figures just given, it will be found that the amounts of digestible matter secured in the later cuttings are considerably lower than those found in the earlier ones. In the Canadian experiments referred to, the three cuttings gave, on the average, the amounts of green alfalfa and digestible matter shown in the table:

Calculated Yields of Dry Matter and Digestible Matter of Green Alfalfa Per Acre in Pounds

	Green alfalfa	Total dry matter	Digestible matter
First cutting	14075	2714	1590
Second cutting	14513	3525	1978
Third cutting	12363	3142	1611

There was a decrease of 18.8 per cent, or nearly one-fifth, of the digestible matter during the two weeks' interval between the last two cuttings, calculated on the yields of the second cutting.

[7] Report, 1899, p. 37.

The largest amount of digestible matter was obtained at the time of the second cutting in these trials, when the growing crop was about one-third in bloom. It is generally recommended to cut alfalfa at this stage of growth, or when between one-tenth to one-third of the plants are in bloom. It will be found, on examination, that new shoots are coming up from the crown of the roots at this time. The cutting should not be delayed until these are sufficiently high to be injured, as the yield of the next crop would be greatly reduced thereby. The exact time to begin cutting alfalfa will naturally vary somewhat according to the area to be cut, the weather, and other conditions. The difficulty of making a good quality of hay from alfalfa that is past bloom, and the large losses of leaves in this case, render it important not to delay the cutting beyond the time stated above.

Hay Crops.—The changes in the chemical composition of the hay crops during the growing season, in so far as they have been studied, appear to be similar to those of alfalfa, and show that these increase in fiber as the plants grow older, and that the nitrogen-free extract changes but little, with the other components decreasing to a considerable extent.[8] In the case of Indian corn, on the other hand, like all grain crops as well as roots and tubers, so far as is known, the highest yield of feed materials is obtained at maturity.

While the best time of cutting hay will vary somewhat according to the use for which it is intended, we note that early-cut hay has, in general, a higher feeding value, ton for ton, than late-cut hay; it is better, therefore, to cut too early than to delay the cutting until past bloom. Practical experience has also shown that the best time for cutting hay is, in general, shortly before bloom or during the early bloom. When the hay is intended for horses or fattening cattle, later cutting may be practised, since these animals relish late-cut hay and are fed hay more for the filling and less for the nutriment it supplies than is the case with dairy cows, young stock, and sheep.

The method of harvesting or preparation of feeding stuffs, furthermore, affects their chemical composition and value. Dried green grass and carefully cured hay have been found to have a similar value as an equivalent of fresh green grass; the only appreciable difference in chemical composition comes from the water content of the three materials. Under ordinary practical conditions, certain losses from leaves and tender stems in hay-making cannot,

[8] Fraps, "Principles of Agricultural Chemistry," p. 381.

however, be entirely avoided; these losses are especially important in the case of leguminous crops, notably alfalfa. The leaves make up about one-half of the weight of the alfalfa plant, and carry four-fifths of the crude protein, over one-half of the starchy components, and only about one-fourth of the fiber of the entire plant. Headden, of the Colorado station,[9] concludes from his studies of the alfalfa plant, "that the minimum loss from the falling of leaves and stems in successful hay-making amounts to from 15 to 20 per cent, and, in case where the conditions have been unfavorable, to as much as 60 per cent or even 66 per cent of the dry crop. For each 1700 pounds of hay taken off the field at least 300 pounds of leaves and small stems are left, and in very bad cases as much as 1200 pounds may be left for each 800 pounds taken." These are lost for feeding purposes, but are returned to the soil, whose supply of humus and valuable fertilizer ingredients they increase, and thus improve its crop-producing power.

When hay is exposed to rain or to sultry weather, important losses occur through leaching and fermentations. The Colorado station made analyses of samples of alfalfa hay exposed to rainy and damp weather for 15 days after cutting, during which time 1.76 inches of rain fell in three showers. Comparing the composition of this hay with that of hay from the same field cut the same day but immediately dried in an air-bath, the results shown in the following table were obtained:

Percentage Composition of Dry Matter

	Ash	Crude fiber	Crude fat	Crude protein	Nitrogen-free extract
Hay cured in an air-bath..	12.18	26.46	3.94	18.71	38.71
Hay exposed to rain.....	12.71	38.83	3.81	11.01	33.64

The damage to the hay was due partly to mechanical losses from leaves and tender parts becoming brittle and breaking off, but largely to the loss of protein, nitrogen-free extract, soluble mineral components, and aromatic principles, through fermentations and exposure to rain. The removal of the latter greatly decreases the flavor and palatability of the hay to stock; such damaged alfalfa hay is not likely to be worth more than one-half as much as good, well-cured hay.

[9] Colorado Bulletins 35 and 110.

What has been said in regard to alfalfa applies with equal force to other leguminous crops and also, to some extent, to other hay crops. These losses arise from two sources, fermentations and respiration in the plant cells, both of which are favored by warm, damp weather. Coarse plants with thick stems, the cells of which are not so rapidly killed on drying, like Indian corn and the sorghums, lose more feed materials from the sources given under unfavorable weather conditions than fine-stemmed plants like the common grasses that are readily dried. This explains how corn fodder left to cure in shocks will lose about 10 per cent of dry matter, even under ideal weather conditions, if standing in the field or kept under roof for a period of a month or more. Corn shocks of different sizes left for some months in the dry climate of Colorado lost from one-third to over one-half of their dry matter, the losses increasing with the size of the shocks.[10] In work by the author in Wisconsin which was continued for four years,[11] the average losses of dry matter and crude protein in carefully shocked fodder corn left in the field from one to several months amounted to about 24 per cent; similar results have been obtained in investigations conducted at a number of other experiment stations.

Since losses like those given will occur in case of corn cured under cover with all possible care, it is evident that the average losses of dry matter in field-cured fodder corn must be still higher under ordinary farm conditions. A careful study of the various experiments on this subject will readily show this to be the case (see p. 108).

The Siloing Process.—The most important method of preparation of feeding stuffs, next to hay-making, is the *siloing process.* The subject of the silo and silage will be discussed later (p. 149), and we shall here refer only to the changes that occur in the composition of the plants during the process in so far as they affect the nutritive values of the feeding stuffs. During the early stages of building silos in this country very large losses occurred in them, due mainly to the form of silos built. These were square and shallow structures which were poorly adapted for silage-making: First, because considerable air was left in the siloed mass and admitted from corners and leaky walls; and, second, because large amounts of silage spoiled while being fed out. The losses in feed materials found in the early silo experiments, therefore, would often go up to fifty per cent, and such results were also generally

[10] Colorado Bulletin 30.
[11] Report 1891, p. 227; *Agr. Science,* vol. 10, p. 299.

obtained in the cases where silage was made in pits in the ground or in open stacks. In modern tall, round silos the losses of dry matter have been greatly reduced, and under ordinary favorable conditions will not amount to more than ten per cent. As in the case of field-curing of corn, this loss falls primarily on the carbohydrates and the protein substances, changing these in part into organic acids and amides, respectively, so that the resulting silage is higher in fiber and lower in nitrogen-free extract than the material from which it was made. The following average analyses of green fodder corn and corn silage will illustrate this fact:

Average Composition of Green Fodder Corn and Corn Silage, in Per Cent

	Dry matter	Ash	Protein	Fiber	Nitrogen-free extract	Fat
Green corn fodder.	79.3	1.2	1.8	5.0	12.2	.5
Corn silage.......	79.1	1.4	1.7	6.0	11.0	.8

There is a slight decrease in the percentage of protein in silage as compared with fodder corn, but there is a further change in the protein compounds during the siloing process which does not appear from the average analyses given. Through the action of enzymes and bacteria, a portion of the protein of the fodder corn undergoes cleavage in the silo, and silage, therefore, contains a considerably larger proportion of non-albuminoid or amide nitrogen than the green corn (p. 11). The latter has been found to contain, on the average, 27 per cent of amide nitrogen, against 40 per cent or over in silage.

Effect of Storage.—Changes in the chemical composition occur in many feeding stuffs in *storage*. These are often quantitatively too slight to appear in statements of chemical analyses, but still are of considerable importance, as, *e.g.*, in the case of new and old oats, corn, hay, etc. These and many other feeds lose moisture on being stored; changes also occur in the composition of the dry matter, which are not yet clearly understood in many cases. New oats thus readily cause digestive disorders, such as colic, when fed to horses, and it cannot be supposed that the difficulty arises merely from the fact that such oats contain, say 10 per cent more moisture than old oats. In all probability the enzymes present in the oats, of which three different ones have been identified, cause certain changes in the composition of the dry matter during storage; although not measurable by the ordinary methods adopted in feed analyses, these changes are still of great importance, and transform the oats from an undesirable feed to the best-relished and most effective available horse feed.

Changes in the chemical composition also occur in the storage of hay, potatoes, and root crops, like sugar beets, mangels, etc. These are caused by the respiration of the plant cells and result in losses of valuable feed components, especially of soluble carbohydrates. As a rule, these changes do not affect the palatability of the feeds, but they do decrease their general nutritive value (p. 134).

QUESTIONS

1. Name the various factors that influence the quality and yield of crops, and state their relative importance.
2. At what stage of growth does Indian corn contain relatively most protein; fat; carbohydrates?
3. Give the approximate increase in dry matter and carbohydrates in Indian corn between tasselling and maturity.
4. State the changes that occur in the composition of alfalfa from buds forming to full bloom.
5. When does (*a*) Indian corn, (*b*) alfalfa yield the largest amounts of dry matter and digestible matter per acre?
6. State the losses that are likely to occur in making alfalfa hay.
7. Give the losses that are likely to occur in curing Indian corn fodder; also the losses in the siloing process.

CHAPTER VII

CONDITIONS AFFECTING THE DIGESTIBILITY OF FEEDING STUFFS

We have already shown the effect of advanced stages of development of plants on their digestibility. Some other factors that influence the digestibility of feeding stuffs will now be considered.

Different Classes of Farm Animals.—As might be expected from the differences in the digestive apparatus of the various classes of farm animals, these differ somewhat in their ability to digest certain feeding stuffs. Concentrated feeds are digested to a similar extent by nearly all classes of farm animals, but this does not hold true in the case of coarse feeds. The digestion coefficients for meadow hay and oat straw obtained by Kellner in the case of steers and sheep will illustrate the differences met with.[1]

Digestibility of Hay and Straw by Steers and Sheep, in Per Cent

	Meadow hay		Oat straw	
	Steers	Sheep	Steers	Sheep
Dry matter	65	62	57	47
Crude protein	61	57	32	19
Fat	61	57	43	50
Fiber	64	61	63	49
Nitrogen-free extract	70	69	58	49

Hay or straw of the same origin was fed to both classes of animals in these experiments. Greater differences are likely to occur where digestion coefficients of feeds of different origin are compared. Steers can, in general, digest bulky, coarse feeds better than sheep can, while with easily digested feeds only minor differences occur in the digestion coefficients obtained with these classes of farm animals.

Horses and other non-ruminants have a lower digestive capacity for coarse feeds than the ruminants. This is especially true as regards the fiber content of feeds. Through their more thorough mastication of roughage, and the fact that the feed is prepared for digestion by being softened in the paunch previous to the stomach digestion, the ruminants are able to better utilize the energy of the fiber in coarse feeds, like hay and straw, than are horses or pigs. The following average figures for digestibility of timothy, alfalfa

[1] Experiment Station Record 9, p. 509.

hay, and wheat straw by horses and ruminants will show the extent of the differences observed:

Digestion Coefficients for Horses and Ruminants, in Per Cent[2]

	Alfalfa hay		Timothy hay		Wheat straw	
	Horses	Ruminants	Horses	Ruminants	Horses	Ruminants
Protein	73	74	21	48	28	23
Fiber	40	46	43	50	18	55
Nitrogen-free extract	70	72	47	62	28	39
Fat	14	40	47	50	66	36
Organic matter	58	61	44	56	21	46

The coarser and less valuable a feeding stuff is, the greater is the difference in the digestibility coefficients obtained with the two kinds of animals. With concentrates no appreciable difference has, however, been observed in the digestibility by ruminants and other farm animals: 77 per cent of the protein of oats is thus digested by sheep and 79 per cent by horses; the latter digest 76 per cent of the protein in corn, and sheep digest 78 per cent. Digestion experiments with swine have shown that, generally speaking, these animals digest their feed to a similar extent as horses or ruminants. The differences which have been observed in the digestion coefficients are small and more likely to have been caused by experimental errors in the technique of digestion trials than by actual differences in the digestibility of the feeds. The experimental errors in determining the digestibility of concentrates are considerable, especially in the case of animals that cannot be fed such feeds alone, and it is only by repeated digestion trials under different conditions as to animals, amounts fed, combinations with other feeds, etc., that the results can be considered trustworthy. Kellner concluded from his investigations of this point:[3] "When only two experiments are made, one with hay and the other with hay and wheat bran, there is danger that the coefficients of digestibility obtained by the most careful work may vary from the actual by $\pm$ 9 per cent in the case of crude protein, $\pm$ 6.4 per cent with the nitrogen-free extract, $\pm$ 19.6 per cent with the crude fat, and $\pm$ 38.5 per cent with the crude fiber. It is plain from this that single experiments give results of very uncertain value, which are almost entirely lacking in significance. Weight can be only given to the averages of many experiments, and only such averages can be regarded as decisive."

[2] Massachusetts Report, 1911.
[3] Experiment Station Record, vol. 9, p. 513.

Even swine are able to digest considerable amounts of vegetable fiber. Direct experiments have shown that the digestion coefficients for fiber obtained with this class of animals are as follows: In the case of wheat bran, 39 per cent; wheat shorts, 37 per cent; barley, 49 per cent; corn, 39 per cent; corn and cob meal, 39 per cent; cracked wheat, 60 per cent; pea meal, 78 per cent; green oats and vetch, 49 per cent. These figures, in most cases, compare favorably with the average digestibility coefficients for the respective feeds obtained with steers or sheep.

Breeds.—Different breeds of the same class of farm animals do not appear to differ appreciably in their digestive capacity, nor do individual animals of the same breed differ in this respect, so long as the animals compared are in good health and have good teeth. Very young as well as old animals are handicapped in eating whole dry grains, on account of their inability to chew their feed well, and it should be fed wet or ground to such animals. Differences in the digestibility of feeds have sometimes been found in the case of individual animals, but there does not seem to be any regularity in the variations observed, and these are, therefore, likely to be accidental and due to errors of experimentation.

Age.—Age does not seem to affect the digestive capacity of animals whose digestive apparatus is fully developed, nor does a fair amount of work influence the digestion, provided that this is done at a moderate rate, like ordinary work of horses, mules, and oxen. Work done at a rapid pace, on the other hand, is likely to diminish the digestibility of the rations fed.

The various conditions bearing on the chemical composition of plants which have already been discussed are also of importance in so far as they affect the digestibility of plants. Among other factors that might be supposed to influence the digestibility of feeding stuffs, besides those already mentioned, are the following:

Quantity of Feed.—The quantity of feed does not appear to appreciably affect its digestibility. It should be said, however, that the testimony on this point is somewhat conflicting. The results of early experiments by Wolff and others, indicating a similar digestibility of small and large rations, have not been corroborated by more recent work. It seems reasonable to suppose that the digestive fluids will vary to a certain extent, both in composition and amounts, with the character of the rations fed, in case of herbivora, as found to be the case with carnivora in the brilliant investigations by the Russian physiologist Pavlov.[4] There is some evidence with herbivora which

[4] "Work of the Digestive Glands," London, 1910.

points the same way, but it cannot be said to be conclusive as yet.[5] The question must be considered still open as to whether a scant ration is digested more completely by farm animals than an ample ration. This matter, however, is more of scientific interest than of practical importance, as no stockman would want to starve or underfeed his animals for the purpose of possibly securing thereby a more complete percentage utilization of the feed. He would know that stock so fed can never yield profitable returns.

Drying and Preparation of Feeding Stuffs.—The mere drying of green or succulent feeds, where this is not accompanied by mechanical or fermentative losses, does not alter their digestibility. According to Jordan, four of six feeds experimented with on this point showed a slight difference in favor of the dried feeds, while two gave the opposite result. It is very certain, however, that as drying and curing of green fodder is carried on under ordinary field conditions there are considerable losses from abrasion of dry and brittle parts, and the remaining feed is, therefore, relatively richer in coarse parts, and its digestibility lower than that of the green feed. Attention was called to this fact in the discussion of the feeding value of alfalfa hay. The losses from these sources are perhaps greater in the case of leguminous hay crops than with other kinds of hay, but they are appreciable in all cases where the harvesting of the hay has been delayed until past bloom, or where the curing has been done under conditions that would render the hay very dry and cause a loss of leaves and tender parts of the plant. As a result, hay or other dried feeds have generally been found to have a lower digestibility than the original green or wet material. The following table of digestion coefficients shows this to be true. As the green and dry feeds of the same kind were not, as a rule, of similar origin, the two sets of figures given are only comparable in a general way.

Digestion Coefficients for Green and Dry Feeding Stuffs, in Per Cent

	Organic matter	Protein	Fiber	Nitrogen-free extract	Fat
Timothy grass..........	66	72	64	68	52
Timothy hay............	64	68	66	63	49
Corn fodder, dent, mature	74	63	66	81	80
Corn fodder, dry........	66	45	63	73	70
Clover, green...........	61	65	53	72	63
Clover hay	55	58	54	65	56
Alfalfa, green...........	61	74	43	72	39
Alfalfa hay	62	74	46	72	40
Brewers' grains, wet.....	63	73	40	62	86
Brewers' grains, dried....	64	71	48	60	88

[5] See Illinois Bulletin 172.

Grinding, Cutting, or Rolling of Feeds.—The digestibility of feeding stuffs is not, as a general rule, materially altered by special methods of preparation, like cutting, grinding, cracking, or rolling. An exception to this rule is found in the case of old or very young animals that cannot chew their feed well, and with small, hard seeds that would largely pass through the digestive tract unbroken and would not be acted upon by the digestive fluids of the body. When used for feeding farm animals, grains like wheat, barley, rye, kafir corn, etc., are therefore usually ground, and other cereals (corn, oats) are ground only when fed to young animals or to very old animals, so as to insure a maximum digestibility. If whole or broken grain reappears in the dung of the animals, it is evident that the feed had better be ground, or, if already ground, that too much is fed, and the allowance should in that case be reduced.

Hay and other roughage is sometimes run through a cutter before being fed out when of poor quality, or for mixing with other feeds, so that the animals may eat as much as possible thereof. In the western States alfalfa hay is frequently cut for steers and dairy cows. This is considered as economical practice, both because it insures the hay being eaten without waste and because it means a considerable saving of storage room. It is a common practice in European countries to feed cut straw mixed with grain to horses and occasionally to other farm animals, so as to induce them to consume a considerable amount of cheap roughage.

Soaking, Cooking, or Steaming Feed.—The digestibility of feeding stuffs is not influenced by soaking or wetting these prior to feeding time, but a depression of the digestion coefficients for protein will occur when the feeds are boiled, steamed, or otherwise subjected to high temperatures. The method of cooking feed was at one time much practised, especially among European farmers, but it has now been generally abandoned, except in the case of feeding swine. Numerous trials conducted at experiment stations have shown that it does not, in general, pay to cook feed for farm stock. There is a certain advantage in cooking potatoes and in steaming cut straw and hay of poor quality when intended for feeding swine, from the fact that the cell tissues are softened by the process, and the non-nitrogenous components are thus acted upon more thoroughly by the digestive fluids.

This does not refer to the protein substances, however, as these are rendered less digestible through the action of heat. The percentage of digestible protein in fresh, wet beet pulp was thus found by artificial digestion to be 60.1 per cent; after being dried at

75° to 80° C., 58.7 per cent, and after drying at 125° to 130° C., 41.1 per cent. The author found the digestion coefficient for protein in old-process linseed meal by artificial digestion to be 94.3 per cent, and for new-process meal, in the manufacture of which higher temperatures are used, 84.1 per cent.[6] The average coefficients for the two kinds of oil meal obtained in American digestion trials with ruminants are 89 and 85 per cent, respectively. A similar depression in the digestibility of protein in feeding stuffs resulting from application of heat has been observed in digestion trials on farm animals for meadow hay, corn silage, vetch silage, wheat bran, and dried beet pulp, and in artificial digestion trials with many human foods as well as with cattle feeds.

The Siloing Process.—From what has already been said, we should not expect that the siloing process will appreciably affect the digestibility of feeding stuffs, since the heat generated in the silo fermentation will rarely exceed 50° C. (122° F.). The following average digestion coefficients for three kinds of silage will show the influence of the siloing process as regards digestibility:

Digestion Coefficients for Green Fodders and Corresponding Silage, in Per Cent

	Dry matter	Protein	Fiber	Nitrogen-free extract	Fat
Corn fodder, dent, mature	72	54	59	75	75
Corn silage, dent, mature	70	51	65	71	82
Clover, green	61	65	53	72	63
Clover silage	45	35	48	45	45
Soybeans	67	78	45	77	55
Soybean silage	67	66	53	65	57

Only a few determinations of the digestibility of the last two feeds have been made so far, and the decrease in the digestibility of these crops in the silo may be found less important than now shown, when as much work has been done with them as with corn silage. It is evident, however, that no improvement in digestibility can be expected in siloing feeding stuffs; the favorable results obtained in feeding silage as compared with dried forage must, therefore, be due to the relatively small losses of feed materials occurring in the siloing process as compared with the curing of fodder or hay, and to the palatability and beneficial effects of silage on the health of the animals.

[6] Wisconsin Report, 1895, p. 75.

Influence of Different Nutrients.—*Carbohydrates.*—It was found, during the early studies of nutrition problems with farm animals, that the digestibility of a ration was appreciably decreased by the addition of large quantities of carbohydrates; the effect was noticed when more than 10 per cent of the dry substance of a ration was composed of soluble or other carbohydrates, and was especially marked as regards the digestion coefficients for protein, fiber, and nitrogen-free extract. Potatoes, roots, or corn will cause such a depression in the digestibility when added to rations of wider nutritive ratios than 1 : 8; the wider the nutritive ratio is, the greater will the depression be. If the protein content of a ration be increased with the allowance of carbohydrates, the depression in the digestibility of protein is decreased. High-protein feeds may, therefore, be fed with starchy coarse feeds, like hay or straw, without affecting their digestibility, but starchy feeds, like roots and tubers, cannot be fed in larger proportions than 15 per cent of the ration, calculated on the total dry matter content, without decreasing its digestibility.

The Massachusetts station lately corroborated these results of early investigators and showed that molasses and molasses feeds have a similar effect on the digestibility of the hay, as given above in the case of potatoes and roots.[7] When molasses constituted more than 20 per cent of the dry matter of a ration of hay and gluten feed, a marked depression in the digestibility of the ration was observed.

Fat (oil).—A moderate amount of oil added to a ration for cows, say one-half to one pound daily per 1000 pounds live weight, exerts a favorable influence on its digestibility, but if larger quantities are fed, the nutritive ratio of the ration becomes very wide, with a resulting depression in the digestibility; more can be fed in the form of the oil-bearing seeds, *e.g.,* flaxseed, than clear oil without seriously affecting the digestibility of the ration or the appetite of the animals. A heavy feeding of oil, even if it were economical, is not advantageous, because it is likely to cause a loss of appetite.

Protein.—An addition of easily digestible protein substances to a ration does not influence its digestibility in any way. In experiments with pigs in which potatoes with varying quantities of meat flour were fed the crude protein of the meat was completely digested, while the proportion of potatoes digested remained unchanged. Protein added to a ration not only does not affect the digestibility of the basal ration, but will counteract any depression in digestibility that might be caused by the addition of large quantities of soluble carbohydrates, as has been stated. It has been found, in general, in ex-

[7] Report 1909, part i, pp. 82–131.

periments with ruminants, that the best conditions for the digestion of rations fed are found when these contain about one part of digestible protein for every eight parts of digestible non-nitrogenous substances (including fat multiplied by 2.25). In the case of swine a depression in the digestibility of carbohydrates will not occur until starch has been added in sufficient quantities to bring the nutritive ratio of the ration down to 1 : 12, and the digestibility of the crude protein was not affected by a ratio of 1 : 9. The result of experimental work shows that the maximum nutritive effect of a ration can be obtained only when the relation between the digestible protein and non-protein (the nutritive ratio) lies within certain limits that may not be outside of 1 : 8 in the case of ruminants and 1 : 9 to 12 in the case of pigs.

Other Components.—The addition of free acids, like sulfuric or lactic acid, will not influence the digestibility of a ration or of its components. Since there are large amounts of free organic acids, like lactic, acetic, and butyric acids, in silage, particularly of the first two acids, this result is important. It is not recommended, however, to give such feeds in large quantities to cows whose milk is used for infant feeding, or for feeding young stock, as they have a tendency to cause looseness of the bowels.

The effect of many other materials on the digestibility of feeding stuffs has been investigated, like calcium carbonate, common salt (sodium chloride), and other mineral salts. In general, no influence on the digestibility of feeds has been observed in experiments conducted for the study of these problems. A moderate amount of common salt will improve the palatability of a feed, however, and may cause an animal to eat more and thus give better returns, if this is adapted to the specific purposes for which it is kept. A good dairy cow, *e.g.*, if stimulated to consume larger amounts of feed than before, will respond to the more liberal feeding by an increase in her milk production, while a cow not bred consistently "along dairy lines," with a view to securing a large milk production, will put on body fat under similar conditions, and the milk yield will be likely to decrease as a result.

QUESTIONS

1. How do steers and sheep differ in their ability to digest (*a*) coarse feeds; (*b*) concentrates?
2. What is the main difference in the digestive capacity of horses and cattle?
3. Name the various factors that influence the digestibility of feeding stuffs.
4. How do (*a*) drying and (*b*) cooking affect the digestibility of protein? Give some examples.
5. Give the influence of different nutrients on the digestibility of feeding stuffs.

CHAPTER VIII

CALCULATION OF RATIONS

Questions relating to rations for the various classes of farm animals will be considered in detail later on, in the discussion of feeding problems connected with the respective animals. We shall here give the general method by which rations are calculated from the tables of composition and digestibility of feeding stuffs.

The Wolff-Lehmann Standard.—We shall suppose that a milch cow yielding about 20 pounds of milk daily is to be fed a ration composed of the following feeds: Hay from mixed grasses, corn meal, wheat bran, and oil meal. Experience has taught us that a cow will eat, on the average, about 20 pounds of hay daily, with a fair allowance of concentrates. It is a good plan to feed concentrates in proportion to the amount of milk or butter fat produced by the cows. We will assume that the cow will receive as a trial ration, in addition to the amount of hay given, three pounds of corn meal and four pounds of wheat bran. From Table I in the Appendix we learn the composition of hay, corn meal, and bran.

Ingredients for a Trial Ration

	Dry matter, pounds	Digestible protein, pounds	Digestible carbohydrates and fat, pounds
100 pounds of hay contain..........	84.7	4.2	44.9
100 pounds of corn meal contain....	88.7	8.0	75.9
100 pounds of wheat bran contain...	88.1	11.9	47.6

Twenty pounds of hay, therefore, contain:

$.847 \times 20 = 16.94$ pounds dry matter;
$.042 \times 20 = .84$ pound digestible protein; and
$.449 \times 20 = 8.98$ pounds digestible carbohydrates and fat.

In the same way three pounds of corn meal will contain:

$.887 \times 3 = 2.66$ pounds dry matter;
$.08 \times 3 = .24$ pound digestible protein;
$.759 \times 3 = 2.28$ pounds digestible carbohydrates and fat; and

Four pounds of wheat bran will be found to contain:

3.52 pounds dry matter;
.48 pound digestible protein, and
1.90 pounds digestible carbohydrates and fat.

We now have the composition of the ration given as follows:

Results of First Trial

	Dry matter, pounds	Digestible protein, pounds	Digestible carbohydrates and fat, pounds
20 pounds hay	16.94	.84	8.98
4 pounds wheat bran	3.52	.48	1.90
3 pounds corn meal	2.66	.24	2.28
Total	23.12	1.56	13.16
Wolff-Lehmann standard	29.0	2.5	14.1
Deficit	5.88	.94	.94

There is, therefore, a deficit both in dry matter and digestible components in the ration; and it is evident that we have to supply a high-protein feed in order to keep the relation between the two classes of nutrients near to the requirements of the standard. Linseed meal serves this purpose very well, and we may add 2 pounds of this to the ration.

Results of Second Trial

	Dry matter	Protein	Digestible carbohydrates and fat	N. R., 1:
Ration as above	23.12	1.56	13.16	
2 pounds oil meal	1.80	.60	.95	
Total	24.92	2.16	14.11	6.5
Wolff-Lehmann standard	29.0	2.5	14.1	5.6
Deficit	4.08	.36	.01*	

* Excess.

The ration is still below the standard in dry matter and digestible protein, especially the former, but may be sufficiently close to the standard for all practical purposes. If we had to feed a poorer grade of roughage than the hay given, more dry matter would have to be supplied in proportion to the digestible matter, and the deficit of dry matter would have been avoided without increasing at the same time the digestible components of the ration. The Wolff-Lehmann standards were framed to conform especially to ordinary European feeding practices, which generally include some straw or low-grade roughage in the rations fed to livestock.

The ration as given might be improved by feeding a concentrate, like cotton-seed meal, in the place of oil meal. This feed contains still more digestible protein than the linseed meal, viz., 37.6 per cent, and, by substituting 2 pounds of it for the linseed meal, the digestible protein of the ration would be raised to nearly the requirements of the standard. It would make a less palatable ration for cows, however, and in most parts of the country would render it somewhat more expensive.

Another change in the ration that would bring it closer to the standard in digestible protein and nutritive ratio would be to replace one-half of the wheat bran by middlings, or one-half of the corn meal by oats or barley. The desirability of making these changes would depend mainly on the cost of the various feeds. The nutritive effect of the ration would not be likely to be materially influenced by the changes suggested, except that it is, in general, advisable to feed a mixture of several feeds to dairy cows and heavy-producing animals rather than only one or two, as it will increase the palatability of the ration and stimulate the appetite. The preceding ration is, however, satisfactory as given and will produce good results "at the pail."

Nutritive Ratio.—We notice that the nutritive ratio of the ration given is 1 : 6.5 instead of 1 : 5.6, as required by the standard. It follows from what has been said, however, that it is not important to bring the nutritive ratio closer than this to the standard.

Up to recent times a definite nutritive ratio was considered important for the specific purpose of feeding in view; *e.g.*, 1 : 5.4 was the required ratio for milch cows, according to the original Wolff (German) standard, and it was not deemed advisable to vary greatly from this ratio. Investigations conducted since the publication of the Wolff-Lehmann standard have shown, however, that, given a certain minimum of digestible protein in a ration, its exact nutritive ratio is of no great importance; but a liberal supply of total digestible matter in a ration is important, and a nutritive ratio of 1 : 7, or even wider, may prove nearly as efficient for feeding dairy cows as a narrow ration, provided the former ration furnishes a more abundant supply of digestible nutrients. This applies with special force to fattening animals,[1] but holds good also in the case of dairy cows and other animals to which it was formerly considered necessary to supply rations of especially narrow nutritive ratios in order to secure a large and economical production.

[1] See Kellner, *Landw. Versuchs-Stationen*, vol. 53, pp. 1–474.

A ration containing a relatively small amount of protein is spoken of as having a wide ratio, *e.g.*, 1 : 7 or higher, and one with a relatively high protein content as having a narrow nutritive ratio, *e.g.*, 1 : 5.4 or less. A medium ratio would lie between these limits. The nutritive ratios of different feeding stuffs range from 1 : 1 or below, as in the cases of dried blood, tankage, cotton-seed meal, to 1 : 20 or above, as in the case of cornstalks, sorghum hay, and straw of the cereals. The former feeds and others in the same class are known as protein feeds or nitrogenous feeds, and the latter as starchy or non-nitrogenous feeds. The nutritive ratio of a feed is of value in showing whether it supplies largely protein or non-nitrogenous components and whether one feed can be substituted for another without change in physiological effect (see p. 38).

Armsby's Energy Values.—As previously stated, the Armsby standards show the amount of digestible true protein and energy values required for feeding different classes of farm animals. The requirements for maintenance and for production are given separately. For a dairy cow the standard thus calls for the following amount of nutrients for the two purposes:

For *maintenance,* 0.5 pound digestible true protein and 6.0 therms of energy values per 1000 pounds live weight.

For *production,* 0.05 pound digestible true protein and 0.3 therm per pound of milk of average quality.

In the example given above the amount of nutrients to be furnished the cow would, therefore, be as follows, assuming the cow to weigh 1000 pounds:

Nutrients in Energy Values

	Digestible true protein pounds	Energy values, therms
For maintenance.....	.5	6.0
For production.......	1.0	6.0
Total requirements	1.5	12.0

By reference to Table III in the Appendix it will be found that the feeds given in the preceding example contain the following amounts of digestible protein and energy values:

Ration Expressed in Protein and Energy Values

	Digestible true protein, pounds	Energy values, therms
20 pounds timothy hay	.41	6.71
4 pounds bran.......	.41	1.93
3 pounds corn meal..	.20	2.67
2 pounds oil meal....	.55	1.58
Total............	1.57	12.89
Variation from standard	.07	.89

The agreement between the standard and the composition of the calculated ration is as close as can be desired in this case. No importance can be attached to the slight excess of 0.07 pound in the digestible protein in the ration or the excess of energy value, 0.89 therm, and we conclude, therefore, that a ration like the one given is theoretically sound, and it will be found practical and efficient in feeding dairy cows producing a medium amount of milk, say 20 pounds a day.

Comparison of Standards.—The Wolff-Lehmann and Armsby standards are recommended for use in calculating rations by different authorities, and both will be found valuable for this purpose. Either set of standards has the advantage over the other in certain points, and students should become familiar with both, so as to be able to apply in each case the particular method of calculation that may best serve the purpose in view. We have seen that the Armsby standards are, in the main, derived from the investigational work done during the last quarter of a century by German scientists, largely Kellner, who worked mainly with mature fattening steers. Only a small amount of research work relative to the application of the system of energy values to the feeding of other farm animals has been done; in case of some animals, like sheep, pigs, and poultry, such work is entirely lacking (p. 51), so that the standards based on energy values, proposed for all animals except fattening cattle, rest on a more or less insecure basis.

The Wolff-Lehmann standards, on the other hand, do not take cognizance of the varying value of digestible matter in different feeding stuffs due to the losses of energy in the processes of digestion and assimilation. Rations composed of feeds that supply similar amounts of digestible matter might, therefore, differ greatly in the amounts of net available energy that they supply, and would in that case have a different feeding value for maintenance or productive purposes. Under ordinary practical conditions, however, rations are composed of roughage and concentrates in about similar proportions, and no great error is therefore introduced by the use of these standards. They have been simplified in this book by combining digestible fat with the digestible carbohydrates, according to its fuel value, so that only dry matter, digestible protein, and digestible carbohydrates and fat are now considered, making the necessary calculations very simple. The fact that these standards are based on the vast amount of work done during the last half century or more, in the lines of chemical analysis, digestion trials, and feeding experiments with all kinds of farm animals, renders them especially valuable to both farmers and students of feeding problems, and they may safely be taken as aids to rational feeding, even though they cannot be considered infallible guides.

Limitations of Feeding Standards.—Feeding standards are intended to be used only as gauges by which the farmer may estimate the quantities of nutrients required by his stock for a certain production, and are not to be followed blindly. Farm animals vary greatly in their productive capacity, as well as in their feed requirements and their capacity to make economical use of their feed; hence feeding standards can apply only to average conditions, a point which should always be kept in mind in using them. In constructing rations according to the standards, several points must be considered besides the chemical composition and the digestibility of the feeding stuffs.

The same feeds vary greatly in chemical composition and digestibility, as we have seen; this fact renders it quite unnecessary to make a certain combination of feeds conform absolutely to the feeding standard, for we have no assurance that the particular feeds available will closely correspond to the average figures for the digestible components given in tables of composition of feeding stuffs; in fact, the chances are that they will vary more or less from the average data given in the tables. Therefore, unless samples of the feeds on hand are analyzed by a chemist, and digestion trials conducted with each feed—both of which are lengthy and laborious tasks—we can know only in a general way what the actual values of the available feeds are. In view of this uncertainty as to the exact composition of the feeds, it is quite useless to try to make a certain combination of feeds conform to a definite standard within a few hundredths or tenths of a pound. The standards are a valuable guide to the practical feeder and the student of animal nutrition, but it would be a mistake to look upon them as precepts that must be rigidly adhered to.

There are several other considerations that should receive attention in formulating rations for farm animals, besides supplying nutrients in the right amounts and proportions and getting an effective ration at as low a cost as possible. Among these are:

First, the feeds must be palatable to the animals fed and must not have any deleterious influence on their digestion or general health or on the products which they furnish. A well-balanced ration for milch cows can be made up of oat straw and oil meal, but it would not be likely to produce satisfactory results, because of the large amount of roughage the cows would have to consume and the unpalatability of the ration.

Second, the rations must contain a fair proportion of roughage and concentrates; they must not be too bulky and still must contain a sufficient amount of roughage to keep up the rumination of the animals, in the case of cows and sheep, and to secure a healthy condition of the animals generally. In the case of dairy cows, about two pounds of hay are generally fed per hundredweight, if this is the sole roughage. If silage is available, one pound of hay and three pounds of silage may be fed per hundredweight, and one pound of concentrates for every three to five pounds of milk produced, according to the character of the roughage and the quality of the milk produced; if a good quality of roughage is available, less grain may be fed, and *vice versa.* Cows producing milk of low fat content should receive less grain per pound of milk than high testing cows (see p. 240). A good rule for feeding grain to cows on mixed hay, corn stover, corn silage, and similar low-protein roughage is to allow as many pounds of grain a day as the cow gives pounds of butter fat in a week. Cows receiving a good grade of alfalfa or other rich coarse feeds will not need more than one-half of this amount of grain feed.

Third, the ration should conform to the system of farming followed, and this should be arranged with a view to growing on the farm, if possible, all the roughage and most of the concentrates which the stock are to receive, so that the farmer may be largely independent of the feed market with its fluctuating prices.

Fourth, the rations are preferably composed of feeds of different origin, so that, especially, the protein substances are supplied from different sources. The recent experiments with cows fed rations balanced from restricted sources (corn, wheat, or oat products only) at the Wisconsin Experiment Station [2] illustrate in a striking way the necessity of furnishing a variety in the make-up of rations for

[2] Research Bulletin 17.

dairy cows at least, and the same doubtless holds true also for other classes of farm animals. Of the rations experimented with, only those composed entirely of corn feeds (corn meal, gluten feed, and cornstalks) proved satisfactory for dairy cows (see p. 166).

Fifth, the local market prices of feeding stuffs are of the greatest importance in determining which feeds to use; the conditions in the different sections of our continent are so different in this respect as to render generalization difficult. As a rule, nitrogenous concentrates are the cheapest feeds in the South and the East, and flour-mill, brewery, and starch-factory refuse feeds the cheapest in the Northwest. Where alfalfa or other leguminous crops form the main dependence of farm animals for roughage, nitrogenous concentrates need not be fed to the extent that is necessary where farmers depend on mixed hay, corn fodder, and other non-nitrogenous forage crops for feeding their stock.

The feeding standards express the physiological requirements of animals for a certain production. The economy of systems of feeding based on the standards does not enter into consideration, nor is it possible to formulate feeding standards of general or permanent value that take into consideration the financial side of the question, since the market prices of feeds vary in different places and at different times in the same places. But for the practical farmer the cost of feeds is a factor of vital importance. It is of little help to him to be told that he can secure a certain production of milk or meat by a special system of feeding if the prices of the different feeding stuffs called for make it impossible or unprofitable for him to adopt them in his feeding operations. However, the standards place before the feeder an ideal which he may approach as nearly as the special conditions by which he is surrounded will allow. The relative cost of different feeding stuffs must always be considered, and the choice of feeds with which to supplement home-grown forage crops and grain must be made accordingly.

QUESTIONS

1. Explain how a ration is calculated according to (*a*) the Wolff-Lehmann standard; (*b*) the Armsby standard.
2. Discuss the relative value of these two standards for (*a*) dairy cows; (*b*) fattening steers.
3. Formulate rations for a 1000-pound dairy cow producing 20 pounds of 4 per cent milk, according to (*a*) Wolff-Lehmann, (*b*) Armsby standards, using the following feeding stuffs: Mixed hay, oats, and wheat middlings.
4. Explain the method of calculating nutritive ratios; give an example.
5. State the limitations of feeding standards. and give at least four points to be considered in formulating rations for farm animals.
6. What is the difference between a physiological standard and a practical feeding standard?

CHAPTER IX

THE FEED-UNIT SYSTEM

The feed-unit system furnishes a convenient and practical method of determining the comparative nutritive values of different feeding stuffs. It originated in Denmark, and has been used there and in other north European countries during the last couple of decades for comparing the feed consumption of farm animals during certain periods and the relative economy of their production. While originally worked out for dairy cows and mostly applied to these, the system has also been adapted to other classes of farm animals, especially swine, calves, and horses.

A simple single figure is obtained by this system for the total feed eaten by an animal during a given period, including that eaten on pasture, and valuable information may thus be secured relative to the economy of the production by a comparison of the total feed consumption and production of the animals. The different feeds are given equivalent values according to the results of elaborate, carefully-conducted feeding experiments, most of which were made at Copenhagen Experiment Station. All feeds are referred to a standard, the so-called feed unit, which is a pound of mixed grain, like corn, barley, wheat, or rye.

Numerous feeding experiments, conducted with the greatest care and scientific accuracy, have shown that, *e.g.*, 1.1 pounds of wheat bran or 2.5 pounds of mixed hay of average quality can be substituted to a limited extent for a pound of grain in ordinary rations for dairy cows without causing any appreciable change in the yield or the composition of the milk produced by the cows, or influencing their body weight or general condition. The quantities of the different feeds given, 1.1 pounds wheat bran and 2.5 pounds hay, are therefore equivalent to one feed unit. Table IV in the Appendix gives a list of feed units obtained largely as a result of Scandinavian feeding experiments with cows, supplemented by results of American trials and feeding experience. In case of coarse feeds, certain limits are given between which the equivalent values may vary, according to the quality of the feed; *e.g.*, a choice grade of alfalfa hay will have a unit value of 1.5; *i.e.*, it would take 1.5 pounds to equal a pound of mixed grain in nutritive effect, while in the case of a poor quality of this hay it will take 3 pounds to equal a feed unit, etc.

The value of pasture may vary between 6 and 12 units per day, according to the production of the cows and the kind and the condition of the pasture. The former figure may be applied in case of dry cows, or for scant or largely dried-up pastures; the latter for heavy-producing cows on luxurious pasture.

A simple example will readily explain the application of the system. We will suppose that a cow ate 750 pounds of hay, 150 pounds of wheat bran, and 90 pounds of ground corn during a certain month.

The cow consequently received 750 divided by 2.5, or 300 feed units in the hay eaten;

150 divided by 1.1, or 136 feed units in the bran, and

90 feed units in the corn,

making a total feed consumption of 526 feed units for the month. If she yielded 30 pounds of butter fat during the month on this feed, she produced 30 ÷ 5.26, or 5.7 pounds of butter fat per 100 feed units.

By the use of the unit values given, the feed consumption of individual cows for an entire year may be obtained and compared with their production, thus enabling a farmer to determine whether a cow is a sufficiently high and economical producer to remain in the herd, and the net returns for the feed which each cow in the herd has yielded. It also makes it possible to compare the results obtained in different herds, and furnishes valuable data for studies of the relation of feed to dairy production.

The Feed-Unit Standard.—The following feeding standard for dairy cows, according to the feed-unit system, has been proposed by Hansson, of the Royal Swedish Academy, for a 1000-pound cow per day:

For maintenance, 0.65 pound digestible protein and 6.6 feed units.

For production, 0.045 pound to 0.05 pound digestible protein and 1/3 feed unit per pound of milk.[1]

Example.—A 1000-pound cow received 30 pounds silage, 8 pounds clover hay, 3 pounds corn meal, and 3 pounds gluten feed. How many feed units does she receive in her feed, and how many units are required per 100 pounds of milk and per pound of butter fat? How much digestible protein and how many feed units should she receive according to the feed-unit standard?

[1] "Kontrolfören. Arbetsfält," Stockholm, 1910.

Ration Compared with Feed-Unit Standard

Ration fed	Feed units	Digestible protein, pounds	Standard		
				Feed units	Digestible protein, pounds
30 pounds corn silage—30 ÷ 6 =	5	.42	Maintenance	6.6	.65
8 pounds clover hay— 8 ÷ 2 =	4	.57	Production ..	7.2	1.20
3 pounds corn	3	.23			
3 pounds gluten feed—3 ÷ .9 =	3.3	.64	Total	13.8	1.85
Total	15.3	1.86			

According to the feed-unit standard, the cow should receive 1.85 pounds of digestible protein and 13.8 feed units per day; we note that the ration supplies 1.86 pounds digestible protein and 15.3 feed units. It is, therefore, somewhat higher in feed units than the standard, but the amount of protein tallies perfectly with that called for by the standard.

The feed-unit system is simple and easily applied. It has been found to give accurate results under ordinary farm conditions, and is scientifically well founded, as has been shown by the fact that the results obtained by this system do not, as a rule, vary from the methods of valuation of feeding stuffs based on their contents of digestible matter or energy values.[2] At least so far as dairy cows and swine are concerned, this system may be depended upon to furnish fully as reliable a guide to practical feeding operations as either of the two methods given, and will doubtless be generally adopted in the future also in this country, especially in the work of cow-testing associations.

QUESTIONS

1. Explain the origin of the feed-unit system.
2. What are the special advantages of this system, and to what classes of farm animals is it especially adapted?
3. How is the value of pasturage determined in this system?
4. Give the feed-unit standard for dairy cows.
5. Formulate a ration for a 1000-pound dairy cow according to this standard, using the following feeds: Mixed hay, corn silage, wheat bran, barley, linseed meal.
6. How does the ration given above agree with the Wolff-Lehmann and Armsby standards for milch cows with the same production?

[2] Wisconsin Circular 37, p. 12.

CHAPTER X

RELATIVE VALUE OF FEEDING STUFFS

We have seen that the relative cost of feeding stuffs is a matter of the greatest importance to the farmer. If he has to buy feeds for his stock in order to supplement the farm-grown crops, as nearly all farmers have to do, he must give due regard to getting the most for his money in actual feeding value. He should be in position, therefore, to ascertain the relative feeding value of the available feeds according to the best information at hand.

The relative value of feeding stuffs may be measured in several ways: According to (*a*) the market prices of the feeds; (*b*) their contents of digestible nutrients; (*c*) their energy values, and (*d*) the feed units which they furnish.

Considering first the market values of feeds, it is well known that these are subject to great variations and are influenced by a number of factors which do not necessarily bear on the intrinsic feeding value of the feeds. To illustrate, alfalfa is as valuable a feed in the western States, where it may be bought at $8 a ton or less at times, as in the eastern or central States, where it generally commands more than twice this price; again, cotton-seed meal and cake are worth as much to the southern farmer as to the Pacific coast feeder or the European dairyman. But these latter have to pay nearly twice as much for it as the former.

The question of cost of transportation is evidently of paramount importance in determining the market price of a feed; another factor is the reputation of a particular feed, which greatly influences the demand for it. The relative prices of cotton-seed meal and linseed meal well illustrate this fact. In many sections of the country the former furnishes considerable more protein at the same or lower prices than the latter, and is fully as good a feed for most purposes, and still does not find as ready sale as linseed meal. The market prices of feeds are often not a reliable guide to their intrinsic value, and they also fluctuate greatly in different places and in different years; hence any attempt to gauge the value of feeds according to their cost is bound to prove unsuccessful. Several authors—and the writer among them—have calculated the commercial values of protein, fat, and carbohydrates in concentrated feeding stuffs from the average composition and market prices of a large number of common feeds, and used the figures thus obtained for comparisons of the cost of different feeding stuffs, but unless at least a dozen different feeds are included in the calculations and these are repeated at frequent intervals, at least every five years, the results obtained are not very satisfactory. Such calculations are laborious, and the results, as may be inferred, are valuable only for a limited period and region.[3]

Methods of Comparison.—The only methods of comparison that have a general value are the three previously given, based on the digestible components of feeds, their energy values, or feed-unit values. The method of comparison to be followed in each case will be explained in the following paragraphs:

(a) *Digestible Components.*—The digestible components of the feeds to be compared are added together, the per cent of digestible fat being first multiplied by 2.25, and the sum divided into the market prices for 100 pounds of the different feeds. The cost per unit of digestible matter is thus obtained, and the feed or feeds that supply a pound of digestible matter at the lowest cost are selected. This method furnishes reliable information in regard to the comparative value of feeds of the same kinds, rough feeds, concentrates, roots, etc., but not when feeds of different classes are compared, on account of the greater losses of energy in the digestion of coarse feeds than in the case of concentrates.

(b) *Energy Values.*—The net energy values for 100 pounds of the different feeds are divided into the price per 100 pounds, and the feed or feeds furnishing a unit of energy value (therm) at the lowest cost thus ascertained. These values are reliable for production of increase in body weight in the case of fattening steers, and approximately so also for other purposes of animal production.

(c) *Feed-unit Values.*—The cost of a feed unit is determined by multiplying the cost per 100 pounds by the feed-unit value of each feed. The lowest cost per feed unit shows the cheapest feeds. The origin and meaning of the feed-unit system is explained in another chapter of this book (p. 79).

Example 1.—Given green corn fodder at $2 per ton; alfalfa hay at $10 a ton; corn at 60 cents a bushel ($21.40 a ton); wheat bran at $24, and linseed meal at $30 a ton, which feeds are most economical for feeding dairy cows?

By reference to Table I in the Appendix, we obtain the following figures:

[3] Wisconsin Report 8, p. 212.

Example 1, Details of Cost

No.	Feed	Cost per 100 pounds, cents	Digestible matter		Energy values		Feed units	
			Total pounds	Cost per pound, cents	Total therms	Cost per therm, cents	Total	Cost per unit, cents
1	Fodder corn	10	13.8	.72	12.4	.81	8.0	0.8
2	Alfalfa hay	50	53.0	.94	34.4	1.45	2.0	1.0
3	Indian corn	107	83.9	1.28	88.8	1.20	1.0	1.07
4	Wheat bran	150	77.7	2.02	48.2	2.49	1.1	1.32
5	Linseed meal	120	59.5	1.93	78.9	1.90	.9	1.35

We note that the rank of the different feeds at the prices given is as follows:

According to contents of digestible matter, 1, 2, 3, 5, 4.

According to energy values, 1, 3, 2, 5, 4.

According to feed-unit values, 1, 2, 3, 4, 5.

The relative value of these feeds does not differ greatly whether one or the other of the methods of calculation be adopted; fodder corn is the cheapest feed according to all three methods of calculation; alfalfa or corn meal comes next, and wheat bran and oil meal are the most expensive feeds. Where differences in the relative rank do occur, it is evident that the digestible matter gives an undue advantage in the case of coarse feeds, and that energy values give corn too much credit over the protein feeds, wheat bran and oil meal, except when fed to fattening steers, in which case the figures given for these values are doubtless the best available. The rank based on feed-unit values, on the other hand, is likely to prove the more correct in case of feeding growing animals, milch cows and sheep.

Example 2.—Both cotton-seed meal and linseed meal can be bought at $32 a ton, gluten feed at $25 a ton, and dried distillers' grains at $28 a ton, which should be bought for feeding dairy cows, supplementary to corn silage and clover hay. By similar methods of calculation as before we have the following data:

Example 2, Details of Cost

No.	Feed	Cost per 100 pounds, cents	Digestible matter		Energy values		Feed units	
			Total	Cost per pound, cents	Total	Cost per therm, cents	Total	Cost per unit, cents
1	Gluten feed	125	80.6	1.55	79.3	1.58	.9	1.13
2	Distillers' grains	140	88.6	1.58	79.2	1.77	.9	1.26
3	Cotton-seed meal	160	80.6	1.99	84.2	1.90	.8	1.28
4	Linseed meal	160	77.7	2.06	78.9	2.03	.9	1.44

As these feeds are all high-protein feeds and adapted to feeding dairy cows, relative cheapness is the important consideration in this case, and we note that the feeds rank in the following order by all three methods in this respect: Gluten feed, distillers' grains, cotton-seed meal, and oil meal. With the roughage on hand, corn silage and clover hay, the feeds may be given preference in the order given. If only starchy roughage were available, cotton-seed meal or oil meal, being richer in protein than the two others, would be more desirable feeds, unless their cost were greatly against them.

QUESTIONS

1. Give three methods by which the relative value of feeding stuffs may be determined.
2. State the special advantages of each one of these methods.
3. What is the relative value of the following feeds for fattening steers, at the prices given, according to the different methods stated: Clover hay, at $12 per ton; cornstalks, at $4 per ton; alfalfa hay, at $15 per ton; shelled corn, at 50 cents per bushel; oats, at $30 per ton, and wheat bran, at $25 per ton?

CHAPTER XI

MANURIAL VALUES OF FEEDING STUFFS

Fertility in Feeds.—When a farmer buys feed for his stock the fertility which is contained therein is often not taken into consideration, especially in the central or western States, where the supply of fertility in the soil, as a rule, has not as yet been depleted by continuous cropping. Farmers in the older sections of our country, and in the countries of the Old World, who pay out enormous sums of money annually for commercial fertilizers, are more likely to consider the manurial value of feeding stuffs. In addition to furnishing feed for farm animals, all plant materials supply valuable fertilizer ingredients (nitrogen and mineral matter) which largely go into the manure and aid in restoring the fertility of the farm land that has been lost through the removal of agricultural crops. Under otherwise similar conditions the feeds that furnish the largest quantities of fertilizing ingredients should, therefore, be selected. We understand by manurial value of feeds the value which these would have if applied directly as manure on the land. This value is figured on the basis of the amounts and cost of the three fertilizer constituents, nitrogen, phosphoric acid, and potash, which have definite and fairly constant market values. Table V in the Appendix shows that a ton of alfalfa hay, *e.g.*, contains 44 pounds of nitrogen, 10 pounds of phosphoric acid, and 34 pounds of potash; these amounts of fertilizer constituents would be worth, at a low valuation (15 cents per pound of nitrogen, 4 cents per pound of phosphoric acid and potash), $8.36 (Fig. 10).[1]

If a farmer buys a ton of alfalfa hay, he therefore receives, in addition to the energy for feeding purposes contained therein, an amount of fertilizer constituents which would cost $8.36 if bought in the form of commercial fertilizers. In the same way, the fertilizer value of Indian corn would be $5.64; oats, $6.63; wheat bran, $11.55; linseed meal, $18.75, and cotton-seed meal, $23.36.

These figures make up a large proportion of the market values of the feeds; a study of them will show that the most expensive feeds, which are all high-protein feeds, have, generally speaking, also the

[1] Present market prices vary considerably from the figures used in these calculations.

highest manurial values. Where there is a choice between different feeding stuffs, the contents of valuable fertilizer ingredients in the feeds should receive careful consideration. By way of illustration we may bring together in a table some of the common feeding stuffs:

Fertilizer Ingredients of Some Common Feeds Contained in One Ton

	Nitrogen	Phosphoric acid	Potash
Coarse Feeds:			
Timothy hay	19	7	28
Corn fodder	12	8	22
Clover hay	39	11	37
Alfalfa	44	10	34
Concentrates:			
Cotton-seed meal	135	58	17
Linseed meal (old-process)	108	33	27
Gluten meal	110	7	1
Dried brewers' grains	80	32	4
Wheat bran	53	58	32
Indian corn	32	13	8

We note that among the coarse feeds the legumes are richer than the grasses, not only in nitrogen, but also in potash, and slightly so in phosphoric acid. Cotton-seed meal, oil meal, and gluten meal, among the concentrates, are all high in nitrogen, but, unlike the first two, gluten meal is greatly deficient in both phosphoric acid and potash. Corn is very low in all three fertilizer ingredients, and brewers' grains are low in phosphoric acid and potash, especially the latter. Feeds of high fertilizer values should, under otherwise similar conditions, be preferred to those of relatively low fertilizer value if they serve equally well the purpose in view. Corn is, therefore, other things being equal, worth less to the farmer than is wheat bran, and linseed meal and cotton-seed meal are worth more than either.

Fertility Retained by Farm Animals.—The amounts of the fertilizer ingredients of feeding stuffs retained by farm animals in their bodies or made use of in their products will vary with different animals, and with the same animals at different periods of growth. The following table[2] shows the proportions of nitrogen and ash constituents voided by animals or obtained in animal products, according to the English agricultural scientists, Lawes and Gilbert, of the Rothamsted Experiment Station:

[2] Warington, "Chemistry of the Farm," 21st edition, 1913, p. 214.

Quantities of Nitrogen and Ash Constituents Voided by Animals or Obtained in Animal Products

	Per cent of nitrogen			Per cent of ash constituents	
	Obtained as animal product	Voided as liquid excrement	In total excrement	Obtained as live weight or milk	Voided in excrement or perspiration
Horse at rest....	None	57.0	100	None	100.0
Horse at work...	None	70.6	100	None	100.9
Fattening ox....	3.9	73.5	96.1	2.3	97.7
Fattening sheep..	4.3	79.0	95.7	3.8	96.2
Fattening pig....	14.7	64.3	85.3	4.0	96.0
Milch cow......	24.5	57.4	75.5	10.3	89.7
Calf fed on milk..	69.3	25.6	30.7	54.3	45.7

We note that milch cows void in the total excrement about 75 per cent of the nitrogen contained in the feed and about 90 per cent of the ash constituents. Young growing animals give somewhat similar quantities, while fattening animals void about 90 per cent of nitrogen and 96 per cent of the ash materials in the liquid and solid excrement.[3] Considering the relation between the different classes of farm animals on most stock farms, young and old, milk-producing and fattening animals, etc., we may assume that at least 80 per cent of the entire manurial value of the feeding stuffs fed on the farm will be voided in the solid or liquid manure of the animals and will contribute to maintain the fertility of the land when the manure is applied thereon. The direct value of feeding stuffs for fertilizer purposes is, therefore, obtained by taking 80 per cent of the total fertilizer value calculated from Table V in the Appendix.

When a farmer sells a ton of alfalfa hay, he sells fertilizer materials that if purchased in the form of common fertilizers would cost him over $8. He sells the amounts of fertilizers off his land in every ton of straw, hay, and other crops, as shown in the table. If he sells 2000 pounds of milk (232 gallons), $1.97 worth of fertility leaves the farm with it; with a ton of butter, 38 cents; with a ton of beef, $9.06; with a ton of pork, $5.93, etc. According to Burkett, a farmer selling hay sells, in the form of fertilizer value, one-half as much as he receives; if he sells pork, he receives twenty times as much for it as the value of the fertilizers contained in it; if milk, forty times, and if butter, one thousand times.[4]

These figures show plainly that, so far as maintenance of the fertility of the land goes, it is a better plan for a farmer to sell

[3] Wisconsin Report 13, p. 270 *et seq.*
[4] "Feeding Farm Animals," p. 311.

animal products than grain or hay. The depletion of fertility from the farm is reduced to a minimum through the sale of these products.

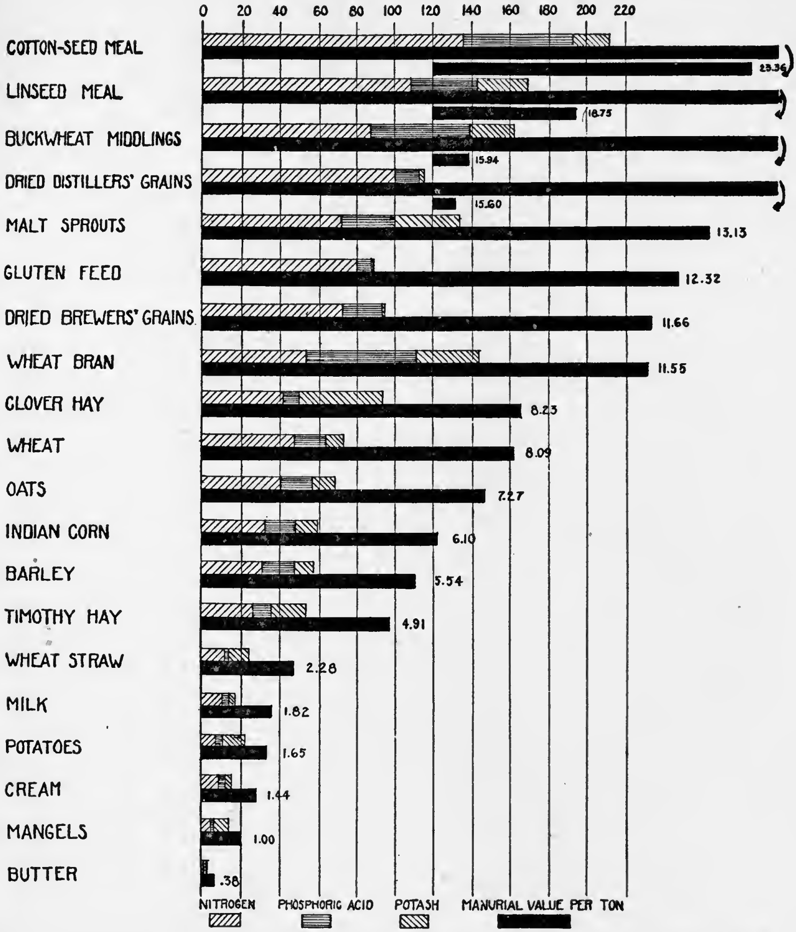

FIG. 10.—Manurial value of feeding stuffs (nitrogen valued at 15 cents per pound, phosphoric acid and potash, 4 cents per pound).

QUESTIONS

1. Explain what is meant by the manurial values of feeding stuffs.
2. Name some feeds that are especially high in fertilizer ingredients; also some that are low.
3. What percentage of nitrogen and of ash constituents are voided in the total excrement by (*a*) milch cows; (*b*) fattening steers?
4. Why is it a poor practice to sell hay or straw from a farm?
5. What is the value of the fertility obtained in a ton of milk; a ton of pork; a ton of alfalfa hay?

PART II

DESCRIPTION OF FEEDING STUFFS

A. COARSE FEEDS

CHAPTER XII

GREEN FORAGE AND HAY CROPS

Farm animals depend on green feed for their sustenance for a considerable part of the year, the period varying according to climatic conditions, from about four months during the summer time in the North to nearly the entire year in the regions more favored in this respect, in the South and Southwest. During this time the stock, as a general rule, receive no feed but what they find growing in the pasture, on the plains or mountain ranges. It is only in sections where somewhat intensive systems of farming have been introduced that other feed is provided for the stock during this period, as in the case of dairy cows in late summer and fall. Both because of the length of time during the year when farm animals depend wholly or mainly on pasture grass for their feed, and because grazing is universal throughout the country at some time of the year, pasture grasses form a most important source of feed for our livestock.

I. PASTURES

Pastures.—We distinguish between natural and artificial pastures. The former are self-sown and consist largely of native grasses. These are the permanent pastures generally found in hilly or wooded regions in the northern States and in the western United States, where wild native grasses cover the wide plains and ranges.

With Spillman we may consider that the United States consists of six different agricultural sections, each one of which is characterized by the growth of special plants of agricultural value. These sections, with some of the main grasses and clovers grown in pastures and meadows in the different sections, are given below.[1]

1. *The Timothy Region* (northeastern part of the United States, as far south as a line from Virginia to Kansas, and east of a line from Kansas to eastern North Dakota): Timothy mixed with red clover or pure seeding, red top, Kentucky blue grass, orchard grass, fescue grass.
2. *The Cotton Belt:* Cowpeas, Johnson grass, soybeans, Bermuda grass, crab grass, Japan and crimson clover.

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[1] Cyclopedia American Agriculture, vol. ii, p. 42.

3. *The Gulf Coast Region:* Crab grass, beggar weed, Mexican clover, velvet bean, carpet grass.

4. *The Plains Region:* Alfalfa, brome grass, foxtail and broom corn, millets, sorghum.

5. *The Rocky Mountain States:* Alfalfa, timothy and clover, orchard grass, wheat and oat hay.

6. *The Pacific Coast:* Alfalfa, grain hay (wheat, oats, and barley), timothy and clover, orchard grass, velvet grass.

The area devoted to permanent pastures is gradually decreasing with the development of more intensive systems of agriculture throughout the country and the settlement of the western ranges. The highest value of good farm land cannot be reached by keeping it in permanent pasture. Arable land so occupied will generally yield only a fraction of the feed that would be secured by a more intensive system of culture from annual cultivated or hoed crops or perennial legumes. According to good authorities, an acre of alfalfa, if used as green feed (soiling, p. 95), will give as much nutritive forage as four acres in permanent pasture. In the experiments conducted at the Pennsylvania station, three to five times as much digestible feed was produced per acre by means of soiling crops, *e.g.*, rye and corn, or corn and clover, as by pasturage [2] (Fig. 11).

Care of Pastures.—The low returns in feed materials secured from permanent pastures are generally due to the fact that they receive little or no attention in the way of remedial measures; they are left to take care of themselves and are therefore likely to produce but little feed. Under a correct system of management, pasture lands are fertilized with farm manure or a complete commercial fertilizer every few years, in the fall or spring, and lime added as needed; they are harrowed, if possible, and seeded with a mixture of grasses and legumes in open places. Weeds are kept down by going over them with a mower once or twice in the season. Stock should, furthermore, not be turned in early in the spring, when the young plants would be seriously injured or checked in their growth by grazing and tramping, and only a limited number of animals are pastured, so that the grass will not be eaten off too closely to enable the plants to resume a quick growth. Drainage of pasture land is also important, as a regular but not excessive water supply is essential to a healthy and rapid growth of plants. The amount of feed that pasture land can supply will doubtless be largely increased by adopting a system of management similar to that just suggested.

[2] Pennsylvania Report, 1889, p. 101.

In describing the Roberts pasture at the Cornell University Farm, Professor Roberts states that after the pasture was well established it carried fully three times as many cattle per acre as the average pasture of the State of New York.[3] The major factors in securing this result were:

"1. The clovers were not allowed to disappear.

"2. The stock was not turned on to the pasture in the spring until the soil was well settled and the grass well started.

"3. It was not overstocked early in the season; the plants thus had an opportunity to tiller and get a firm hold on the soil.

"4. It was mowed early in June."

Fig. 11.—Shade trees and a running stream in the pasture make for the health and comfort of farm animals. (Cornell Station.)

The artificial pastures are grown in rotation with other crops; they are generally sown with a mixture of grasses and legumes, and remain in grass for a period ranging from only one or two years to a series of years, according to the system of rotation adopted. The yields of feed materials obtained from an acre of land in the case of these pastures are also, as a rule, considerably smaller than those secured by growing annual cultivated or hoed crops.

Pasture Grasses.—There are over one thousand different species of native and introduced grasses grown in the United States at the present time. Of this number about fifty are found on the market, and only about a dozen make up our main cultivated species in pastures and meadows.

Among the more important tame perennial grasses in this country may be mentioned Kentucky blue grass (or June grass), timothy, orchard grass, meadow fescue, red top, smooth brome grass,

[3] "Pastures in New York," Cornell Bulletin 280.

rye grass, and Bermuda grass. The characteristics and method of seeding, special adaptation, and agricultural value of these and other tame grasses are discussed in standard works on agronomy or forage crops, and will not be considered here (see p. 177). The various grasses differ considerably in chemical composition and feeding value, and differences due to the stage of development are also of importance.

Chemical Composition.—The chemical composition of some of the common pasture grasses is shown in the following table:

Composition and Digestibility of Pasture Grasses, in Per Cent

	Moisture	Ash	Digestible		N. R.,
			Protein	Carbohydrates and fat	1 :
Pasture grass	80.0	2.0	2.5	11.2	4.5
Kentucky blue grass	65.1	2.8	2.8	21.5	7.7
Timothy	61.6	2.1	1.5	21.3	14.2
Orchard grass	73.0	2.0	1.2	14.5	12.1
Red top	65.3	2.3	1.9	22.4	11.8
Italian rye grass	73.2	2.5	1.5	14.2	9.5
Meadow fescue	69.9	1.8	1.6	19.7	12.3
Bermuda grass	71.7	2.1	1.3	14.3	11.0

We note that the moisture contents of pasture grasses range from 60 per cent to 80 per cent, and in the case of very young plants, especially of Indian corn or legumes, it may even go over 90 per cent. The proportion of nutrients that animals on pasture receive in the early season is, therefore, very small, and they have to consume large amounts thereof to maintain their body weights. Unless they receive a feed of dry roughage in addition, they will not be likely to increase in weight or maintain a fair production on such immature forage crops. Most of the analyses given in the table show the average composition of the grasses at the time of bloom, when they would be cut for hay, while the pasture grass was cut and sampled at a rather immature stage. This explains why the nutritive ratio of pasture grass is 1: 4.5, while the ratios of the other grasses approach or exceed 1: 10. Timothy is seen to have the widest nutritive ratio, viz., 1: 14.2.

Grasses are generally sown in mixtures with clover or other legumes, since the growing habits of the different plants differ, and a permanent palatable herbage will thereby be secured throughout the season. Grasses and hay crops, like other crops, will yield the largest amount of nutritious feed when grown on well-fertilized land. Where farm manure is available, it is generally put on the pasture or meadow during the fall or early spring. Artificial fertilizers applied in the fall or spring make valuable substitutes. Nitrogenous fertilizers favor especially the growth of the grasses, while the clovers and other legumes are mostly benefited by potash and lime fertilizers. There are many experiments on record showing that the application of fertilizers on grass lands will give good returns in increased crop yields and an improved quality of the crop.

Value of Pasturage.—Pasture grasses furnish a very nutritious and highly palatable feed for all classes of farm animals; it is the best feed for milk-producing animals that we have, and these produce the largest amount of milk when on good pasture. During the summer and early fall, pasture forms, as a rule, the sole feed for cattle and other farm stock, and when there is an abundance of green feed the cheapest gains and most economical production are made at this time. On account of the watery growth during early spring, stock should not be turned out too early, both for the good of the pasture and the stock. A feed of dry roughage, if available, or of good silage at this time, as well as late in the season, will produce better results than pasturage alone.

Feeding grain to cows on good pasture has not shown immediate direct results, so far as dairy production is concerned, according to investigations conducted at a number of experiment stations,[4] but cows are brought to a better body condition by receiving grain while on pasture. They are also likely to maintain their flow of milk longer during the balance of the lactation and to do better the following lactation period than if no grain is fed (p. 243). On scant or dried-up pastures it is necessary to supply additional feed, either green soiling crops, hay, or grain feed, in order that the flow of milk may be maintained. This is so much the more important as a shortage of pasture feed is likely to come at a time when extreme hot weather and flies tend to make cows uncomfortable and largely reduce their milk production.

QUESTIONS

1. Name six different agricultural sections of the United States, with characteristic pasture grasses and hay crops grown in each.
2. Why are only low yields obtained from many permanent pastures? Outline a correct system of pasture management.
3. How much moisture, digestible protein, carbohydrates, and fat are generally present in pasture grasses?
4. Give the characteristic differences between hay from grasses and legumes.

[4] Cornell (N. Y.) Bulletins 13, 22, 36, and 49; North Dakota Bulletin 16; Kansas Report, 1888; West Virginia Bulletin 109.

II. SOILING CROPS[5]

The soiling system consists in furnishing farm animals a succession of green feed in the stable or enclosures during the entire summer period. This system has long been practised by European dairy farmers; it became known in this country mainly through the essays on "Soiling of Cattle," by Josiah Quincy of Massachusetts, written nearly one hundred years ago.

The main advantages of the system as compared with pasturage may be briefly stated as follows:

1. Less land is required to produce the feed necessary for a certain number of animals than with pasture.

FIG. 12.—Indian corn grown for the silo or for soiling. ("Productive Farming," Davis.)

2. There is no waste through tramping, lying down on the grass, or fouling with manure; the feed is cut at the proper time, and is always fresh and palatable (Fig. 12).

3. Less fencing is required, as cows need only a small enclosure for exercise under the soiling system.

4. The cattle are often more comfortable and in better condition when fed green feed in the stable than when left to find their own feed in the pasture, with the uncertainties as to condition of pasture, weather, etc.

5. The production of a large and even flow of milk is therefore favored, or a uniform increase in live weight in the case of fattening stock.

6. All the manure is saved and the fertility of the farm is therefore better maintained than under pasturage. Quincy gives as his experience that this saving alone is "a full equivalent for all the

[5] Adapted from an article on this subject by the author in Cyclopedia American Agriculture, vol. ii, pp. 569–574.

labor and expense of raising, cutting, and bringing in the feed, feeding, currying, and other care of the cattle."

Disadvantages.—Against these advantages, there are the following disadvantages of the system: The increase in labor required to prepare the soil; to plant, harvest, and haul the various green crops, and to feed the herd. The last point is of the greatest importance, as the feed must be cut regularly once or twice every day, rain or shine, no matter how pressing other farm work may be. The system also calls for much skill and care in planning for and planting the succession of green crops for the season, and can be successfully adopted only under an intensive system of farming, on land that is kept in a high state of fertility and suited to the growing of large crops of green forage.

Partial Soiling.—This is a modified soiling system in which green forage crops are fed supplementary to pasturage at the time when the pastures cannot be depended upon to furnish sufficient feed for the stock, viz., during late spring and, especially, during the late summer and fall months. This system is of the highest value to dairy farmers without silos, and will likely be more generally adopted in the future with the development of our dairying industry.

Soiling Crops.—Among crops that have proved satisfactory soiling crops may be mentioned: Indian corn, alfalfa, clover, vetch, sorghum, peas, oats, winter grains (cut before blooming), soybeans, cowpeas, rape, millet, etc. In the eastern and central States fodder corn is probably the most valuable soiling crop, and alfalfa, wherever it grows well. The latter crop is all-important for soiling dairy cows in the irrigated regions in the West, where it is often the only forage crop grown and fed. Peas, peas and oats, and rape also rank high as soiling crops, the last crop especially for sheep and hogs.

The chemical composition of the more important soiling crops will be seen from the following table:

Composition of Important Soiling Crops, in Per Cent

	Moisture	Ash	Digestible		N. R.,
			Protein	Carbohydrates and fat	1 :
Fodder corn	79.3	1.2	1.0	12.8	12.8
Alfalfa	71.8	2.7	3.6	13.0	3.6
Red clover	70.8	2.1	2.9	16.5	5.7
Sorghum	79.4	1.1	.6	12.3	20.5
Green oats	62.2	2.5	2.5	20.5	8.2
Green rye	76.6	1.8	2.1	15.0	7.1
Peas and oats	79.7	1.6	1.8	11.1	6.2
Canada field peas	84.7	1.3	1.8	7.6	4.2

Succession of Soiling Crops.—The succession of soiling crops to be grown, and the details in carrying out either full or partial soiling, will vary greatly according to climatic conditions and the crops adapted to each locality. An extensive literature has been published by our experiment stations and the United States Department of Agriculture relating to this system. The following references include the more important experiment station publications relating to soiling conditions in the various States:

Connecticut (Storrs) Bulletin 9; Reports, 1891, 1895.
Iowa Bulletins 15, 19, 23, 27; Circular 12.
Kansas Bulletin 125.
Maryland Bulletin 98.
Massachusetts Reports, 1887–1891, 1893; Bulletins 72 and 133.
Michigan Bulletin 223.
Mississippi Bulletin 95.
New Jersey Bulletin 158; Report, 1902.
Pennsylvania Reports, 1889, 1904–1905; Bulletins 65, 75, 109.
South Dakota Bulletin 81.
Utah Report, 1892; Bulletin 15.
Vermont Bulletin 158.
Wisconsin Report, 1885; Bulletins 103, 235.
Ontario (Guelph) Report, 1890.

Fig. 13.—The relative expense of producing and feeding soiling crops is considerably greater than in the case of silage. (Wisconsin Station.)

Summer Silage.—It has been shown that the soiling system calls for considerable extra labor and is attended with special difficulties during rainy and stormy weather; it may, moreover, break down more or less in seasons of extreme drought. For these and other reasons, it has largely been superseded during late years among dairy farmers in eastern and central United States by feeding summer silage. We shall see that the silage can be preserved perfectly for feeding during the summer months, and it has the advantage over soiling crops in at least three ways: Convenience of feeding, uniformity, and palatability (p. 153). The practice of feeding summer silage, either of Indian corn, clover, or alfalfa, is, therefore, being adopted by more and more stockmen, and the soiling system is becoming less important with every year. By either system a maximum and uniform production may be secured during the trying weather conditions of late summer or early fall, and either system is a great step in advance of the practice still followed by many farmers of leaving stock to subsist on largely burnt-up pastures[6] (Fig. 13).

QUESTIONS

1. What is the soiling system? Give its main advantages and its disadvantages.
2. What is (*a*) partial soiling? (*b*) summer silage?
3. Name some of the more important soiling crops and their characteristics.

III. HAY CROPS

Hay Crops.—In northern countries, where snow covers the ground during a part of the year, it is necessary to provide winter feed for the stock from forage crops harvested during the summer and fall. The main hay crops are grasses and clover, which are cut at the appropriate time (p. 58) and air-dried (cured), after which they are stored in hay barns or shed, to be fed as required during the winter and spring, until next year's forage crops become available.

Hay raising forms an important agricultural industry in our country, the hay crop ranking next to Indian corn in value. Over 72,000,000 acres were sown to hay and forage crops in 1909, the most important kinds being timothy and clover mixed, "wild, salt, and prairie hay," and timothy alone. Each of these makes up about 25 per cent of the total acreage of hay and forage crops. Hay crops of relatively minor importance, when the whole country is considered, but important in their respective regions, are alfalfa (7 per cent of the total acreage), grains cut green, coarse forage, clover alone, millet, and Hungarian grasses, "other tame or cultivated grasses," and root forage making up the balance of the acreage. More than one-half of the entire acreage in hay and forage crops

[6] Wisconsin Bulletin 235.

is grown west of the Mississippi, but the individual crops are quite differently distributed. The timothy and clover mixed, or clover and timothy alone, are grown largely east of the Mississippi and in the North, while prairie hay, grain hay, and root forage are grown more extensively in the West than elsewhere.

Yields of Hay.—The average yield of hay per acre in 1909 for the entire country was 1.35 tons, the maximum average yields being credited to the Pacific and mountainous divisions, with 1.73 tons, and the lowest average yield to the South Atlantic division, with 1.20 tons per acre. These are average figures only and do not show the yields secured by good methods of farming or on irrigated land. The yield of hay obtained is dependent on various factors, as the character and condition of the soil, the method of management as to fertilization, seeding, time of cutting, etc. A good hay field will yield from two to three tons of timothy and clover hay to the acre. There are, however, authenticated reports of yields of over 7 tons of well-dried timothy and red top hay, obtained in two cuttings on a Connecticut farm, and an alfalfa field yielded at the rate of 6 tons to the acre.[7] These yields were obtained by intensive culture and heavy fertilization and seeding; they show what can be done under optimum conditions in humid regions. In the semi-arid regions under irrigation still heavier yields are secured regularly year after year, *e.g.*, in central and southern California, on irrigated land, alfalfa will yield 7 or 8 cuttings, averaging a ton or more to the acre per cutting.

Chemical Composition.—The chemical composition and contents of digestible components of hay crops will be seen from the table:

Composition and Digestibility of Hay Crops, in Per Cent

	Moisture	Fiber	Ash	Digestible		N. R.,
				Protein	Carbo-hydrates and fat	1 :
Mixed grasses	15.3	27.2	5.5	4.2	44.9	10.7
Timothy	13.2	29.0	4.4	2.8	45.3	16.2
Orchard grass	9.9	32.4	6.0	4.9	45.6	9.3
Red top	8.9	28.6	5.2	4.8	49.1	10.2
Kentucky blue grass	21.2	23.0	6.3	4.4	41.0	9.5
Bermuda grass	7.1	25.0	3.5	6.4	48.5	7.6
Johnson grass	10.2	28.5	6.1	2.9	47.4	16.3
Marsh grass	10.4	30.0	7.7	3.1	41.7	13.5

[7] Cyclopedia American Agriculture, vol. ii, p. 436.

Timothy (*Phleum pratense*) is the common hay crop of northeastern United States, being grown either mixed with red clover or in pure seeding. The mixed timothy and clover makes the more valuable hay of the two, because of the larger protein content and the lower fiber content of this hay. Timothy is a favorite hay with farmers and, especially, horse owners; the main reasons for this preference are: Clean, good timothy seed is generally available at a low price; timothy is quickly established, and usually holds well; it may be readily cured into clean, bright hay, which is rather free from dust and may be handled without much waste.

Timothy is especially adapted for feeding horses, while it has a relatively low value for growing animals or dairy cattle. For these animals it is greatly improved by a liberal admixture of clover. The yields of timothy hay obtained depend on the character of the soil, the climatic conditions, thickness of planting, and also, to a large extent, on the time of cutting. The following table prepared by Hunt[8] shows the yield per acre of the dry matter of timothy cut at different stages as indicated, according to trials at three experiment stations:

Influence of Maturity of Timothy on Yield of Dry Matter, Pounds per Acre

Stage of maturity	Connecticut	Illinois	Pennsylvania	Average
Well headed out	2750	....	....	....
Full bloom	3300	3285	2585	3057
Out of bloom	3115	3425	....	(3270)
Seed in dough	....	4010	....	....
Seed nearly ripe	3615	4065	3065	3582

The largest yield of dry matter was obtained in all three cases when the timothy was cut at a late period of growth, when the seed was nearly ripe. The quality of the late-cut hay is poorer than that cut earlier, as we have seen, both as regards chemical composition and digestibility. Hence it is generally recommended to cut timothy when in full bloom or just out of bloom. Late cutting does not greatly decrease the palatability of the hay to horses, but renders it practically worthless when used as sole roughage for young stock, dairy cows, and sheep.

Red or alsike clover, according to Henry, should always be sown with timothy, for the combination furnishes more and a superior quality of hay than timothy alone, even for horses. "Grown together, the hay of the first season will consist largely of clover.

[8] "Forage and Fiber Crops of America," p. 59.

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.[9]

Kentucky blue grass, often called June grass (*Poa pratensis*), is a common grass in the meadows and pastures in northeastern United States and also in other parts of the country. It makes a compact sod when once established, is greatly relished by all kinds of stock, and has high nutritious properties.

"Blue grass ripens in early summer, having largely gathered the necessary food materials 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 throughout 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."[10]

Red top (*Agrostis alba*) is especially valuable for moist lands sown in mixtures with other grasses. It is slow in starting growth in spring and does not reach full development when other grasses in the mixture are ready to be cut, but it produces leaves and stems late in the fall and makes a good second growth for pasture. It produces an abundance of pasturage on suitable soils, and makes a fairly palatable hay of fine stems and numerous leaves, although it is not considered equal to timothy hay in quality, and when present in timothy reduces the market value of this hay.

Orchard grass (*Dactylis glomerata*) is mostly grown along the

[9] "Feeds and Feeding," p. 167.
[10] Henry, *loc. cit.*, p. 166.

southern border of the timothy region, in Virginia, North Carolina, Tennessee, and Kentucky (p. 90), although it is recommended for many northern States and for a variety of soils. It succeeds well in shady places and orchards, but grows in bunches and forms a very rough sod. It is generally grown in mixtures with Kentucky blue grass and white clover. Orchard grass is one of the earliest grasses to start in the spring and is ready to cut before timothy. If cut when in bloom or earlier, it makes a hay of very good quality. If cut after bloom, the hay is coarse and unpalatable to stock.

Like red top, orchard grass hay is high in digestible nutrients, being higher both in digestible protein and carbohydrates than timothy.[11]

Smooth brome grass (*Bromus enermis*) is a most important perennial pasture and hay plant in the eastern part of the northern plains region. It occupies a similar place in this region as timothy and Kentucky blue grass do in northeastern United States. This grass makes a good hay crop for a number of years, and is relished by cattle, sheep, and horses. It is especially valuable as a pasture grass for Kansas, Nebraska, and the Dakotas, but it is not adapted to the warm climate of the southern States, or, apparently, to conditions in the northeastern part of the country.

Bermuda grass is the foundation of all the best permanent pastures in the South, and in many localities is important for hay. As the seed is expensive and somewhat uncertain in germination, this grass is usually propagated by planting small pieces of sod. The yield of hay on rich bottom land may be as much as four tons per acre, less on poor soil, and on dry clay hills not worth harvesting. Its feeding value is about equal to that of timothy.[12]

Johnson grass gives a heavy yield of excellent hay in the South and furnishes good grazing for one or two seasons, but is such a pest when grown in fields where it is not wanted that its planting in clean fields cannot be recommended. It spreads both from seeds and by its vigorous creeping root-stocks.[13] Johnson grass is also undesirable from the feeder's standpoint, in so far as it may contain prussic acid (hydrocyanic acid), if the growth has become rank, and fatal results have followed when cattle have eaten of it. It is, therefore, a plant that cannot be recommended, in spite of the fact that it yields heavily and furnishes a good quality of soiling crop and hay, under favorable conditions.[14]

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[11] U. S. Bureau of Plant Industry, Bulletin 100, vi.
[12] Farmers' Bulletin 509.
[13] Farmers' Bulletins 279 and 509.
[14] Bureau of Plant Industry, Bulletin 72, iii; Bulletin 90, iv.

Marsh Hay.—Along the coast of the New England States there are extensive acres of salt marshes that furnish considerable quantities of hay for stock feeding. The marshes are cut at low tide, generally at a time when the grasses are in bloom. The yield of cured hay secured varies from one-half to one ton to the acre. The hay from these tide marshes contains about 6 per cent protein, 2 per cent fat, and 30 per cent fiber; its digestibility does not differ greatly from that of common hay. Throughout the country there are also large stretches of marshes that are cut for hay, especially in dry seasons. The composition and general value of such marsh hay are similar to those of salt marsh hay; the better kinds of these grasses make a fair quality of rough feed, of a similar value as cornstalks.

Market Hay.—The growing of hay for the market is an important industry, especially in the northeast and western States. It is estimated that about one-fifth of the 1908 hay crop in this country, or over 15,000,000 tons, was removed from the farms and sold on the local market or shipped to city hay markets. Hay markets supervised by an organization of hay dealers are established in a number of our larger cities which provide for official inspection of the hay sold, and for standard quotations and methods of weighing.[15] These markets recognize five grades of hay, viz., the standard grades: Choice, No. 1, No. 2, and No. 3, and "No-grade" hay. The following kinds of hay are quoted and sold on these markets: Timothy, clover-mixed, prairie, midland, packing hay, and alfalfa.[16]

The percentages of different grades of timothy on the market are about as follows, according to McClure: Choice, 10 per cent, and No. 1, 20 to 30 per cent, leaving 60 to 70 per cent of all market hay to grade as No. 2, No. 3, or "No-grade." When shipped to the market the hay is put up in bales of different dimensions. The statement given below shows the sizes of standard hay bales in common use.

Standard Sizes of Hay Bales

	Dimensions	Weight, pounds
Small bales	14×18×38 16×18×36	70–100
Middle-sized bales	17×22×36 18×22×36	100–150
Large-sized bales	22×28×46	150–250

[15] Farmers' Bulletin 508; Vermont Bulletin 171.

[16] The requirements for market hay of the different grades are given in Farmers' Bulletin 508; see also Woll, Handbook, p. 406 *a* and *b*.

The best quality of hay is obtained when the meadows are kept in grass only for a period of three or four years at the outside. A common fault of growers of market hay is to leave the meadows too long in grass after weeds and foreign grasses have entered to lower the quality. The hay crop should be a part of a regular crop rotation, which should include some leguminous crop, and a regular system of fertilization, so that the fertility of the soil may be maintained and a choice marketable hay produced. Hay is often cut at a too late stage of growth, after full bloom has passed. Late cutting, faulty methods of curing, the presence of other grasses and weeds, injuries from the weather in curing and before baling, improper baling and loading into cars cause much hay to grade low and are sources of great losses to hay growers. Choice hay always finds a ready sale, for the demand usually exceeds the supply. The better grades of hay, while more expensive, require a smaller addition of concentrates to rations for farm animals than the lower grades, and are, therefore, generally speaking, the best kinds to buy.

Rule for Measuring Hay in the Stack.—Both when hay is sold in the stack and in planning for feeding stacked hay to stock, it is important to know how to measure hay put up in this way. The Government rule used in purchasing hay for army posts has given satisfactory results and has been generally adopted. It is as follows:

Multiply the width of the stack in feet by the " over " (*i.e.*, the distance of the stack from the base on one side to the base on the other), divide the product by 4, and multiply the quotient by the length. This gives the contents of the stack in cubic feet; for hay that has stood less than 30 days, divide by 512; for 30 to 60 days, by 422; over 60 days, by 380. The quotient gives the tonnage of the stack.

Example: A stack is 20 feet wide by 40 feet " over " and 60 feet long. 20 multiplied by 40 equals 800. 800 divided by 4 equals 200. 200 multiplied by 60 equals 12,000. 12,000 divided by 512 equals 23½ tons.[16]

QUESTIONS

1. State the difference between early- and late-cut timothy hay, and the relative value of the two kinds of hay.
2. Give the characteristic features of six of the common grasses, and their relative value for stock feeding.
3. Name the different grades of market hay.
4. State some common defects of market hay, and suggest improvements in the present method of growing hay for market.
5. Give the Government rule for measuring hay in the stack.

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[16] Barnes, " Western Grazing Grounds," p. 139. See also Bureau of Plant Industry Circular 131; Woll, Handbook, p. 397.

CHAPTER XIII

GREEN FORAGE AND HAY CROPS (Continued)

I. ANNUAL FORAGE CROPS

Indian Corn (*Zea mays*).—The proportion of corn grown especially for forage in the United States and fed either green, cured, or as silage is relatively small, although increasing with every year. A fuller discussion of this crop will, therefore, be given under "Cereals," Chapter XVI.

When grown for forage, Indian corn is planted thicker than when grown for the sake of the grain. The difference in the amount of grain and fodder secured by different methods of planting is shown by experiments conducted at the Illinois station.[1] In these trials dent corn was planted on a rich prairie soil, in rows three feet eight inches apart, with kernels from three to twenty-four inches apart in the row. The following table shows the main results obtained:

Results of Planting Corn Kernels Different Distances Apart in Rows

Distance between kernels in row	Yield per acre		Digestible substance per acre			Stover per acre	Stover for each pound of corn
	Good ears	Poor ears	Stover	Grain	Total		
	bu.	*bu.*	*lbs.*	*lbs.*	*lbs.*	*tons*	*lbs.*
3 inches	13	46	3968	2250	6218	4.8	3.6
6 inches	37	39	3058	2922	5980	3.7	1.9
9 inches	55	22	2562	2977	5539	3.1	1.5
12 inches	73	16	2480	3113	5593	3.0	1.3
15 inches	63	11	2398	2782	5180	2.9	1.4
24 inches	49	6	2066	2141	4207	2.5	1.5

We note that the highest yield of good ears, seventy-three bushels per acre, was obtained when the grain was planted twelve inches apart in the row, and that this method of planting gave the smallest proportion of stover (cornstalks) to ear corn. On the other hand, the largest yields of stover and of digestible substances per acre were secured when the kernels were planted three inches apart in the row, and the yield of nubbins per acre was also largest in the

[1] Bulletin 13.

case of this planting. The same results would not necessarily be obtained on other kinds of soils or under different climatic conditions, but the effect of thick planting on the growth of corn plants would be similar in all cases. The plant is not able to reach its full development by thick planting, and the yields of perfect ears obtained by this method are relatively small; the total yields of feed materials secured from a certain area are, however, likely to be larger, the thicker the corn is planted, up to a certain limit; in the case of the fertile soil investigated, with kernels 3 inches apart in the row. Evidently, therefore, where the corn is grown for green feed, for silage, or to be cured as fodder, the best method is to plant thick, so that but few perfect ears are formed; conversely, if corn is grown for the sake of the grain, the general method of thin planting, say in hills 3½ by 3½ feet, will give the best results, but a smaller proportion of stocks will be secured.

Yields of Corn.—Green fodder will yield from about 8 to 20 tons per acre, containing 1½ to 4 tons of dry matter; an average yield on good land would be about 15 tons of green forage, containing about 3½ tons of dry matter. This is a considerably larger yield of feed materials than can be obtained in case of most other soiling crops without irrigation.

Corn makes an excellent soiling crop in regions adapted to its culture, and furnishes a large quantity of feed that is greatly relished by cattle and other farm animals. If cut early, say before tasselling, it will contain only about 10 per cent of dry matter, while at later stages of development toward maturity it will contain 25 to 30 per cent of dry matter. It is largely a carbonaceous feed and is low in protein (average digestible protein, 1.1 per cent; carbohydrates and fat, 16.1 per cent; nutritive ratio, 1: 15.1). If fed to dairy cows or young stock which require considerable protein, it should be supplemented with a mixture of suitable protein feeds, like wheat bran, gluten feed, oil meals, dried brewers' or distillers' grains, etc.

Proportions of Nutrients in the Corn Plant.—Even when corn is grown for the sake of the grain, a considerable proportion of feed materials remains in the stalks and becomes available for feeding farm animals. The proportion of ears to stover has been determined by a number of experiment stations. The average results obtained at four different stations (New Jersey, Connecticut, Pennsylvania, and Wisconsin), are as follows: [2]

[2] Pennsylvania Report, 1887.

Average Yields of Ear Corn and Stover, Per Acre

	Ears, pounds	Stover, pounds
Average yields..	4415	3838
Ratio..........	100	87

About 87 pounds of cured stover were obtained, on the average, for every hundred pounds of ear corn, when the corn was grown for the sake of the grain; or, to put it in another way, nearly one-half of the weight of the corn crop (46 per cent) is found in the stalks. Since 57 per cent of the dry matter of cornstalks has been found digestible, and 88 per cent in the case of ear corn, the total amounts of digestible dry matter furnished in the stalks are considerable, amounting to over one-third of the entire plant under ordinary method of corn culture.

These figures plainly suggest the importance of taking advantage of the large amounts of feed materials found in the cornstalks and utilizing these for stock feeding so far as possible. The relation between different groups of feed materials in the ears and stalks, as given by Armsby, is shown below:

Digestible Feed Materials in the Mature Corn Plant, in Per Cent

	Crude protein	Carbo-hydrates	Fat	Total digesti-ble matter
Ears..........	75	61	85	63
Cornstalks....	25	39	15	37

Since one-fourth of the entire digestible protein and 37 per cent of the entire digestible nutrients of the corn are found in the stalks, their utilization for feeding purposes becomes a matter of great economic importance. It should be stated that the figures in the table make a too favorable showing for cornstalks, for the reason that more energy is consumed in the digestion of equal weights of stalks than ear corn, and less, therefore, remains for nutritive purposes. Making due allowance for this difference, it is nevertheless evident that a great waste of national resources has been allowed to take place in past years, and is still going on, by leaving cornstalks to decay in the fields; thousands upon thousands of acres of cornstalks are left largely unutilized every year, in the corn belt and outside of it. These would furnish good feed for farm animals, especially young stock, cattle, and horses doing light work, and would produce considerable revenue to the farmer by proper handling and feeding with other materials.

Method of Harvesting.—The method of handling the corn crop generally practised in the main corn-growing sections is to harvest the grain in the field without cutting the stalks, and to turn cattle into the field during late fall and early winter to eat off the leaves and tender parts of the stalks, the rest being wasted. On the better-managed stock farms, especially in dairy regions, corn is cut by machinery and placed in shocks in the field, and the ear corn is harvested late in the fall, the shocks of stalks remaining in the field until needed for feeding to stock. Owing to the bulky nature of the stalks and the slowness with which they are cured, they cannot be stored under roof in large quantities. The corn is, however, now often husked and run through a shredder in the same operation in the late fall, and the shredded corn fodder is stacked for feeding during the winter. This makes a valuable feed for farm animals and forms a good partial substitute for more or less expensive hay.

Field-curing of Indian Corn.—Considerable losses of nutrients occur in the corn fodder when this is left in shocks in the field exposed to the severe weather of late fall and winter. These losses have been studied at a number of experiment stations, among others at the Wisconsin station by Professor Henry and the author. The results which were obtained in studies of the relative economy of field-curing and siloing Indian corn (referred to later on p. 157) stated briefly show that, as an average of four years' experimental work, a loss of 24 per cent of the dry matter and of crude protein was found in the case of shocks of corn left in the field for an average period of about two months. The results obtained elsewhere have shown that the figures given are rather low for ordinary farm conditions. Exposure to rain and storms, abrasion of dry leaves and thin stalks, and other factors, tend to diminish the nutritive value of the fodder, aside from the losses from fermentations, so that very often only one-half of the feed materials originally present in the fodder is left by the time this is fed out. Furthermore, the remaining portion of the fodder has a lower digestibility and a lower feeding value than the fodder corn had when shocked, for the reason that the fermentations occurring during the curing process attack the most valuable and easily digestible components of the nitrogen-free extract, viz., the sugar and starch, which are soluble, or readily rendered soluble in the process of digestion.

Grain hay is commonly made and fed to farm animals in western United States, and occasionally in other regions of the country as well, when conditions render it necessary or desirable to use it for this purpose. Barley, oats, wheat, and rye are used for hay-making and for pasturage or soiling. Oats make the best hay, while rye and barley are especially adapted for soiling or pasturage. The grain crops are, in general, cut for hay when the kernels are in the early milk stage; cut at this stage, they make a very nutritious and palatable hay. Oats may be cut a little later than this for hay, and barley preferably somewhat earlier, while the beards are still soft, so that they will not give trouble in feeding the hay. Wheat and barley hay are the common grain hays used on the Pacific coast, while oat hay is more generally fed in the southern States. Grain hay will yield an average of two to three tons of hay per acre on good land. Cut for either soiling purposes or for hay, the cereal crops yield forage of excellent quality and palatability and furnish large amounts of valuable feed components. At the stage given, early milk, the plants are relatively richer in protein than during the ripening period, and the nutritive ratio is, therefore, then considerably narrower than later on; hence more starchy, and, as a rule, cheaper concentrates may be fed with hay cut at this time than at a later stage of growth.[3]

Sorghum is a common soiling crop in the southern and central western States, and is also made into hay or silage. It resists drought well, and has the further advantage of retaining its green leaves late in the season. When intended for hay, it is generally sown thickly, using about three bushels of seed to the acre, so as to prevent a coarse growth. It is cut for hay at the late milk stage, and, for soiling, any time after blossoming till approaching maturity. When intended for silage, it should be left until mature before it is cut (p. 157). On good soils sorghum will yield two to four good crops of hay, often aggregating eight to ten tons during the season. Matured sorghum may be cut and left shocked in the field and fed in the same way as cornstalks, or may be run through a shredder. It may be considered to possess a feeding value nearly similar to that of fodder corn, ton for ton, although it contains considerably less protein and somewhat more fiber than green corn (nutritive ratio of Indian corn, 1 : 12.8; of sorghum, 1 : 20.5).

[3] In Kentucky Bulletin 175 attention is called to the fact that young green rye, wheat, and oats contain more protein than green legumes.

Serious trouble, and even death, has at times resulted from cattle or horses eating second-growth sorghum. This generally occurs after periods of frost or extreme drought, when the plants have been stunted in their growth and afterwards begin to grow. It is due to the formation of a glucoside in the new shoots which sets free prussic acid through the action of a ferment. Accidents usually have happened when pastures are short and cattle get into a field of sorghum, eating considerable of it on empty stomachs. They should, therefore, be given some feed before being let into fields of

FIG. 14.—A field of dwarf black-hull kafir corn, a good grain-sorghum for western States. (Ball.)

such sorghum; since no trouble will occur when second-growth sorghum is made into hay or silage, the safer method in case of doubt is to use it for one or the other of these purposes.

The non-saccharine sorghums, so-called grain sorghums, kafir corn, milo maize, and durra, are largely grown for the sake of the grain in western States; they are also occasionally used as green and dry forage, as well as for silage, for cattle, horses, and sheep. These sorghums are discussed more fully under "Cereal Grains" (Chapter XVI). Second-growth kafir corn and other grain sorghums sometimes have poisonous properties, under similar conditions, as in the case of second-growth sweet sorghum, and must be fed with great care in the green condition (Fig. 14).

Sudan grass (*Andropogon sorghum* var.) has been recently introduced into southern States. It is an annual, drought-resistant plant, closely related to the sorghums. It resembles Johnson grass somewhat in appearance, but, unlike this grass, it has no root-stocks and is not, therefore, likely to become a pest. Sudan grass makes a fair quality of hay, giving two cuttings in a season. The yields obtained will range from two to eight tons per acre, according to climatic and soil conditions. It is well suited for use as a soiling crop and may also prove valuable for the silo. This grass promises to be of special value to southern agriculture and in irrigated regions as a forage to be fed supplementary to alfalfa.

Millets.—The millets are annual forage plants. They are rarely grown for the sake of the seed in this country, as is the case in Asia, where millet seed is a common grain crop. They include a very large number of different species. Those grown in this country may be separated into four groups: The foxtail or common millet, broom-corn, barnyard, and pearl millets. The most important of the millets for stock feeding are the German millet and the Hungarian grass, both of which belong to the group of foxtail millets. Millets are essentially hot-weather grasses and are drought-resistant, which renders them especially valuable hay crops under semi-arid conditions. They are grown chiefly in central western States, like Kansas, Nebraska, and Missouri, for the purpose of supplementing the hay crop. Under favorable moisture conditions they will yield from three to five tons of cured hay per acre. They should be cut as soon as the blossoms appear; on account of the small, hard seeds and woody stems they make an unsatisfactory feed if the cutting is delayed till a later stage of growth. Cut early and fed in moderate amounts, the millets make a valuable hay for horses, cattle, and sheep. They should not be fed exclusively or for long periods at a time to horses, as they are likely to cause digestive and other troubles in that case. The millets do not differ greatly in chemical composition or feeding value from Indian corn fodder or sorghum, but are not relished by stock to quite the same extent.

Foxtail is a common weed in grain fields and meadows in many parts of the country. It is especially troublesome in alfalfa fields in the western States. The first crop of alfalfa on old weedy fields is often rendered useless through the growth of foxtail therein, unless it be cut early, while the beards are still soft and can be eaten without injury. If cut at this time, foxtail makes a fine and very nutritious hay that compares favorably in feeding value with a good quality of oat hay. The following table shows the digestible components of these two kinds of hay:

Digestible Components of Foxtail and Oat Hays

	Protein	Carbo-hydrates	Fat	N. R., 1:
Foxtail........	4.3	41.4	.9	10.1
Oat hay.......	4.5	43.7	1.5	10.5

Teosinte is an annual forage plant, closely related to Indian corn. It is believed to be the ancestor of our corn, and has similar habits of growth. It is not grown as a forage plant outside of the southern States, as it needs a long season of hot weather, abundant moisture, and a rich soil in order to do well; under such conditions it is a remarkably vigorous grower, the stalks reaching 10 to 12 feet in height, with an abundant supply of leaves and slender stems, which continue to grow until killed by frost. The Louisiana station reports a yield of over 50 tons of green forage per acre of this crop on rich alluvial soils. Harvests of 18 to 30 tons per acre are not uncommon, according to Spillman. Teosinte makes one of the best soiling plants in the South on account of the immense yields of green forage which it produces. It stools freely and sometimes grows as many as 50 stalks from a single seed. Its leaves are similar to those of sweet sorghum, but much larger, and the stalks contain 8 to 10 per cent of sugar.[4] If cut when from four to five feet high, it makes an excellent fodder and will produce a second cutting fully as large as the first. If left until September or October, it furnishes good material for silage and yields more heavily than either Indian corn or sorghum.

These remarks apply to conditions in the Gulf States only; the value of teosinte outside of this region is rather doubtful. In green condition it is very watery, containing only about 10 per cent of dry matter, with a similar percentage of digestible protein as green corn (0.9 per cent), and less than one-half as much digestible carbohydrates and fat as corn.

Japanese cane is another Southern forage plant that has come into some prominence of late years. It is a variety of sugar cane, well adapted to the climate and soil of the Gulf States. It will do well in any section in which the velvet bean will mature seed, *i.e.*, a territory within 200 to 250 miles north of the Gulf of Mexico. It is used as a silage crop, for winter pasture, or stored as dry forage. The Florida station found it one of the cheapest and most economical forage crops that a farmer in that State can grow for silage.[5] The chief value of the plant lies in its high content of carbohydrates, particularly sugar. Like sorghum, it should be left to mature before cutting, whether intended for silage or for dry forage.

QUESTIONS

1. State the relation of grain to fodder secured by different methods of planting Indian corn.
2. What proportion of nutrients is found in the ear corn and the corn stover in the ordinary method of growing Indian corn?
3. Describe the value of Indian corn, grain hay, sorghum, and millets for feeding farm animals.

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[4] Farmers' Bulletin 509.

[5] Bulletin 105.

II. HAY FROM LEGUMINOUS CROPS

Value of Legumes.—The legume family is of the greatest value to the stock farmer in two respects:

1. The legumes enrich the soil with nitrogenous components which have been built up largely from the free nitrogen of the air by the bacteria found in the root nodules of the plants of this family. As the nodules decay their nitrogenous compounds are taken up by the host plant and go to increase the nitrogen content of these plants. The legumes are, therefore, often spoken of as nitrogen gatherers, or "soil renovators" or "improvers." Deep-rooted legumes, like alfalfa and red or mammoth clovers, will leave in the roots and stubble a large proportion (one-half or more) of the nitrogen substances elaborated from the atmospheric nitrogen during the growth of the plants, and, on their decay, the nitrogen compounds are broken down, forming humus and inorganic nitrogen compounds (nitric acid), thus adding to the supply of soil fertility.

2. Legumes furnish larger proportions of protein and valuable mineral components, lime, phosphoric acid, and potash available for feeding livestock than the grasses. Hay from leguminous crops is nearly twice as rich as that from grasses, and larger crops per acre are also obtained than from grasses. The average composition of hay from grasses and from leguminous plants will be seen from the following table:

Average Composition of Hay from Grasses and Legumes, in Per Cent

	Protein	Carbohydrates	Fat
Hay from grasses	7.52	75.64	2.70
Hay from leguminous plants	14.37	64.14	3.23

Assuming that common grasses will yield two tons of hay per acre and clovers and other leguminous plants three tons, the latter will furnish from two to four times as much protein per acre as the common grasses, together with as much more fat and somewhat more carbohydrates. They also contain nearly three times as much nitrogen and about twice as much potash as does hay from grasses.[5]

The more general culture of legumes and the production of hay therefrom during the last couple of decades have come largely as a result of the teachings of modern agricultural science, and are

[5] Farmers' Bulletin 16.

a hopeful sign of agricultural progress in this country. The legumes furnish the cheapest sources of nitrogen and nitrogenous feed components available to the farmer, and by their culture he will, in a measure, become independent of both fertilizer and feed manufacturers.

The most important species of the legumes adopted for feeding farm animals are clover (red, mammoth, alsike, white, crimson, Japan), cowpea, soybean (Fig. 15), vetch, pea, bean, beggar weed, and peanut. Brief mention will be given in the following pages of these different species that are of special importance as forage crops.

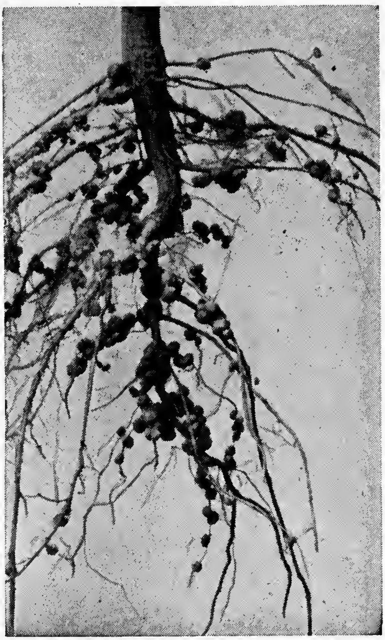

FIG. 15.—A soybean nitrogen factory. The free nitrogen of the air is changed by the bacteria in the root nodules into forms that are used by the host plant for the elaboration of protein compounds. (Wisconsin Station.)

Alfalfa (*Medicago sativa*)[6] (Fig. 16) is one of our most valuable forage plants. In the western part of the United States it ranks first in importance as a soiling and hay crop. It was introduced into California from Chili in 1854, and gradually spread over the irrigated regions of the West, and from there eastward, until it is now grown in every State in the Union, as well as in Canada. It requires a deep, well-drained and fertile soil, with a permeable subsoil, for its best development, and under optimum conditions will yield enormous crops of forage. Several cuttings are obtained during the season from alfalfa fields, the number increasing from two to six or more as we go southward. The highest yields are obtained on the irrigated land in southern California and the southwestern States, where eight to ten tons of hay per acre are frequently obtained. As it generally takes about four tons of green alfalfa to make a ton of hay, this corresponds to a yield of forty tons of green alfalfa per acre. Good alfalfa fields in the humid regions will yield at the rate of four to five tons of hay per

[6] In Europe and Canada often called *Lucern.*

acre. When well established and cared for, alfalfa will yield large crops for a series of years—at least in the West and Southwest, where the plants are not weakened by rigorous cold of winter. Weeds that may appear in the first cutting will be choked out by the alfalfa if cut before seeding, and later cuttings will give a clean hay. As already stated, foxtail is often a bad weed in western alfalfa fields early in the season, so that the first cutting of hay may cause trouble in feeding cattle, sheep, or pigs on account of the rough bristles of the foxtail heads. If this cutting is placed in the silo, there will be no difficulty in this respect, as the foxtail heads are softened in the siloing process (p. 158).

FIG. 16.—Alfalfa will furnish an abundance of green feed throughout the growing season. It is rapidly becoming one of the most valuable forage crops in the country. (*Pacific Rural Press.*)

Composition of Alfalfa.—Alfalfa is one of the richest forage crops American farmers can grow. It contains more protein than any of the leguminous plants used for feeding purposes, with the possible exception of sweet clover, peas, and vetches. A good quality of alfalfa hay contains at least 15 per cent protein, 2 per cent fat, and about 25 per cent fiber, while the lower grades contain less than 10 per cent of protein and over 30 per cent fiber. Compared with red clover, alfalfa furnishes a heavier yield of hay that contains more protein than clover, and, once established, it will occupy the land for a considerable period, while clover, being a biennial, must be reseeded every three years. Alfalfa has a high digestibility and is greatly relished by all classes of farm animals. It is used in four different ways for feeding, as soiling crop, for hay, silage, or for pasture. It is one of our most valuable green feeds, especially for cattle, hogs, and sheep; its protein content renders it a highly desirable feed for dairy cows and young stock. As it has a nutritive ratio of about 1 : 3.6, it is too high in protein for the best results when fed alone, even with the animals mentioned, and may, therefore, be supplemented to advantage with Indian corn or other starchy feeds. In the corn belt and eastern States the common farm-grown feeds are starchy and low in protein, like corn fodder, mixed or timothy hay, cereals and roots, and alfalfa is, therefore, of special value as a supplemental feed in this important agricultural section of our country. It may be partly substituted for wheat

Fig. 17.—Curing and harvesting alfalfa. ("Productive Farming," Davis.)

bran or similar feeds in rations for dairy cows, in the proportion of about 1½ pounds of alfalfa to 1 pound of bran, and the bill for concentrates thus greatly reduced. Choice grades of alfalfa will nearly approximate wheat bran in feeding value, and can generally be produced at a cost less than one-half of what this concentrate commands (Fig. 17).

Alfalfa furnishes an excellent pasture after the first year, under certain restrictions, viz., that it is not eaten off too closely, especially in the fall, and that cattle and sheep are not put on the pasture when hungry and while the dew is on; otherwise they are likely to bloat, death resulting in severe cases. Alfalfa pasture is especially valuable for dairy cows, growing cattle, brood sows, and young farm animals of the various classes. It makes one of the best hog pastures in the country; an acre will supply sufficient feed for ten to twenty hogs, and these will make good gains on it with a small grain allowance of corn, barley, or shorts, viz., 600 to 1000 pounds of pork for the season. Alfalfa-fed beef goes on the market without any grain on the Pacific coast; in the eastern and central States such cattle are fattened with corn or small grains with excellent results.

Changes in Composition.—The changes in the chemical composition of alfalfa with the progress of the growing period have already been considered (p. 56); briefly stated, young plants contain most water, ash, and protein (total and amides), and older plants contain most fiber. The digestibility of the plant also decreases as it approaches maturity. Owing to the large proportion of valuable feed materials in the leaves and tender parts, carefully-cured alfalfa hay cut at the right time, when new shoots are appearing, will have a much higher feeding value than hay that has been left standing too long, or cured by faulty or careless methods so as to lose a considerable portion of the leaves, or that has been exposed to rain storms after cutting. Much of the alfalfa hay is of poor quality, from one or more of the reasons just given, especially the first two—too late cutting and careless methods of hay-making. Choice or prime alfalfa hay[7] is well worth the high price that it commands on the hay market in comparison with the lower grades. The experience of the Ontario Agricultural College with regard to late-cut hay is worthy of note in this connection:[8] "The decrease in digestibility is so rapid that by the time the plant has passed the full blooming stage, it appears to be unsafe to feed it in large quantities to any animal. . . . Because of the rapid decrease in feed value, also because of the rapidity with which the new crop comes on when the old one is removed, and because of the danger in allowing stock to eat the fodder when the plant becomes hard and woody, alfalfa, whether in the pasture field or in the hay field, should not be allowed to stand later than the early blossoming stage."

Red clover (*Trifolium pratense*) is grown in pure seeding mostly for the purpose of seed production; for forage purposes it is, as a rule, sown with timothy, and with this plant forms the main hay crop in eastern and northern United States. Clover furnishes

[7] Woll, "Handbook for Farmers and Dairymen," p. 406*a*.
[8] Report, 1898.

two or three crops a year. The yields obtained vary from two to five tons per acre, according to the season and the fertility of the soil. The yield of the last crop is especially variable and is frequently too small to be worth while cutting. If it is not cut, the clover is generally pastured by cattle or sheep. At early stages of growth, clover is very low in dry matter, viz., less than 10 per cent, and relatively small yields of hay are secured from early cuttings. On good land very heavy yields are obtained, however, aggregating 16 to 20 tons of green clover for the season. The tendency of green clover to cause bloat in cattle and sheep may be overcome by feeding some dry forage prior to turning on to pasture, or by placing hay or straw in feed racks in the field. According to Henry, cattle and sheep will resort instinctively to the dry feed when bloat threatens.

Experience and chemical analyses have shown that the best time to cut red clover for hay is when about one-third of the heads have turned brown. The crop then yields the maximum amounts of total dry matter and digestible nutrients. Red clover hay is an excellent feed for dairy cows, sheep, pigs, and all kinds of young stock. It ranks second to alfalfa in feeding value for these animals. Clover hay is less adapted to working horses on account of its liability to be dusty. This is a disadvantage that hay from all legumes has, compared with that from grasses, and comes from the larger proportion of leaves in the former; these are brittle and readily crumble into dust unless the clover is carefully cured and handled.

Clover makes an excellent supplementary feed to the corn plant, timothy, and other crops grown on the farm, as these are, in general, of a starchy character and low in protein and mineral substances. In the feeding of growing animals or dairy cows clover may, therefore, make up a part of the ration to great advantage, and is much relished by them.

Besides being a valuable hay and soiling crop, clover makes a good silage crop, if properly put up in air-tight, tall silos. The main conditions for making good clover silage, or silage from other legumes, will be further discussed in the chapter on silos. We shall see that the crop must be siloed directly after being cut, before it has lost much moisture, and that it is preferably run through a cutter, and must be carefully distributed and packed in the silo so as to exclude as much of the air as possible. Even well-preserved clover silage, as that of other legumes, has often a strong and not particularly pleasant odor, and is not quite as palatable to dairy cows or other farm animals as corn silage, as it soon dries out on exposure to air. It may, however, be considered of similar feeding value as corn silage, and makes a valuable feed for farmers who have difficulty in curing clover into hay on account of rainy weather. Like other legumes, clover may be safely placed in the silo wet with dew or rain. If it has been allowed to dry out before being siloed, water should be added as it is elevated into the silo or after each load is filled into the silo.

Mammoth clover (*Trifolium medium*) is a somewhat later variety than red clover, generally maturing three to five weeks later. As its name suggests, it has a larger and coarser growth than red clover and produces but one crop a year. It is, therefore, frequently pastured for several weeks in the early spring, and will make a good growth when the stock is removed. It requires a similar soil and climate as red clover, and is better able to thrive under unfavorable conditions than this crop on account of its stronger root system and its perennial growth. It does not make as palatable hay as red clover on account of its ranker habit of growth, but its ability to do well on relatively poor soils and its perennial character make it a valuable hay crop to the stock farmer.

Alsike or Swedish clover (*Trifolium hybridum*) is grown for both hay and pasture, often in mixture with red clover and timothy, or with red clover only. It produces a fine, soft hay that is greatly relished by stock and eaten without waste. Alsike flourishes on land that is too acid or too moist for other clovers, although it will not grow in really wet soils. While red clover usually dies out the third year, alsike will often live for several years, a feature which greatly increases its value for pasture.[9]

Crimson clover (*Trifolium incarnatum*, Fig. 18) is an annual, especially valuable as a cover crop in orchards and for green manuring. It is also used for pasture, as a soiling crop, and, to a limited extent, for silage. It does not make as satisfactory hay as other clovers on account of the minute barbed hairs on its blossom heads, which become spiky as the heads ripen. Hay from over-ripe crimson clover tends to make hair balls, often 3 to 4 inches in diameter, of compact, felt-like structure, in the stomachs of animals, especially horses, and cases are on record of animals dying as a result of eating such hay.[10] The difficulty may be avoided by cutting the hay at

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[9] White clover (*Trifolium repens*) is not a hay crop, being used in pastures and lawns only, in mixtures with grasses.

[10] Division of Botany, U. S. Department of Agriculture, Circular 8; Farmers' Bulletin 579.

the time of blossoming. This clover is best adapted to the climate of the south Atlantic States, and has been especially recommended by the New Jersey and Delaware experiment stations.

Japan clover (*Lespedeza striata*) is a southern forage plant of special value for pasture; it also furnishes a good quality of hay if cut when in full bloom. It will yield one to three tons of hay per acre on good land, of a quality that is considered equal to the best clover hay. According to Tracy, Japan clover, with cotton seed as grain feed, is the cheapest milk-producing ration in many sections

FIG. 18.—Crimson clover. ("Productive Farming," Davis.)

in the South. It is of great value to southern agriculture as a soil-renovator, increasing the nitrogen content and improving the composition and texture of soils that are largely unproductive, so that they will grow other crops. It affords valuable pasturage for cattle, horses, sheep, and hogs, though the animals must be accustomed to it in order to relish it. It is considered by some authorities the best pasture plant for the poorer clay soils of the cotton belt. It does not differ greatly in composition from red clover, the hay being somewhat lower in ash and fiber and higher in nitrogen-free extract than red clover hay.[11]

[11] Farmers' Bulletin 441.

Sweet clover (*Trifolium melilotus,* Fig. 19) is grown as a forage crop to a limited extent in some of the central and southern States. It will grow on soils that are too poor in humus for the successful production of either alfalfa or red clover. Sweet clover may be used as hay, silage, soiling crop, or as a pasture for all classes of farm animals. It must be cut before blooming, since the plant rapidly becomes coarse and unpalatable to stock after this stage. Owing to the presence of a bitter principle (cumarin) in sweet clover, animals at first refuse to eat it, but appear to relish the plant when once accustomed to it, whether in dry or succulent form. Sweet clover stands next to cowpea hay and alfalfa in its content of crude and digestible protein, but is also somewhat higher in fiber than other legumes.

Average Composition of Leguminous Hays, in Per Cent [12]

	Protein	Fat	Fiber	Ash	Digestible		
					Protein	Carbohydrates and fat	Nutritive ratio
Sweet clover hay	13.3	2.1	26.9	7.5	9.9	40.8	1:4.1
Alfalfa.........	14.3	2.2	25.0	7.4	11.0	42.3	1:3.8
Red clover......	12.3	3.3	24.8	6.2	6.8	39.6	1:5.8
Cowpea........	16.6	2.2	20.1	7.5	10.8	41.1	1:3.8

Canada field peas (Canadian peas, *Pisum sativum,* var. *arvense*) are grown extensively in the States along the northern border of our country that are favored with fairly cool summer temperatures and a moderate amount of precipitation. Although its culture in this country is extending, we are still far behind Canada in taking advantage of the possibilities of this crop. Field peas are grown for seed or for forage as a soiling crop, for pasture, or cured as dry forage. The seed makes a valuable rich grain feed for horses, cattle, and sheep, and is generally fed mixed with oats, wheat bran, etc.

Peas are frequently grown in conjunction with oats as a soiling crop for milch cows, or for pasturage for sheep and swine, for both of which purposes it is of superior value. Large areas of peas sown alone early in the spring at the rate of two bushels per acre, with a small amount of wheat or oats, are grown in the northern mountainous States for sheep and lamb feeding. These are turned on to the land when the peas are ripe, and harvest both grain and

[12] Farmers' Bulletin 485; Michigan Circular 23.

vines, making a gain of about 8 pounds per month while thus grazing. An acre of peas will fatten 10 to 15 lambs, putting these in the finest possible condition for the market in the course of 70 to 90 days. A somewhat longer period is required for ewes that are lean when first turned into the pasture. Swine will keep healthy and make rapid gains on a pea pasture alone when turned in as soon as the peas are full-sized. For both these classes of animals the growing of field peas presents great possibilities in the northern sections of the country where this crop grows to the best advantage.

Fig. 19.—Sweet clover is an excellent soil builder. Cut for hay at an early stage (before blooming), it makes a good quality of hay which resembles alfalfa in composition. (*Breeders' Gazette.*)

When peas are grown for canneries, the whole crop is now generally delivered, and the peas are separated from the vines at the factory by means of threshers. The vines, which often contain many peas with pods, are either siloed and the silage used for sheep and steer feeding; or cured into hay. Pea vines make a very nutritious hay that is relished better by horses, cattle, and sheep than the straw of the grain crops (Stone). If cut before maturity and well cured, it appoaches clover hay in feeding value.[13]

[13] Delaware Bulletin 41.

Vetches.—Only two of the vetches grown in this country are of importance for feeding purposes: Common vetch (*Vicia sativa*) and hairy or Russian vetch (*V. villosa,* Fig. 20). The former is an annual grown rather extensively for hay on the Pacific coast and to some extent in the South. There are two strains: Winter vetch, sown in the fall, and spring vetch, sown in the spring. Hairy vetch is a biennial, much more hardy than the common vetch, and

FIG. 20.—A South Carolina vetch field. Hairy vetch will grow in most sections of the country, yielding, on the average, about two tons of hay of excellent quality. It is a good crop to grow where red clover fails, and also makes a good cover crop. (*Breeders' Gazette.*)

can be grown almost anywhere in the country, withstanding well the winters of northeastern United States. Both vetches make an excellent quality of hay and also furnish luxurious pasture that is eagerly eaten by farm animals. The yields of hay obtained average about 2½ tons to the acre. Hairy vetch is perhaps the best legume for sections where red clover fails, and this is especially true for sandy soils. In the northern States it can be used to seed in corn at the last cultivation, and will furnish a subsequent crop for green manuring or hay.[14]

Cowpea (*Vigna cutjang*) is grown for both forage and seed. The latter is used as a food for both man and beast. The plant reaches its highest development in the South, where it has been of untold value in enriching poor soils and furnishing abundant green and dry feed for farm animals. During the last decade experiments have been conducted in many States with the view to determining the value of the cowpea as a forage plant, and its cultivation has extended considerably northward as a result. It has been found to do well in the lower New England States, Ohio, Indiana, Illinois, Missouri, and Kansas; in the States east and south of those mentioned its agricultural value is fully established. The entire plant has a high feeding value, and it is generally fed, seed and all, to farm animals in the South. The Alabama station obtained an average yield of about 3600 pounds of hay and 510 pounds of peas in trials continued for three years.[15] A good quality of cowpea hay possesses a similar value as alfalfa hay, and is nearly as valuable as wheat bran, ton for ton; hence it is often used in rations for dairy cows to take the place of a portion of the concentrates, as is the case with alfalfa. In this way it is often possible to lower considerably the cost of production of milk and butter fat. In a feeding trial with dairy cows at Alabama station[16] a saving of 23 per cent in the cost of the ration was thus effected by substituting cowpea hay for wheat bran. Experiments have shown that one-half of the concentrates fed to cows or fattening steers may be replaced by cowpea hay without decreasing the feeding value of the rations. The chemical composition of the different parts of the cowpea plant is shown in the following table:

Composition of Parts of the Cowpea Plant, in Per Cent

	Moisture	Ash	Protein	Fiber	Nitrogen-free extract	Fat
Green forage...	83.60	1.70	2.40	4.80	7.10	0.40
Hay...........	10.70	7.50	16.60	20.10	42.20	2.90
Silage.........	79.30	2.90	2.70	6.00	7.60	1.50
Seed, shelled...	14.80	3.20	20.80	4.10	55.70	1.40

Cowpeas are often planted with either sorghum or Indian corn, especially if the Indian corn is intended for silage; this makes a

[14] Farmers' Bulletin 515.
[15] Bulletin 118.
[16] Bulletin 123; Experiment Station Record 15, p. 72.

very satisfactory combination in regions where the cowpea does well and reaches maturity at about the same time as either sorghum or corn. Sumac sorghum and some vigorous growing variety of cowpea, like Brabham or Unknown, appear to give the best crops, six parts of cowpeas with one part of sorghum making about the desired proportionate stand in the mixture. The hay is greatly relished by stock if cured properly.[17]

Soybean (*Glycine hispida,* Fig. 21) is of greater importance for seed production than for forage purposes, except in the South, where its value as a forage plant, for feeding green, as hay or as silage, is about as great as for production of seed. It is grown for the sake of the seed throughout the United States about as far north as corn will mature. In the Gulf States it will usually yield six to ten tons of green forage or silage to the acre and one and one-half to three tons of hay. Soybean fodder is a high-protein feed that can be produced under practically the same conditions as can Indian corn.[18] The composition of the soybean plant is quite similar to that of alfalfa, as will be seen from the following table:

Composition of Soybean Plant, in Per Cent

	Water	Fat	Fiber	Ash	Digestible		N. R.,
					Protein	Carbohydrates and fat	1:
Green fodder	80.0	.9	5.4	2.1	2.7	9.7	3.6
Hay	11.8	4.3	24.2	7.0	10.6	43.6	4.1
Straw	15.0	1.8	36.1	6.1	2.4	40.2	6.8
Silage	74.2	2.2	9.7	2.8	2.7	11.7	4.3
Seed	14.0	16.7	4.7	5.0	28.4	57.9	2.0
Alfalfa hay	8.1	2.1	28.9	8.8	10.5	42.5	4.0

Velvet bean (*Mucuna utilis*) is another forage crop that is highly recommended for southern agricultural conditions. It is considered especially suited to Florida, but has a similar range of culture as Japanese cane (p. 112). It is grown for both seed and forage; in the latter case the crop may be cut for hay when the young buds are well formed, allowed to wilt for about 48 hours, and cured in shocks for several days; or it may be left in the field throughout the winter and fed as needed. The beans contain about 18.8 per cent protein, 6.3 per cent fat, and 53.7 per cent nitrogen-free extract. They are fed in the same manner as cowpeas or cotton seed in the South, and are relished by all farm animals except horses, that apparently do not care for them. Velvet bean forage

[17] Farmers' Bulletin 458.
[18] Cornell Bulletin 310; Delaware Bulletin 96; Farmers' Bulletin 58.

has also a high feeding value and should be fed along with other kinds of hay or starchy concentrates. Fed in this manner, it makes a valuable feed for all classes of live stock.[19]

Florida beggar weed (*Desmodium tortuosum*) is a sub-tropical plant that is grown in the South for either green forage or for hay, and is well liked by all classes of farm stock. It has rather woody stalks, from three to eight or ten feet high, with abundant leafage; when grown for hay it is cut at the beginning of bloom, three to four feet high, when it makes a very fine quality of hay, yielding about four tons to the acre. The hay contains about 12 per cent of

FIG. 21.—A field of soybeans, a valuable protein feed, both for seed production and as a forage crop. (Wisconsin Station.)

crude protein and 29 per cent of fiber, on the average, indicating that it is of somewhat lower feeding value than alfalfa or clover, ton for ton.[20]

Peanut (*Arachis hypogea*).—This legume is grown for commercial purposes in the south Atlantic States and westward to and including California. The fruit or nut is matured beneath the surface of the ground, instead of above ground, as in the usual order of things. It is an important human food, and the by-products, cull nuts, pods, and vines, furnish excellent forage for farm stock. The tops of the plant are also often cut and cured in the same manner as other legumes, and make a hay of a feeding value almost equal to that of clover hay. Peanuts form a valuable substitute for

[19] Farmers' Bulletin 451; Division of Agrostology, U. S. Department of Agriculture, Circular 14; U. S. Bureau of Plant Industry, Bulletin 141, iii.
[20] Division of Agrostology, U. S. Department of Agriculture, Circular 13.

cowpeas, especially on soils that are not adapted to the growing of this crop. One to two tons of hay per acre may be obtained by planting the Spanish peanut in rows 24 to 30 inches apart and quite close in the row. After the hay has been removed, the pods can be turned out by means of a plow, and cured and stored for winter feeding. Instead of harvesting the crop in this manner, hogs are frequently turned in to gather it.[21]

Poisonous Plants.—A number of plants that are poisonous to stock are found in different parts of the country, the more important of them being loco weeds, larkspur (*Astragalus*), death camas, water hemlock (*Cicuta*), common horsetail (*Equisetum*), etc. Serious losses are often sustained by animals eating these plants, especially in western grazing districts where sheep, cattle, or horses are kept in large numbers and eat these plants for want of better feed.

Marsh has shown that stock poisoning as a general rule is due to a scarcity of feed.[22] He concludes, from his investigations of the subject in the western range country and elsewhere, that stock seldom eat poisonous plants by choice, but only when induced or compelled by a scarcity of feed. The following precautions are recommended:

"1. Stock should not be turned out upon the range where there is little to eat except poisonous plants. This is especially dangerous when the stock have been on dry feed.

"2. In a region where certain areas are definitely known to be infested with poisonous plants, stock should be kept away. This is especially necessary when the general range is short, either because grass has not started or because it has been overgrazed. When the range is well covered with good grasses, herding away from poisonous areas is ordinarily unnecessary.

"3. When stock are trailed from one place to another, they should, so far as possible, be driven through a country with plenty of good feed. If it is necessary to drive them through a locality supposed to be infested with poisonous plants, care should be taken to see that the stock are not hungry when going through this region. It is much better to make such a drive in the afternoon rather than in the morning. Special precautions must be taken when it is necessary to pass over a trail that has been used by many others, for all good feed will have disappeared and the stock will eat whatever is left. Sheep should not be bedded for several successive nights in the same place."

Other sources of poisoning are plants containing prussic acid (such as second-growth sorghum and kafir, Johnson grass), cornstalk disease, ergot, corn cockle, castor beans, mountain laurel, night shade, etc.[23]

QUESTIONS

1. What are the special points in favor of growing leguminous hay crops?
2. Discuss briefly the value of alfalfa to the American stock farmer.
3. Mention the different species of clover used for hay crops, and give the main points in favor of each.
4. Describe the value and uses of field peas, vetches, cowpea, and soybean in stock feeding.
5. Give a number of southern leguminous forage crops and state their main uses and feeding values.
6. Name some of the more important poisonous plants. State where stock poisoning most frequently occurs and with what classes of farm animals.
7. How may poisoning of stock be best avoided?

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[21] Farmers' Bulletin 431. [22] Farmers' Bulletin 536.

[23] See Chestnut, "Thirty Poisonous Plants of the United States," Farmers' Bulletin 66, 1897; Pammel, "Manual of Poisonous Plants," Cedar Rapids, Iowa, 1911.

III. STRAW OF CEREALS AND LEGUMES

Straw is the stems and leaves of cereals and legumes after the ripe seeds have been removed. During the latter stage of the vegetative period of the plants soluble materials are transferred to the seeds, and other parts of the plants are left relatively depleted in feed components. Hence we find that straw is low in protein and fat and in more valuable carbohydrates, although still high in nitrogen-free extract and likewise high in fiber. Straw from cereals cut at different stages of ripening differs considerably in chemical composition and feeding value. Kellner gives the following analyses of oat straw cut at three different periods of growth—unripe, ripe, and over-ripe: [24]

Composition of Dry Matter of Oat Straw at Different Periods of Ripening, in Per Cent

	Crude protein	Fat	Nitrogen-free extract	Fiber	Ash
Unripe	10.1	1.9	50.6	29.4	8.0
Ripe	4.9	1.2	48.6	37.8	7.5
Over-ripe	4.3	1.4	36.9	49.8	7.6

The amount of net energy yielded in the digestion of straw cut at the usual time is small, and in some cases, like coarse rye or wheat straw, it is not sufficient to maintain an animal at an even body weight. Oat and barley straw is more valuable than the other kinds of straw, and is used as a regular part of the feed rations of horses and fattening cattle, especially in European countries. It is generally cut fine and fed wet, mixed with concentrates or sliced roots. It is fed in this way both for the net nutrients that it supplies and also, perhaps largely, because it is believed to act as a filler and enables animals to digest their grain feed more thoroughly when thus diluted with cut straw.

The different kinds of cereal straw have, on the average, the following chemical composition: 3 to 4 per cent total protein; 36 to 39 per cent fiber; 36 to 46 per cent nitrogen-free extract, and 1 to 2 per cent fat.

The digestibility of the dry matter and the nitrogen-free extract is low, viz., 40 to 50 per cent, and that of protein only 20 to 30 per cent. The total digestible matter in straw ranges from 37 to

[24] "The Scientific Feeding of Animals," p. 169.

43 per cent. Practical feeding experience and the results of chemical analyses and digestion trials suggest that cereal straw ranks in the following order as regards feeding value: Oats, barley, wheat and rye straw. Straw is often used for feeding in the stack. On grain farms where straw is abundant, only little stock is, as a rule, kept, and the straw, if utilized at all, is fed in the stack, or baled and shipped to be used for bedding.

Cornstalks.—The straw of the Indian corn plant, known as stover, cornstalks, or corn fodder, is an important rough feed on all American farms where corn is grown. It is either left standing in the field where cattle nibble the leaves and tender parts during the fall and winter months, or it is cut and cured in the field in shocks that are later brought in and used as feed for cattle, sheep, and horses (p. 108). The cornstalks are now often run through a shredder in the same operation as the shock corn is being husked, and the shredded fodder is stacked for use in the fall and winter. The shredded cornstalks make a fair quality of rough feed, which is generally eaten up clean by farm animals. This is never the case when whole cornstalks are fed, and rarely so when they are cut before feeding. Shredded fodder also makes a better stable absorbent than either whole or cut stalks.

Corn stover, like straw of the small grains, makes a valuable feed for young stock, idle horses, or cattle, that are being carried over the winter, in fair condition until spring time. The Massachusetts station found, as the result of four years' experiments,[25] that moderately thin yearling steers lost only 33 pounds per head when wintered on whole cornstalks alone. This feed will, therefore, furnish nearly a maintenance ration for such animals. In trials at the Nebraska station two-year-old steers fed one-half alfalfa hay and one-half cornstalks did nearly as well as those fed clear alfalfa hay, similar amounts of corn being fed in both cases. In one experiment lasting 168 days the average gains made were even slightly greater than when alfalfa was fed as the sole roughage.[26] Trials at the New Hampshire station [27] show that cut corn stover may be considered a good substitute for timothy for winter feeding of horses when fed with concentrates. Other experiments have shown the value of cornstalks for feeding cows and sheep. It is evident, therefore, that cornstalks are well worth utilizing for feeding purposes to a far greater extent than has heretofore been the case, especially on farms in the corn belt. A proper appreciation of the value of cornstalks and grain straw for feeding live stock

[25] Bulletin 71. [26] Bulletins 90, 93, 100. [27] Bulletin 82.

would be a powerful aid in the further development of our animal industry.

The straws of legumes and miscellaneous grain crops, like buckwheat, millet, etc., do not differ greatly from the cereal straws, except that the legume straws are higher in protein and possess a somewhat higher digestibility. They are, however, rather coarse and unpalatable, and therefore less suited for the purpose of stock feeding than grain straw. Pea and bean straw, like legume straw in general, are much used as a feed for cows and sheep, especially in sections where these crops are largely grown. They are considered a valuable roughage, as they generally contain appreciable quantities of seeds and pods.

QUESTIONS

1. Name the different kinds of straw of cereals used for feeding farm animals, and the special value of each one.
2. Name the different kinds of straw of leguminous crops used for feeding purposes, and state their approximate value in comparison with (*a*) cereal straw, (*b*) timothy hay, (*c*) corn fodder.
3. To what purpose are cornstalks best put in feeding farm animals, and how best prepared for feeding?

CHAPTER XIV

ROOTS, TUBERS, AND OTHER SUCCULENT FEEDS

Root crops are grown for stock feeding to only a relatively limited extent in this country. There can be no question as to their value for this purpose; all agree that they are highly nutritious feeds and greatly relished by farm animals. The main objection to their use is the cost and the difficulty of growing them. It may be that this objection is, in general, well founded, and that there are crops equally valuable as stock feeds that can be grown with less labor and expense, *e.g.*, corn in the central and eastern States, and alfalfa in the West, to mention only those two important forage crops. But roots have a special place to fill in the feeding of livestock. They have a very beneficial effect on the health and the production of milch cows, ewes, and other farm animals and can often be produced in immense quantities, making it well worth while for stock farmers to look into their culture.

The main reason why roots are not grown more extensively in the dairy sections of our country and elsewhere is that corn silage is now a common feed on dairy and stock farms. Silage compares favorably with roots as regards nutritive effect and can, as a rule, be produced at less expense and in larger yields of dry matter per acre.

Relative Yields of Roots and Silage.—A number of experiment stations have furnished data for a comparison of the yields and the cost of production of roots and corn silage; in these experiments roots of different kinds were raised for one or more years under similar conditions as those for Indian corn. The following table shows the average yields per acre of four kinds of root crops and of Indian corn obtained in experiments at the Maine, Pennsylvania, Ohio, and Ontario (Guelph) experiment stations:

Comparative Yields of Root Crops and Fodder Corn.

	Yield of root crops per acre		Yields of fodder corn per acre	
	Total weight, pounds	Dry matter, pounds	Green substance, pounds	Dry matter, pounds
Rutabagas	37,240	4146	34,200	5600
Mangels	35,120	3550	30,200	5920
Turnips	37,310	3470	34,169	5608
Sugar beets	25,300	4003	30,200	5900
Averages	33,740	3792	32,190	5757

The figures in the table show that larger gross yields were obtained in the case of all roots, except sugar beets, than of corn; on the average for all four root crops, nearly 17 tons were harvested per acre, against 16 tons of fodder corn. The amounts of dry matter harvested in these crops were, however, 3792 pounds in roots and 5757 pounds in the corn, a difference of 52 per cent in favor of the latter crop. The roots have a somewhat higher digestibility than fodder corn. If we assume that the dry matter in the former crops is 87 per cent digestible, on the average, and that of the fodder corn 70 per cent digestible, we find that there is a difference of 22 per cent in the yield of digestible matter obtained per acre in favor of the fodder corn. It is fair to suppose that both kinds of crops were grown under as favorable conditions as the season would permit in these experiments, and we may, therefore, conclude that fodder corn will produce, on the average, about one-half more dry matter and over one-fifth more digestible matter per acre than root crops under conditions similar to those which prevailed in these experiments.

While accurate information as regards the cost of raising roots and fodder corn is limited, it seems evident, from the accounts published by different stations, that it will cost at least twice as much to grow, harvest, and store a ton of roots as to grow and put a ton of Indian corn in the silo. When calculated on a basis of the cost of total dry substance or digestible matter in the two crops, the comparison, therefore, comes out still more unfavorably for root crops. Both in point of the actual yields secured and the expense of growing, roots are, in general, less desirable crops to raise than Indian corn wherever the conditions are favorable for the culture of the latter crop.

In view of the facts stated, it is not surprising that root crops are grown to only a relatively small extent for feeding purposes in this country, and no system of farm management can be safely advocated that would give prominence to the growing of root crops by American farmers as a general proposition. There are, however, conditions where it may be advisable to grow roots to a much larger extent than is now done, outside of the culture of sugar beets for the sake of sugar production; this is a different proposition from the growing of roots for stock feeding, and is not considered in the present discussion. The more important ones of these conditions are discussed in the following paragraphs.

Value of Roots.—Root crops are especially valuable as appetizers, for exhibition animals, and for dairy cows that are being fed heavy rations with a view to securing a maximum production of milk. For these purposes no crops are equally valuable to farmers and breeders. Roots are also grown to advantage where Indian corn will not do well on account of climatic and other conditions. They grow best in a cool and moist climate. This may be inferred from the fact that they are important crops in European countries, especially Great Britain, where the growing of turnips is a distinctive feature of farming and figures largely in the making of the fine quality of mutton and beef produced there. Also in Denmark, a highly specialized dairy country, the growing of roots, especially mangels and rutabagas, is largely practised, and their culture has increased in a marked manner during the present century, because the dairy farmers have found it advantageous on agricultural and economic grounds.

Roots are, in general, characterized by a high digestibility and palatability. They contain large proportions of water, as has been shown, viz., 70 to 90 per cent, and only small amounts of both fat and fiber. The protein is also low, and about 40 per cent thereof is in non-protein form. The nitrogen-free extract, on the other hand, is relatively high and consists largely of soluble carbohydrates. The root crops are, therefore, especially valuable sources of carbohydrates. They are greatly relished by stock and have a favorable influence on their digestion and general health. The only exception is that care is necessary in case of feeding root crops (mangels and sugar beets) to breeding rams and perhaps also to ewes and cattle, on account of the possibility of formation of kidney and bladder stones. There is no danger in this respect in the case of fattening animals, according to the Iowa station.[1]

The main root crops used for feeding farm animals in this country are mangels, rutabagas, turnips, sugar beets, and carrots. Cabbage, rape, and kale belong to the same botanical genus as turnips and rutabagas (*brassica*), of the mustard family (Latin name, *cruciferæ*), and parsnips belong to the carrot family (*umbelliferæ*). These crops will now briefly be considered.

Mangels are also called mangel-wurzels or field beets (*Beta vulgaris*, Fig. 22). Like root crops in general, mangels have a high feeding value for the amount of dry matter they contain, which is less than that of any other root crop, viz., 9 per cent on the average. There is considerable difference in different varieties in this respect, the average dry matter contents of these ranging between 6 and 16 per cent. The average digestion coefficients for

[1] Bulletin 112; Farmers' Bulletin 465.

the dry matter of mangels is 87 per cent, and that of the carbohydrates 95 per cent. The carbohydrates are largely sugar and pectins, and make up nearly 70 per cent of the total dry matter. The protein substances (nitrogen × 6.25) consist of only 40 per cent of true protein, the balance being amides and nitric acid combined with alkalies. Very large yields of mangels are grown on rich land and with an ample water supply. Ontario Agricultural College reports a yield of nearly 28 tons to the acre, and Cornell station 23.6 tons, the fine average for five different stations being about 20 tons.

Mangels grow considerably out of the ground and are easily pulled by hand. In the mild winter climate of the southern States

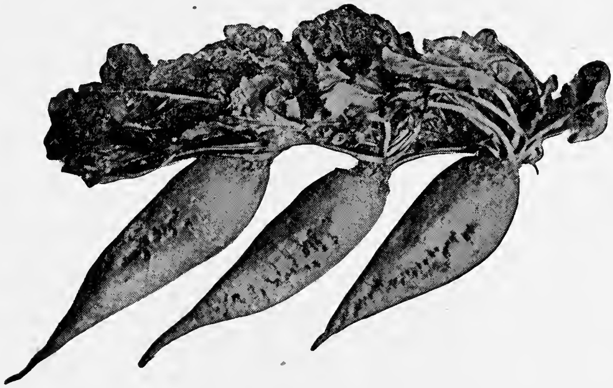

FIG. 22.—Half-sugar mangels. The most desirable kind to grow for stock feeding, according to Cornell Station.

and California they are generally left in the field until wanted for feeding, while in the eastern and central States they are stored in root cellars in the fall and kept cool and ventilated. They should not be fed for a few weeks after harvesting, as the freshly-harvested mangels tend to scour stock. Mangels furnish a good feed for all kinds of livestock, except perhaps horses. They are usually run through a root cutter or pulped before feeding. Danish feeding experiments have shown that the dry matter of mangels has a feeding value similar to grain feed, pound for pound, and that they may largely replace grain in feeding milch cows when substituted in this ratio—say 1 part of grain for 10 to 15 parts of roots, according to the water content, or, on the average, 1 to 12½ by weight. Danish dairy farmers feed as much as 100 pounds of mangels per head daily to their cows, and similar heavy root feeding is also practised by eastern dairy farmers who are feeding their cows for official tests with a view to securing a maximum milk yield. Half-sugar mangels are recommended by the Cornell station as the most desirable root crop to grow for stock feeding.[2]

Rutabaga or Swedish turnip (*Brassica campestris,* Fig. 23) gives yields similar to mangels and, as a rule, contains somewhat more dry matter. It is considered a good sheep feed and also makes an excellent winter feed for swine, especially for brood sows. Rutabagas are extensively grown by British and Canadian farmers, but less than mangels or sugar beets in this country.

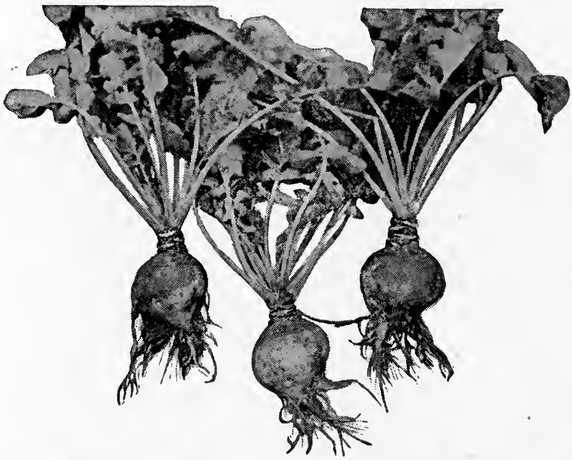

FIG. 23.—Rutabagas (Bloomsdale), a good type for stock feeding. (Cornell Station.)

Kohlrabi (*Brassica caulorapa*) has been developed for its thickened stem instead of for its leaves and root. Although not a root in the botanical sense, it may be discussed under this heading, as it serves the same purpose as roots in stock feeding. According to the Cornell station,[3] kohlrabi can be grown wherever rutabagas are grown, and will thrive under similar conditions. In the middle West, where rutabagas have a tendency to run to necks and form little root, this crop is a good substitute. The yields of the two crops appear to be about the same; as kohlrabi grows well out of the ground, it may be readily pastured by sheep, and these animals also relish greatly the leaves of the plant.

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[2] Bulletin 317. [3] Bulletin 244.

Turnips (*Brassica rapa*) are low in dry matter, containing often a smaller percentage thereof than mangels (less than 10 per cent, on the average); the yields obtained are similar to those of mangels. They are especially valuable for sheep feeding, and are also sometimes fed to cattle. When fed to milch cows they impart a strong turnip flavor to the milk, unless fed after milking; the same difficulty is likely to occur in the case of rutabagas and other crops of the mustard family (*Cruciferæ*). Turnips do not keep as well as mangels or rutabagas, and must be fed out during the fall or early winter.

Sugar beets (*Beta vulgaris*) are grown for the manufacture of beet sugar in the western States and in Michigan, Wisconsin,

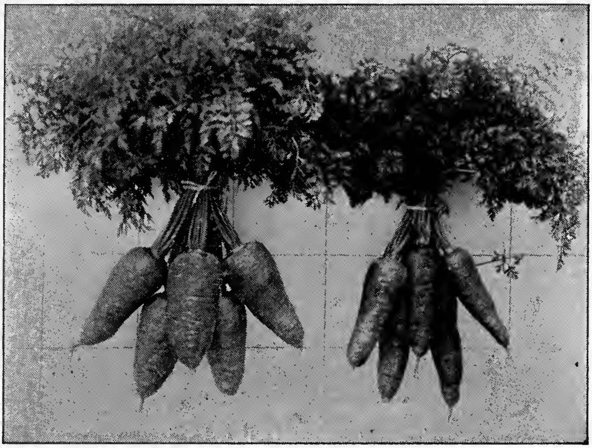

Fig. 24.—Carrots for stock feeding (Improved Rubicon and Danvers Half-long), fairly easy to harvest and capable of good yields. (Cornell Station.)

and other central States, and are of minor importance for stock feeding. Their culture is more difficult and exacting than that of other root crops, and the yields obtained are smaller, viz., about 12 tons, on an average; owing to their relatively high per cent of dry matter, 15 to 18 per cent (of which at least four-fifths is sucrose), they will, however, generally yield about as much dry matter per acre as other root crops.

Sugar beets are greatly relished by stock and often fed, pulped or sliced, to milch cows, fattening cattle, sheep, and swine, especially when these are being fitted for exhibitions.

Carrots (*Daucus carota*, Fig. 24) are considered particularly valuable as a horse feed, but are also fed occasionally to cows. The red or yellow varieties impart a rich color to the milk, owing to the coloring matter (carotin) which they contain, and produce a yellow cream and butter, making the use of artificial coloring in butter-making quite unnecessary. Stock carrots will yield 10 to 20 tons per acre, according to the character of the soil, or still more under favorable conditions. They contain, on the average, about 12 per cent of dry matter, of which the greater portion is sugar (sucrose and glucose). They may be used to replace a portion of the oats in the ration of horses that are hard worked, feeding about six to eight pounds per head daily.

Potatoes (*Solanum tuberosum*) are used extensively for stock feeding by European farmers, but only to a small extent in this country. The growing of this crop for the purpose of furnishing feed for farm animals cannot be recommended, on account of the relatively low yields obtained (average, 200 bushels at 60 pounds, or six tons) and the expense of production; but on most farms a supply of cull potatoes is available, and in potato-growing districts large amounts of such potatoes may be profitably used for feeding farm animals.

Potatoes are primarily a fattening feed and are used especially for feeding swine. They may also be fed to advantage to other classes of stock,—horses, wethers, and milch cows, as a partial substitute for grain. They are generally cooked for swine, and are fed sliced, mixed with grain feed, to other classes of farm animals.

Potatoes contain about 20 per cent of dry matter, of which over 80 per cent is composed of carbohydrates, largely starch. Like all roots and tubers, they are low in fat; the high starch content places them among our foremost starchy feeds and renders them especially valuable for fattening purposes. Danish feeding experiments have shown that four pounds of boiled potatoes are equal to a pound of mixed grain for feeding swine, and that for dairy cows it takes six pounds of raw potatoes to equal a pound of mixed grain (1 feed unit, p. 79).

Unripe potatoes contain a poisonous nitrogenous compound called *solanin,* which also accumulates in considerable quantities in the sprouts; in feeding old sprouted potatoes the sprouts must, therefore, be carefully removed to prevent accidents.

During recent years machinery for drying potatoes has been greatly perfected in Germany, and dried potatoes in the form of flakes or chips are now a regular article of commerce in Europe. It takes, on the average, about 3.8 tons of raw potatoes to make a ton of dried potato flakes. These are pronounced "much cheaper than oats, and, pound for pound, as valuable as a feed for horses." Experience from abroad suggests a fruitful line of experimentation for American feed manufacturers with this product, as there can be no question but that our potato industry can be readily further developed, and that it would be of great benefit to potato growers as well as to feeders to have cull or other potatoes made into a feed of unquestioned merit which can be kept indefinitely.

Miscellaneous Succulent Feeds.—A number of miscellaneous succulent feeds of minor importance for stock feeding, like cabbage, rape, kale, pumpkins, etc., may be conveniently considered at this time.

Cabbage (*Brassica oleracea*) is a favorite feed among many sheep men, especially for fitting sheep for shows. It is also occasionally fed to milch cows and laying hens. On account of the relatively small yields obtained and the expense of growing cabbages, it will not pay to use them for stock feeding, except in the case of unfavorable market conditions, or where the cost of the feed is not an important factor, as in the case of feeding for exhibition stock or preparing cows for official tests. As with other plants of the mustard family, cabbages are likely to taint the milk when fed to dairy cows and should, therefore, be fed after the milk has been removed from the stable. Cabbages contain, on the average, less than 10 per cent solids, 2.6 per cent digestible protein, and 6.1 per cent digestible carbohydrates and fat, the nutritive ratio being 1:2.7. A considerable proportion (30 per cent or more) of the protein is, however, present in amide form, in this as in other green plants, making it less valuable as a source of protein than is indicated by its narrow nutritive ratio. Trials conducted at the Cornell station showed that on the average for three years cabbages yielded 22.5 to 43.8 tons to the acre, containing 1.8 to 3.1 tons of dry matter (average dry matter content, 6.3 to 7.1 per cent).[4]

Rape (*Brassica napus*) is a valuable forage crop, especially adapted to a relatively cool and moist climate. It does well in northern United States and Canada, but can also be successfully grown further south and in the semi-arid sections of the country, either with or without irrigation. The parts of the plant eaten by stock are the numerous leaves and fleshy stems. Rape is used either for pasturage or as a soiling crop for sheep and swine, generally the former, while it is cut and fed green to cattle. It may be sown broadcast in the early spring and later at intervals of

[4] Bulletin 242.

two to three weeks. This will secure a succession of green feed for summer and fall feeding that will serve to make the farmer independent of short pastures and will keep the stock in a vigorous, thrifty condition (Fig. 25). Rape is also sown in drills, about 30 inches apart, with the plants two to three inches apart in the row, either with spring grain or with corn just before the last cultivation. This will furnish an abundance of green forage for fall feeding. Rape may be cut or pastured from eight to ten weeks from the time of seeding, when it will be 12 to 15 inches high.

Fig. 25—Pigs on rape. This crop forms a very valuable succulent feed for pigs and sheep. (Wisconsin Station.)

The variety of rape generally sown is Dwarf Essex, which is a biennial. Nearly all the seed of this variety on the market is imported. The seed of bird-seed rape, which is an annual, is sometimes sold as Dwarf Essex, and care should, therefore, be taken to buy seed from reputable seedsmen only, as the former variety is worthless for forage purposes.

Rape contains about 14 per cent dry matter and 2 per cent digestible protein, its nutritive ratio being about 1 : 4.3. Both on account of its relatively high water content and its narrow nutritive ratio, it will not give satisfactory results when fed alone, but should be supplemented with grain feed, preferably with low-protein feeds, such as corn and other cereals, wheat middlings, or dried beet pulp, or with grass pasture, mixed hay, cornstalks, etc. Rape has proved an excellent feed for sheep, swine, and cattle. At the Ottawa station a bunch of 22 steers made an average gain of 50 pounds live weight in three weeks on an area of two acres; about 30 sheep had been allowed to pasture on a part of this field for ten weeks. The sheep also had access to a limited area of natural grass pasture. In an experiment with pigs, 60 pigs were fed on an acre and a half of rape; in addition to the rape pasture, about 500 pounds of grain were required for each pig from weaning time to an average of 185 pounds weight in October or November.[5]

The value of rape as a forage plant has also been established by experiments at the Wisconsin, Iowa, Michigan, and other stations. At the Wisconsin station a gain of 413.5 pounds of mutton was obtained from 9¾ tons of rape and 1439.8 pounds of grain (wheat and oats). The highest yield obtained from three cuttings at about four inches from the ground was at the rate of 36 tons of green forage per acre. An acre of rape was found to have a feeding value equivalent to 2657 pounds of grain fed to pigs four to ten months old. Young pigs did better when pastured on rape than on clover, grain being fed in both cases. Rape has an excellent effect on the milk secretion, and therefore makes a valuable soiling crop for dairy cows. As in the case of turnips, cabbages, and other plants with strong flavor, it should be fed after milking. Rape can be used to good advantage as a part of the ration for animals that are being fed in pens for market or for the show ring. It is also a valuable feed for young lambs and pigs at weaning time. Rape can stand quite cold weather, and will, therefore, last a long time after the pasture grasses succumb to frost; by the use of this crop stock can be put into good condition for the holiday markets or for winter, and there need be no check in growth, fat, and milk production through insufficient succulent feed during the late summer and autumn months, as is too frequently the case.[6]

Kale (*Brassica oleracea,* var. *Asephala*) belongs to the mustard family and stands quite close to the cabbage in composition and feeding value. It is only grown to a small extent for forage purposes in this country, the only States where its use appears to have spread being Oregon and western Washington. On rich land, well supplied with moisture, it gives an immense amount of nutritious

[5] Ottawa Bulletin 42.

[6] Farmers' Bulletin 164; Division Agrostology, U. S. Department of Agriculture, Circular 12; Wisconsin Report 20, pp. 46–55 and 281–283.

green feed for fall and early winter feeding, viz., 30 to 40 tons or more per acre. Under ordinary conditions 20 tons are probably an average yield. All kinds of stock, including poultry, like kale, and it is specially valuable as a feed for milch cows, sheep, and swine. According to the Oregon station, 35 pounds of kale a day, with 20 pounds of hay, make an excellent ration for dairy cows, very little grain feed being needed in addition.[7]

Pumpkins (*Cucurbita pepo*).—The use of pumpkins in feeding stock is old in this country, being planted in the corn and left in the field till "the frost is on the punkin and the fodder's in the shock!" The crop has never assumed much importance as a stock feed, however, and is fed, especially to milch cows and swine, more as an appetizer than for the amount of nutrients that it supplies. It contains about 10 per cent of dry matter, and resembles turnips quite closely in composition. The Vermont station[8] found that two and one-half tons of pumpkins are equal to one ton of corn silage for dairy cows. They are generally cooked for swine and mixed with grain feeds, but it is a question whether the cooking adds anything to their value (p. 67). The seeds are often removed in feeding pumpkins; some farmers believe that they tend to dry up cows. There is probably no foundation in fact for this belief. According to Grisdale, pigs like the seeds best, and no injury comes from feeding them. Henry states[9] that the seeds contain much nutriment and should not be wasted.

Pie melons (also called citron or cow melons) are grown for feeding purposes to a limited extent in western States. "Like the ordinary field pumpkin, they can be produced readily in large quantities on most lands, and ripen at a time when green feed is likely to be scarce. When fed to dairy stock they produce an increased milk yield, which is more than commensurate with their actual content of feed substance. This is because of their palatability and beneficial effects upon digestion and the addition of wholesome variety to the ration. They may be fed with profit to swine and poultry when in confinement, and to sheep, especially during nursing periods.[10] Pie melons contain 5.5 per cent dry matter on the average, or only about one-half as much as field pumpkins. The relative feeding value of the two crops is, in all probability, represented by this ratio.

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[7] Circular Bulletin 5.
[8] Report, 1908.
[9] "Feeds and Feeding," 10th ed., p. 195.
[10] California Bulletin 132.

Jerusalem artichokes (*Helianthus tuberosus*).—This hardy perennial is grown for the sake of its tubers, which resemble potatoes in composition and are used as a human food, and also as a feed for hogs and horses. The large leaves and stems, which may be cut off about two feet from the ground when the plants are five or six feet high, make an excellent green feed for sheep, goats, young cattle, and even milch cows, according to European authorities. If cut at this time, the yield of tubers does not appear to be appreciably affected.[11] The Massachusetts station[12] reports a yield of 8.2 tons of artichoke tubers per acre. The tubers may be harvested in the same way as potatoes, or may be rooted up by hogs turned into the field. As artichokes can withstand severe periods of drought, they may be worthy of a trial by farmers in the northwestern States, but a word of caution is in order in regard to this as well as other relatively unknown crops; their importance is often greatly exaggerated in the agricultural press.

Parsnips (*Pastinaca sativa*) are grown for the sake of their thickened stems and roots, which are used both as a human food and for stock feeding. They are grown on the islands of Jersey and Guernsey as a dairy feed, but only to a very limited extent in this country. The yield obtained is small, and it is, moreover, difficult to harvest the crop, as the roots grow entirely in the ground. Its use for stock feeding is, therefore, not likely to be extended much beyond its present confines. The following table shows the chemical composition of leaves, stems, and tubers of artichokes, of parsnips, and of potatoes, for the sake of comparison:

Composition of Artichokes and Parsnips Compared with Potatoes, in Per Cent

	Dry matter	Protein	Fat	Fiber	Nitrogen-free extract	Ash
Artichokes, green leaves and stems	31.0	3.2	.7	6.0	18.0	3.1
Artichokes, tubers	20.5	2.6	.2	.8	15.9	1.0
Parsnips	11.7	1.6	.2	1.0	10.2	.7
Potatoes	20.9	2.1	.1	.4	17.4	.9

Chufa (*Cyperus esculentus*) is a southern perennial sedge that produces an abundance of small, underground tubers. The crop is generally harvested by hogs that are turned into the field as the tubers ripen in October or November. Chufas are a noxious weed on low, damp places on southern farms. They grow best on light, sandy soils, where they give an average

[11] Pott, "Landw. Futtermittel," part i, p. 196.
[12] Report 10.

yield of 100 bushels to the acre. The Alabama station [13] showed as the average of two trials that chufa will produce pork at the rate of 307 pounds per acre, after allowance was made for the grain feed eaten, while in trials at the Arkansas station an acre of chufa produced 592 pounds, against 1252 pounds from an acre of peanuts and 436 pounds from an acre of corn.[14]

The sweet potato (*Ipomœa batatas*) is another southern crop that grows as far north as Illinois, Kansas, and New Jersey. Its greatest importance is as a human food, but, in the absence of good near-by markets and proper transportation facilities, it becomes of considerable value as a feed for stock, especially swine, in regions adapted to its culture. Fed sliced, they make a good cattle and horse feed. Pigs do their own harvesting. Three pounds of sweet potatoes contain nearly as much dry matter, quite as much carbohydrates, and less than one-half as much protein as are generally contained in one pound of Indian corn.[15] By using one-half pound cotton-seed meal, or one pound cowpeas for every ten pounds of sweet potatoes, the deficiency in protein will be fully covered. The Florida station [16] found that sweet potatoes can replace one-half of the corn in rations for work horses, the feeds being substituted in the ratio of three to one. Trials with dairy cows at the same station indicate that 100 pounds of sweet potatoes have a nutritive effect similar to 150 pounds of corn silage. Sweet potatoes contain, on the average, 31.7 per cent water, 1.1 per cent ash, 1.9 per cent protein, 26.8 per cent carbohydrates, and 0.7 per cent fat. Their high sugar and starch contents (4 to 6 per cent and 16 to 18 per cent, respectively) render them especially valuable as a feed for fattening swine.

Sweet potato vines are also utilized as a feed for cattle. They may be considered similar to cowpea vines in feeding value, and are better suited for feeding green than for curing into hay or for silage.

Sweet Cassava (*Manihot aipi*).—This is a sub-tropical plant belonging to the milk-weed family, which is cultivated for its starchy roots. These are used for the manufacture of starch and for stock feeding. Ninety-five per cent of the cassava grown in this country is fed to livestock; all classes of farm animals eat it with a relish and thrive on it better than when confined to only dry feeding.[17] Cassava is grown in the Gulf States in this country, and cannot be grown outside of an area extending 100 miles from the coast of the Gulf States, and possibly South Carolina. Five to six tons of roots per acre are a fair crop. The following analysis shows the composition of cassava roots:

> 66.0 per cent moisture, 0.7 per cent ash; 1.1 per cent protein, 1.8 per cent fiber, 30.2 per cent nitrogen-free extract, 0.2 per cent fat; nutritive ratio, 1 : 28.5.

On account of its wide nutritive ratio cassava is best supplemented with high-protein feeds common in the South, like cowpeas, velvet beans, cotton-seed meal, etc., in feeding growing animals, milch cows, or animals that are being fattened. It furnishes an excellent substitute for winter pasture as well as for the silo where a farmer does not have a sufficient number of animals to make the investment in a silo profitable.

Apples and other fruits are at times available for stock feeding in orchard regions during the summer and fall and may be fed with advantage to cattle, sheep, swine, or horses, all of which eat them

[13] Bulletin 122.
[14] Bulletin 54; see also Farmers' Bulletin 102.
[15] Farmers' Bulletin 26.
[16] Bulletin 72.
[17] Farmers' Bulletin 167.

with great relish. As much as 40 to 50 pounds of apples may be fed daily per head to milch cows with good results. In experiments at the Vermont station[18] apples were found to have about 40 per cent of the feeding value of corn silage when fed to dairy cows. They make an excellent swine feed, if fed either steamed or sliced with the grain feed, but should always be fed while fresh, before fermentations set in. According to the results of trials at the Utah station,[19] apples have a similar feeding value for swine as grass pasture when fed with skim milk and shorts. The preceding remarks as to the value of apples for stock feeding hold good also for other fruits—windfalls and culls of pears, prunes, figs, oranges, etc. They are especially adapted for fattening swine, and are quite generally so used in fruit-growing districts.

The chemical composition of the more important fruits as given by the California station[20] are shown below:

Composition of Fruits, Edible Portion, in Per Cent

	Water	Ash	Protein	Fiber	Nitrogen-free extract	Fat
Apples	84.8	.5	.4	1.5	12.5	.3
Oranges	88.3	.4	.8	10.5	10.5	...
Pears	83.9	.5	.6	2.7	11.5	.8
Apricots	85.1	.5	1.0	13.4*	13.4*	...
Figs	79.1	.6	1.5	18.8*	18.8*	...
Grapes	80.1	.5	1.3	...	...	...
Plums	78.4	.5	1.0	20.2*	20.2*	...
Watermelons	90.3	.8	1.1	7.9*	7.9*	...

* Chiefly sugar.

The main portion of the nitrogen-free extract of the fruits consists of different sugars (fructose, dextrose, and some sucrose). Organic acids (chiefly malic acid), pectin and dextrin, starch and pentosans, etc., are also present. The nutritive ratio of apples is about 1:44.2; that of apple pomace (the residue obtained in the manufacture of apple cider), 1:24.7; pears, 1:33.7; oranges, 1:10.9; figs, 1:16; watermelons, 1:9.7, etc.

According to Jaffa and Anderson, 100 pounds of apples have a feeding value equivalent to 20 pounds of alfalfa hay, 15 pounds of corn or barley, or 18 pounds of wheat bran.[21]

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[18] Report 1901. [19] Bulletin 101. [20] Bulletin 132.

[21] A table showing the comparative values of fresh and dried fruits and hay, grains, etc., is published in California Bulletin 132, p. 52; see also Woll, "Handbook for Farmers and Dairymen," p. 19.

Range and Desert Plants.—The common plants growing in the deserts and mountain ranges of western United States are sage brush, greasewood and species of salt bush (*Atriplex*). These plants are able to grow in the regions mentioned because of their ability to withstand extreme drought and a considerable amount of alkali in the soil which would kill other vegetation. Sheep and other stock are, however, able to browse on these plants and derive considerable nourishment from them. Their value for stock feeding is not definitely known, as but few chemical analyses or digestion trials have been made with them, and there are no comparative feeding trials on record with these plants. The Arizona Experiment Station has published analyses of salt bushes and greasewood[22] which show that they contain high percentages of crude protein, fiber, and ash, with medium amounts of nitrogen-free extract and fat. The following average results were obtained in the analyses of different range forage crops:

Composition of Air-dry Range Forage Plants, in Per Cent

	Water	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat	No. of samples
Salt bush..........	6.10	17.20	12.89	24.53	37.44	1.78	4
Australian salt bush	6.30	17.90	14.13	20.75	38.81	2.11	1
Greasewood........	4.55	14.41	19.81	24.50	34.28	2.45	1
Water grass.......	7.60	11.76	8.88	33.62	36.53	1.61	1
Grama grass.......	7.17	9.87	4.03	30.90	46.51	1.52	2

As in the case of all plants growing in arid regions, the percentage of ash in these forage plants is very high, but the fiber content is no higher than in average grades of hay, except in the case of the water grass. According to the results of the chemical analyses made, greasewood contains more protein and no more fiber than alfalfa hay of good quality, but, in the absence of digestion experiments and carefully-conducted feeding trials, definite judgment cannot be pronounced as to its nutritive value. The Colorado station found the native and Australian salt bushes to have the following digestion coefficients, according to the results obtained in trials with sheep: [23]

Digestion Coefficients for Salt Bushes, in Per Cent

	Dry matter	Protein	Fat	Fiber	Nitrogen-free extract	Fat
Native salt bushes.......	46	66	52	8	49	72
Australian salt bushes...	60	85	24	27	64	60

[22] Report, 1903, p. 349.
[23] Bulletins 93 and 135.

According to Jaffa,[24] sheep and cattle have subsisted altogether on salt bushes through an entire season, and sheep feeders and cattle men report favorably as to their nutritive value when eaten in connection with hay and grain feeds.

Spineless cacti (species of *Opuntia,* Fig. 26) and prickly pears are desert plants used as a forage for cattle in cases of emergencies, and occasionally in a limited way as a regular forage crop. There are many varieties of cacti used for this purpose, some with, some without spines. The former are generally singed with a special gasolene torch before being fed to farm animals, while the latter are fed directly, either whole or after being run through a

FIG. 26.—Spineless cactus yields large crops of a very watery feed under favorable conditions; it is greatly relished by cattle and hogs.

cutter. There is no material difference in the chemical composition of the two kinds of cacti. In the case of either kind the composition of the plants will vary according to the parts analyzed. The older, somewhat woody stems contain less water than the young, succulent joints. Cattle appear to prefer the more mature joints, and doubtless derive the greater amount of nutriment from these. Spineless cacti will contain 75 to 92 per cent of water (average about 85 per cent), about 0.9 per cent protein, 2.6 per cent fiber, 14.7 per cent nitrogen-free extract, 0.4 per cent fat, and 4.2 per cent ash. As might be expected, the ash content and the nitrogen-free extract are very high, while protein is relatively low; it is, therefore, a starchy feed and has a very wide nutritive ratio.

[24] California Bulletin 132.

The spineless cacti have been considerably exploited in the southwestern States and California during recent years as a feed for farm animals, and extravagant claims are often made as regards the yields obtained and the nutritive value of the plants. The yields have been calculated on the basis of the weight of slabs from a single young plant, or perhaps a small field during a single season, and enormous figures, as high as 1000 tons per acre, have been claimed as a result. As against these figures we have accurate information as to the yields secured at the Arizona station and at Chico, Cal., where the United States Department of Agriculture has conducted experiments with this plant for a number of years past. The results obtained at the latter place show an average annual yield between 20 and 25 tons to the acre. This is with expert cultivation and maintenance of a perfect stand. "The plantation has been carefully cultivated, all weeds have been kept down during the growing season, and a good tilth has been maintained during the summer. Once or twice a year the whole plantation has been gone over, and missing plants replaced."

Cactus is well liked by most farm animals, and is especially adapted for feeding cattle and swine. Instances are on record of dairy cows eating 100 to 150 pounds of cacti a day per head, for months at a time, receiving no dry feed in addition, but on account of the laxative effect of the plant, and on general principles, the better practice is to feed either dry roughage or grain feed, or both, in connection with it, whether the animals fed be fattening steers, milch cows, or swine. According to Griffiths, 6 pounds of green prickly pears, when singed, have a feeding value similar to a pound of dry sorghum hay when fed to dairy cattle.[25] A carload of range steers fed 96 pounds of singed prickly pears and 4.3 pounds of cotton-seed meal per head daily for a period of 104 days gained 1.75 pounds daily per head on this feed; it required, therefore, 55 pounds of pears and 2.5 pounds of cotton-seed meal per pound of gain, at a cost of about 3½ cents per day for feed.

References.—The following Department of Agriculture or experiment station publications have been issued during late years on the subject of prickly pears and spineless cacti: "Singed Cacti as a Forage," Arizona Bulletin 51 (Timely Hints No. 52), May, 1904. "The Prickly Pear and Other Cacti as Feeds for Stock," Griffiths, U. S. Bureau of Plant Industry, Bulletin 74, 1905. "Feeding Prickly Pears to Stock in Texas," Griffiths, U. S. Bureau of Animal Industry, Bulletin 91, 1906. "Prickly Pear and Other Cacti as Food for Stock," Griffiths and Hare, New Mexico station, Bulletin 60, 1906. "The Prickly Pear as a Farm Crop," Griffiths, Bureau of

[25] Bureau Animal Industry, U. S. Department of Agriculture, Bulletin 91.

Plant Industry, Bulletin 124, 1908. "Experiments on the Digestibility of Prickly Pear by Cattle," Hare, U. S. Bureau of Animal Industry, Bulletin 106, 1908. "Spineless Prickly Pears," Griffiths, Bureau of Plant Industry, Bulletin 140, 1909. "Native Cacti as Emergency Forage Plants," Thornber and Vinson, Arizona Bulletin 67, 1911. "The Thornless Prickly Pears," Griffiths, U. S. Farmers' Bulletin 483, 1913. "Behavior under Cultural Conditions of Species of Cacti Known as Opuntia," Griffiths, U. S. Department of Agriculture Bulletin 31, 1913.

QUESTIONS

1. What root crops are commonly used for stock feeding in this country?
2. Give the characteristic points in favor of the six most important root crops.
3. What is the relative value of roots and silage to the stock farmer?
4. Name the farm animals to which potatoes may be fed, and method of feeding these.
5. Describe briefly the value for feeding farm stock the following crops: Cabbage, rape, pumpkins, and sweet potatoes.
6. What is the general value of fruits for feeding farm stock?
7. Name some of the main range and desert plants and discuss briefly their value for stock feeding.

CHAPTER XV

SILOS AND SILAGE

A silo is an air-tight structure used for the preservation of forage crops in a succulent condition (Fig. 27). The green forage placed in the silo undergoes certain changes, through fermentation processes and respiration of the plant cells. The resulting feed is known as silage (formerly ensilage).

While the history of the silo dates back to antiquity, it is only during relatively recent years that special silo structures have been

FIG. 27.—Stave silos. Dimensions, 12 feet in diameter, 36 feet high, capacity 84 tons.

built in this country. The introduction of the silo on American farms may be said to date from the latter part of the eighties. The silo was first introduced into the dairy sections of the eastern and central States, the silage being made from Indian corn and used largely for feeding dairy cows. Gradually, however, the silo has spread to all kinds of stock farms, especially in the corn belt, and it is now a part of the permanent equipment on nearly all such farms where modern methods of management prevail.

Silo Types.—The various steps in the evolution of silo buildings are as follows: First, a pit or trench dug in the ground; second, a square or rectangular, relatively shallow stone or wooden structure;

third, modern round silos. Silos of the first kind are still met with in beet-growing districts, where the wet pulp from the beet-sugar factories is cured or siloed in trenches near the factories, or in shallow silos built up with board walls. Silos of the second type are no more built or used, so far as is known.

The first silo of the third type was built at Wisconsin Experiment Station, in 1891, by the late Professor F. H. King, who strongly urged the building of these silos in preference to other silo types. This original round silo had a diameter of 16 feet and was 27 feet high (capacity, about 90 tons of green corn). Since the construction of this silo the tall, round silo has become well-nigh universal in this country. While the materials used and the dimensions have varied considerably, the principle of construction of practically all silos built since the early part of the century has been that first worked out and described by Professor King.[1] Modern silos are built a great deal taller than was previously the case, the silos built during the last decade or two being 30 to 40 feet high or more, with a diameter varying from 12 to 24 feet, according to the capacity wanted. It is not recommended to build silos of larger diameter than 20 feet, as it is difficult to feed out the silage from such silos rapidly enough to prevent considerable loss through decay of the surface layer, except in cases of very large herds. The following table shows the relation between the size and capacity of different silos of a diameter from 10 to 26 feet and a height of 20 to 40 feet:

Approximate Capacity of Cylindrical Silos for Well-matured Corn Silage, in Tons (King)

Depth of silo, feet	Inside diameter of silo, feet												
	16	12	14	15	16	18	20	21	22	23	24	25	26
20	26	38	51	59	67	85	105	115	127	138	151	163	177
21	28	40	55	63	72	91	112	123	135	148	161	175	189
22	30	43	59	67	77	97	120	132	145	158	172	187	202
23	32	46	62	72	82	103	128	141	154	169	184	199	216
24	34	49	66	76	87	110	135	149	164	179	195	212	229
25	36	52	70	81	90	116	143	158	173	190	206	224	242
26	38	55	74	85	97	123	152	168	184	201	219	237	257
27	40	58	78	90	103	130	160	177	194	212	231	251	271
28	42	61	83	95	108	137	169	186	204	223	243	264	285
29	45	64	88	100	114	144	178	196	215	235	255	278	300
30	47	68	93	105	119	151	187	206	226	247	269	292	315
31	49	70	96	110	125	158	195	215	236	258	282	305	330
32	51	73	101	115	131	166	205	226	248	271	295	320	346
36	64	105	130	139	155	190	235	...	...	...	...	...	...
40	75	121	150	165	180	228	279	...	...	...	...	...	...

[1] Wisconsin Bulletin 28; Report 10, p. 201.

The figures for the capacity of silos given in the table refer to Indian corn cut when nearly mature. Somewhat larger quantities can be put in of immature corn or sorghum, and less of dry corn, alfalfa, grain sorghums, and similar crops that do not pack well. If cut when nearly ripe, the grain sorghums will occupy at least one-third more space than Indian corn cut at the usual time, and the capacity of a silo for these crops would then be decreased in this ratio from the figures given in the table.

Important Points in Building Silos.—The following points should be kept in mind in building silos:

1. *The silo must be air-tight.* The process of silage making is largely a series of fermentation processes. Bacteria pass into the silo with the green fodder and after a short time begin to multiply there, favored by the presence of air and an abundance of feed materials in the fodder, especially soluble carbohydrates. As a result of this action, as well as of the respiration of the plant cells, carbon-dioxide and heat are evolved. The more air at the disposal of the bacteria, the further the fermentations will progress, and the greater will be the losses of feed materials. If a supply of air is admitted to the silo from the outside, the bacteria will have a chance to continue to grow, and more fodder will, therefore, be wasted. If no further supply of air is at hand, except what remains in the air spaces between the siloed fodder, the bacteria will gradually die out, or only such forms will survive as are able to grow in the absence of air. The changes occurring in siloed fodder are also due in part to intramolecular respiration in the plant tissues, which continues until the cells are killed. When there is available oxygen in contact with the plant cells, these will live longer and the loss of plant materials will be greater than when only a smaller supply of air (oxygen) remains in the air spaces in the siloed mass.

2. *The silo must be deep.* Depth in the silo is essential in making silage so as to have the siloed mass under great pressure; this will cause it to pack well and will leave as little air as possible in the interstices between the cut fodder, thus reducing the loss of feed materials to a minimum.

The early silos built in this country or abroad were shallow structures, often not over 12 to 15 feet deep, and were longer than they were deep. Experience showed that it was necessary to weight heavily the fodder placed in these silos in order to avoid a large amount of moldy silage. In modern silos no weighting is necessary, since the material placed in the silo, on account of the great depth, is sufficiently heavy to largely exclude the air in the siloed fodder and thus secure a good quality of silage. In case of deep silos the loss from spoiled silage on the top is smaller in proportion to the amount of silage stored, and a smaller loss occurs while the silage is being fed out. As the silage packs better in a deep silo than in a shallow one, the former kind of silos will hold more silage per cubic foot than the latter (Fig. 28).

Fig. 28.—A good concrete silo costs more than a wooden silo, but will last indefinitely when properly cared for, and needs no attention beyond an application of a coat of pure cement wash every two or three years. (Wisconsin Station.)

3. *The silo must have smooth, perpendicular walls,* which will allow the fodder to settle without forming cavities along the walls. In a deep silo the fodder will settle several feet during the first few days after filling. Any unevenness in the wall will prevent the mass from settling uniformly, and air spaces thus formed will cause the surrounding silage to spoil.

The walls of the silo must be made rigid and very strong, so as not to spring when the siloed mass settles. The lateral (outward) pressure of cut corn when settling at the time of filling is considerable, and increases with the depth of the silage, at the rate of about eleven pounds per square foot for every foot in depth of silage. At a depth of 20 feet there is, therefore, an outward pressure of 220 pounds per square foot; at 30 feet, a pressure of 330 pounds. It is because of this great pressure that it was difficult to make large, rectangular silos deep enough to be economical, since the walls of rectangular silos always spring more or less under the pressure of the silage, and this seldom kept as well in them as it does in those whose walls cannot spring. In the round wooden silos every board acts as a hoop, and, as the wood does not stretch much lengthwise, there is but little danger of spreading of such walls; it is on account of this fact and because of the economy of construction that only round silos are now built.

After the silage has once settled there is no lateral pressure in the silo; cases are on record where a filled silo has burned down to the ground with the silage remaining practically intact as a tall stack.

Silo Structures.—It does not lie within the scope of this book to discuss different methods of silo construction; suffice it to say that there are four or five different kinds of materials now used in the building of silos: Wooden silos (either stave, so-called re-saw, plastered), cement (solid or block), brick, stone, glazed tile, and steel. A satisfactory and more or less permanent silo can be built of any one of these materials, provided due care is taken in the construction. The cost of different kinds of silos will vary greatly

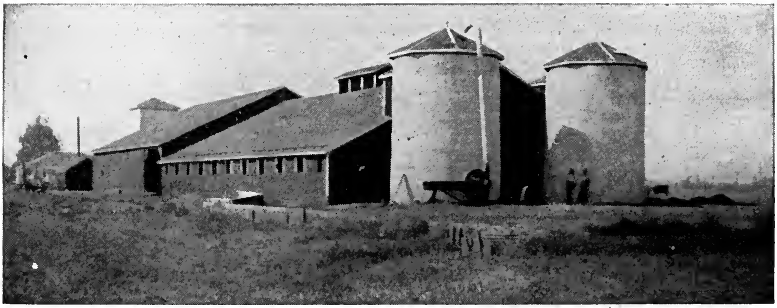

FIG. 29.—A California dairy barn, with concrete silos, accommodating four rows of cows, with a driveway in the middle.

in different sections, according to the relative prices of lumber, cement, brick, etc. A number of different experiment stations have published bulletins on silo construction which describe the silo materials best adapted to the conditions in the respective States, and these may profitably be consulted before a silo is built. Silos built by farmers living in the same localities may also be examined, and advantage thus taken of the experience of others (Fig. 29).

Advantages of Silos.—There are several reasons for the rapid increase of silos on American farms during the past few decades; the most important ones are given below.

1. Generally speaking, the silo enables the farmer to secure the largest possible amounts of feed materials in the corn crop for feeding farm animals in the most convenient and cheapest manner.

2. Corn silage furnishes a uniform succulent feed during the winter and spring, which is greatly relished by all classes of farm

animals and especially adapted for feeding dairy cows and beef cattle.

3. The silo will preserve feeds like corn, sorghum, clover, alfalfa, pea vines, etc., in a succulent condition for feeding any time during the year, and thus furnishes valuable supplementary feeds for late summer and early fall feeding when pastures are likely to be short, as well as for winter feeding when other succulent feed is either scarce or lacking.

4. The silo makes the farmer less dependent on weather conditions than when hay is made, and enables him to get along with smaller barns than otherwise, since less room is required for storing feed in a silo than in the form of hay in a barn.[2]

Fig. 30.—A "re-saw" silo being filled with alfalfa. These silos are well adapted to mild climates, as that of California and the southern States. (*Pacific Rural Press.*)

The value of the silo on American stock farms, and especially to dairy farmers and cattle men, has been fully established during the past few decades by numerous carefully-conducted feeding experiments with different classes of farm animals, as well as by practical feeding experience. The present general distribution of the silo in this country has been the most important factor in the

[2] The advantages of silos are discussed more fully in the author's "Book on Silage" (Chicago, 1900; now out of print) and in "Modern Silage Methods," published by Silver Manufacturing Company, Salem, Ohio, both of which books have been freely used in the preparation of this chapter.

development of our livestock industry that has come since the introduction of modern agricultural machinery (Figs. 30 and 31). The silo is most economical where the number of stock kept is sufficiently large to consume at least 100 tons of silage during the season. The investment in a silo and necessary machinery is relatively high for smaller silos, and the cost of storing and loss of silage through spoiling relatively larger than with large silos. The silo belongs with intensive farming, where the greatest profit results from keeping as large a number of livestock as possible on a given acreage.[3] For small herds of, say, 12 head of cattle or less, the growing of roots where the land is suited to these crops may prove a more economical practice for supplying succulence in the rations fed than making silage.

FIG. 31.—Battery of four cement silos on a California cattle ranch. Dimensions 20 feet in diameter, and 46 feet high, capacity about 350 tons each. (*Pacific Rural Press*)

SILAGE CROPS.—Indian corn is preëminently the great American silage crop and is, in general, better adapted for siloing purposes than any other agricultural crop. The reason for this is easily seen: The thick stems and broad leaves of the corn plant, when cut, pack well in the silo; corn is rich in starch and other non-saccharine carbohydrates, which insures silage of a moderate acidity, and it is relatively low in protein substances, so that the danger of undesirable fermentations in the silo is removed. The acids normally present in corn silage are lactic and acetic. Lactic

[3] Bureau of Statistics, U. S. Department of Agriculture, Bulletin 73, p. 37.

acid is non-volatile and makes up about two-thirds of the acidity of silage made from nearly matured corn, or about 1 per cent on the average, while acetic acid is present in from 0.2 to 0.5 per cent on the average. This and related acids give to well-preserved silage its pleasantly acidulated, aromatic odor, and make corn silage particularly palatable to farm animals.

Corn is planted thicker when grown for silage than for grain (p. 106). The closeness of planting varies in different regions, according to soil and climate. The common practice is to plant the corn in hills, three and a half feet apart both ways, for grain, and in drills, three and a half feet apart, with stalks eight to ten inches apart in the row for silage. This will secure a fair proportion of ears and a maximum yield of dry matter in the crop taken off the land (p. 105). Experiments conducted with regard to the effect of methods of planting corn have shown that the yields obtained are not influenced materially by the distribution of the seed so long as the amount of seed per acre remains the same.[4] The question of planting corn in hills or drills may, therefore, be decided on the score of convenience of cultivating the field and handling the crop.

Corn for the Silo.—Experience and direct trials have proved that it is best to plant a variety of corn for silage that will mature in the locality given, and to grow a maximum amount of dry matter to the acre, which will mean that the yield of perfect ears will be smaller than when grown for grain. As the quality of the silage made from well-matured corn is better than that made from rather immature grain, the best practice is to allow the grain to nearly ripen before it is cut for the silo. This is advantageous also because of the rapid increase in the yield of dry matter per acre during the last stages of the growing period when the kernels begin to harden (p. 55). If the grain is fully matured by the time the silo can be filled, a quantity of water added to the mass in the silo or in the blower as the corn goes into the silo will secure a good quality of silage. Frosted corn can likewise be made into good silage by a liberal application of water in the same way.

The amount of silage that can be obtained from an acre of corn will vary with the fertility of the land, the season, and the care used in growing the crop, from 6 tons or below to over 20 tons in exceptional cases. A 50-bushel crop will yield about 8 to 12 tons of silage per acre, depending upon the amounts of foliage and stalks that accompany the ear. Southern varieties of corn, as a

[4] Illinois Bulletin 31, Connecticut Report, 1890.

rule, carry a larger proportion of the plant in the form of stalks and leaves than do northern-grown varieties.[5]

The general practice adopted by farmers in the corn belt is to silo the corn, "ears and all." The entire crop is run through a cutter and filled into the silo, where it is evenly mixed and tramped down carefully, especially along the walls of the silo. Experiments conducted by the author at the Wisconsin station[6] and by Hills at Vermont station[7] showed conclusively that this method of handling the crop is more economical and convenient than to husk, shell, and grind the corn separately and feed it to dairy cows, with silage made from corn fodder or stover. According to the results obtained in the Vermont trials, one acre of corn silage made from the whole corn plant, including ears, is equal in feeding value to one and one-quarter acres of silage made from corn stover fed with the corresponding amount of ground grain.

The fact that corn silage is relatively low in protein has led to the suggestion that leguminous crops be placed in the silo with the corn. The most successful crops for this purpose are cowpeas or soybeans grown in the corn, both being cut for the silo at the same time. Cowpeas mature at about the same time as corn in the South, and furnish large yields of feed; they make a valuable mixed silage for southern stock farms. Soybeans may be successfully used for the same purpose and can be grown farther north; grown together with Indian corn, they make a good quality of silage that is considerably richer in protein than corn silage alone (p. 340).

Sorghum has been highly recommended as a silage crop by the Kansas and Tennessee experiment stations on account of its being more drought-resistant than Indian corn. It will give heavier yields than this crop in regions where the rainfall is too light or too irregular for growing a good crop of corn. The sorghums are less liable to damage by insects than corn, and remain green far into the fall, so that the work of filling the silo may be carried on long after the corn is ripe and the leaves all dried up. Yields of green sorghum of 20 tons per acre are reported from Kansas, or one-half as much again as a good crop of corn. It is important, in making silage from sorghum, that it be harvested late, when the seed has become hard, as it will make a very acid silage if cut at an earlier stage of growth. Cut at harvest time, it will make a good quality

[5] Farmers' Bulletin 578.
[6] Reports 1891 and 1892.
[7] Report 1892.

of silage, of nearly similar feeding value and palatability to corn silage.

The grain sorghums (Egyptian corn, kafir, milo maize, feterita, etc.) are used for silage to a limited extent in the western States. They make a good silage if cut when the seed is ripe; this is not relished quite as well as corn silage, and is eaten in smaller amounts than this, *e.g.,* by dairy cows 20 to 25 pounds per head daily as a maximum feed. The Kansas station found that kafir silage ranks second to corn silage as a feed for dairy cows, and that it is better than sorghum silage for production of milk.[8]

In dry, hot sections, where the grain sorghums give relatively large yields and where Indian corn cannot be successfully grown, these crops will doubtless assume great importance in the future as silage crops on dairy and other stock farms.

Alfalfa is used only to a limited extent as a silage crop. There is ordinarily no difficulty in making it into good hay in the western States where this crop grows to best advantage and is of the greatest economic importance. It is, however, made into silage by many farmers; if run through a cutter and siloed immediately after mowing, before it has wilted much, and carefully tramped down in the silo, it will make good aromatic silage that is palatable to dairy cows, steers, sheep, and other farm animals after they have become accustomed to it. Like all silage made from legumes, it has sometimes a stronger and less agreeable flavor than corn silage, owing to the butyric acid formed therein, but stock soon learn to like it. It has not been shown, however, that alfalfa silage has a higher feeding value than corn silage, ton for ton, although it is considerably richer in protein and contains somewhat more dry matter per ton than corn silage.

In California and other western States where foxtail is often a serious pest in alfalfa fields during the early part of the season, the first crop is siloed by some farmers, and the foxtail thus rendered harmless; the beards remain soft in the silage and do not cause trouble to farm animals eating it, as is generally the case when this crop is made into hay, especially if cut rather late, after the foxtail heads are nearly ripe. Silage from such weedy alfalfa will be of good quality if put up in accordance with the directions given, and is often better than that from pure alfalfa. The last crop of alfalfa is also frequently siloed in the region mentioned, owing to the rainy weather that is likely to prevail at this time, rendering it difficult to make this crop into hay.

[8] Circular 28.

Clover and other legumes are not often used as silage crops for the reasons stated above, and when so used the silage is generally made under conditions similar to those just given for alfalfa, when they cannot very well be cured into hay. As the legumes have a large proportion of leaves and tender stems, they dry out rapidly and must be run through a cutter and siloed as soon as possible after being mowed. Clover, like alfalfa, is cut for the silo when about one-third of the plants are in full bloom, or before the first single heads are beginning to wilt. According to trials conducted at several experiment stations, the largest yields of dry matter and of all feed components except fiber are obtained from clover when it is cut at this stage (p. 57). If the cutting has been delayed beyond this stage, the safer plan is to add water to the clover as it is elevated into the silo, or to add water in the silo after each load or half-day run.

The losses of feed materials in the siloing process in the case of clover, alfalfa, etc., are but slightly larger than for corn, so far as can be judged from the limited data at hand regarding this point. When put up in the manner stated and well packed in an air-tight silo, the necessary loss of dry matter in clover or alfalfa will not be likely to exceed 10 per cent. This is a much lower loss than that sustained in making hay from alfalfa (and probably from clover and other leafy legumes as well), on account of the unavoidable and often considerable abrasion of leaves and tender parts in the process of haymaking; as previously shown, this has been estimated at 15 to 20 per cent as a minimum, and as high as 60 per cent of the hay crop in extreme cases (p. 59). Aside from the losses sustained through abrasion, rain storms, when these occur, may reduce the value of the hay one-half. The losses from either of these sources are avoided in preserving the crop in the silo, and in their place a small loss of 10 per cent or less will occur under ordinary favorable conditions through the respiration of the plant cells and the fermentations in the silo.

The reason why legumes are not siloed more generally must be sought in the fact that it is more difficult to secure a good quality of silage from these crops than from Indian corn, unless the necessary conditions for success in making legume silage are clearly understood; furthermore, the flavor of the silage is not, as a rule, as agreeable as that of corn silage, and farm animals do not relish it quite so much. When once accustomed to legume silage, however, they do well on it; dairy cows will eat 20 to 25 pounds of clover or alfalfa silage per head daily. On account of the larger amount of protein furnished in this feed than in corn silage, less or cheaper concentrates may be fed in the rations and the cost of production thus decreased.

Cowpeas and soybeans are used as silage crops to some extent in the South, either mixed with Indian corn (Fig. 32), as previously stated, or grown and siloed separately. The Maryland station found cowpea silage of somewhat higher feeding value than corn silage. The cowpeas should be siloed when the peas are well ma-

Fig. 32.—Corn and soybeans grown for silage. When cut and placed in the silo (one ton of soybeans to three tons of corn) this crop makes a very valuable feed for dairy cows. Wisconsin Station.)

tured, since immature vines make an acid, watery silage. Farmers who have had considerable practical experience with this silage are of the opinion that it has no equal as a feed for cows and sheep; it is also a good hog feed, and is considered greatly superior to pea-vine hay for all these animals. In feeding experiments at the Delaware station, six pounds of pea-vine silage fully took the place of one pound of wheat bran, and the product from one acre was found equivalent to two tons of bran.

Soybeans make silage of a fair quality when siloed alone, and can be more easily handled than cowpeas. The larger late varieties yielding heavy crops of forage are to be preferred for the silo.

Corn-soybean silage gave better results with dairy cows than straight soybean silage, in experiments by Professor Humphrey and the author at Wisconsin station.[9]

Pea or corn cannery refuse is often put up in large silage stacks near the factories or in ordinary silos. It makes a valuable feed for fattening cattle, sheep, or dairy cows, and compares favorably with corn silage; by some feeders it is considered superior to this silage, especially for dairy cows. It is also fed to horses, mules, and hogs to a limited extent.[10] Like other kinds of silage, it should be fed with dry hay or cornstalks, and, for best results, with some grain feed, and not as exclusive feed, as is sometimes done.

Green oats and other cereal fodders are occasionally siloed when grown for forage or in case they cannot be used for grain. They are cut when the kernels are past the milky stage and filled into the silo after having been run through a cutter. If the grain has become nearly ripe, it is necessary to add considerable water to the green fodder as it goes into the silo, either through the blower or in the silo after each load, and the cut mass must be carefully distributed in the silo and tramped down along the wall of the silo. Oat silage made in this manner is of excellent quality and furnishes a very palatable, nutritious feed for cattle and sheep.

Beet tops and leaves are generally siloed in European beet-growing countries by being placed in large trenches in the field and covering these with boards or straw and a layer of dirt. Preserved in this way, they make a slimy, strong-smelling silage, which is, however, greatly relished by milch cows and fed heavily on the dairy farms on the Continent. Because of the shallowness of the pits, large losses of feed materials are sustained by this method of siloing, viz., 25 to 33 per cent or more of the dry matter in the leaves and tops.

Beet pulp is preserved in similar trenches or shallow pits in the western States where the manufacture of beet sugar is an important industry. The siloed ("cured") beet pulp is an excellent feed for fattening steers, sheep, or dairy cows; as it is made mostly in regions where alfalfa is the main hay crop, it is generally fed with alfalfa hay, which it supplements nicely, being high in insoluble carbohydrates (2.8 per cent) and relatively low in protein (1.0 per cent crude protein and 0.3 per cent digestible crude protein). Its feeding value may be considered equal to about one-half that of corn silage. Of other materials made into silage may be mentioned:

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[9] Report 21, p. 67; Cornell Bulletin 310.

[10] Bureau of Plant Industry, U. S. Department of Agriculture, Circular 45.

Apple pomace,[11] wet brewers' grains, sorghum bagasse, cane tops,[12] potato tops, hop vines, sugar-beet tops and shocked corn,[13] prickly pears,[14] thistles, and other weeds.[15]

None of these materials are, however, of sufficient importance to call for more than a mere mention.

Publications by Experiment Stations on Silos and Silage Crops. (r., report; b., bulletin; c., circular.)—Ark., r. ii, 1889, pp. 68–77; Col., b. 30, 1895, pp. 21–23; b. 200, Aug., 1914; Conn. (Storrs), b. 70, Jan., 1912; Del., r. 1902, p. 30; Fla., b. 78, Mar., 1905; 92, Mar., 1908; 16, Jan., 1892; Ill., b. 43, 101; Ind., b. 40, June, 1892, b. 163; Iowa, b. 100, July, 1908; 107, June, 1910; 141, July, 1913; c. 6, Jan., 1913; Kan., b. 6, June, 1889, pp. 61–74; c. 28, b. 48; La., b. 143, Mar., 1914; Md., r. 1889–91; b. 129, July, 1908; Mich., b. 47, April, 1889; spec. b. 6, Dec., 1896; b. 255, May, 1909; Minn., b. 40; Miss., b. 8, Aug., 1889; Mo., c. 48, 67; Mont., b. 94, July, 1913; Neb., b. 17, 1891; b. 138, May, 1913; N. H., b. 14, May, 1891; c. 16, June, 1914; N. J., b. 161; N. Y. (Geneva), b. 102, N. S.; N. Y. (Cornell), b. 167, March, 1899; N. C., b. 80, Oct., 1891; N. D., b. 98, July, 1912; Ohio, b. 5, vol. ii, No. 3, S. S., June, 1889; Okla., c. 33, 34, and 36, June–Aug., 1914; Ore., b. 9, Feb., 1891; b. 85; Pa. (Bd. of Agr.), r. 1894, pp. 232–237; b. 118, Oct., 1912; S. D., b. 51, Feb., 1897; Tenn., b. 105, April, 1914, vol. 17, No. 1, Jan., 1904; Va., b. 53, pp. 53–80; 70, pp. 115–119; 182, June, 1909; Wash., b. 14, Nov., 1894; pop. b. 10, Sept., 1908; W. Va., b. 129; Wis., b. 19, April, 1889; 28, July, 1891; 59, May, 1897; 83, April, 1900; Farmers' B. 32, Nov., 1895; 292, Dec., 1907; 353, April, 1909; 556, Oct., 1913; 578, May, 1914; Bur. Animal Industry, r. 23, 1906; c. 136, Jan., 1909; Ontario (Canada), b. 32, Aug., 1888; 42, May, 1889; r. 1905, p. 101; (Bur. of Ind.) b. 39, April, 1892; Ottawa (Canada), b. 65.

QUESTIONS

1. What is a silo, and of what materials are silos built?
2. What is the capacity of a round silo 16 feet in diameter and 36 feet high? Of one 14 feet in diameter and 32 feet high?
3. Of what dimensions would you build a silo of a capacity of (*a*) 50 tons, (*b*) 100 tons?
4. What capacity and dimension of silo would you need for a herd of 25 dairy cows, feeding these on the average (*a*) 30 pounds per head daily for a period of 120 days, (*b*) 25 pounds daily for a period of 200 days?
5. Give three important points in building silos.
6. State the main advantages of the silo on American dairy and stock farms.
7. Mention the six main silage crops and their characteristics for feeding different classes of farm animals.

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[11] Vermont Report 1903.

[12] Louisiana Bulletin 143, p. 12.

[13] Wisconsin Bulletin 228, p. 42.

[14] *New South Wales Gazette*, 8, p. 505.

[15] *Ibid.*, 9, p. 71. See also "A Book on Silage," by the author, Rev. ed., pp. 34 and 35.

CHAPTER XVI

THE CONCENTRATES

Concentrates[1] are feeding stuffs containing a large amount of nutrients in small bulk, such as grains, mill feeds, and oil meals. Another general name for these feeding stuffs is concentrated feeds or "grain feeds." They are, in general, characterized by relatively high amounts of valuable feed components and a high digestibility, and by relatively low amounts of water and fiber. There are probably several hundred feeds of this kind used for the nutrition of farm animals in this country, but only the more important kinds will be considered in this book. They may conveniently be discussed under the following heads:

1. Cereal grains and other seeds.
2. Flour-mill and cereal feeds.
3. Brewery and distillery feeds.
4. Starch- and glucose-factory feeds.
5. Sugar-factory feeds.
6. Oil-mill feeds.
7. Packing-house feeds.
8. Dairy products.
9. Proprietary feeds.
10. Miscellaneous feeds.

I. CEREAL GRAINS

The cereal grains are standard feeds, more or less familiar to all farmers, and until recently the main reliance of feeders for concentrates. When market prices are not prohibitive, no better or more highly nutritious feeds can be obtained for feeding farm animals. The cereals contain a medium percentage of protein (8 to 12 per cent, nearly all true protein), a high percentage of carbohydrates (about 70 per cent, largely starch), and a medium fat content (2 to 8 per cent). The percentage of ash is rather low, on account of relatively large amounts of carbohydrates and other organic components, but it is high in potash and phosphoric acid, and low in lime. The starch in the grains is formed during the last part of the growing period; hence, if this is checked by drought or lodging of the crops, the grains will be lower in carbohydrates and relatively higher in protein than normally ripened grain. Damaged, shrunken grains, No. 3, No. 4, or rejected grains are, therefore, as a general rule, of a higher feeding value than grain that is graded high and commands the highest prices on the market. The leading cereals, so far as stock feeding goes, will now be con-

[1] This term was originally introduced by Professor W. A. Henry, of Wisconsin, in the nineties, and has now come into general use.

sidered in the order of their importance for this purpose, followed by the minor grains, leguminous seeds, and oil-bearing seeds.

Indian corn (maize, *Zea mays*) is the most important cereal crop in our country. In 1909 the area in corn made up more than one-half of the entire acreage devoted to grain raising; wheat coming second, with 28 per cent of the total acreage, and oats third (20 per cent of the total acreage). Corn was grown on 82 out of every 100 American farms, according to the United States census of that year. While Indian corn may be grown successfully in every State in the Union, it thrives best and reaches its greatest importance as a cereal and a forage plant in the vast interior of our continent, lying between the large eastern and western mountain ranges, especially in the prairie States in or near the Mississippi valley. The latter are generally spoken of as the "Corn belt." The most important corn-producing States, according to the census of 1909, were:

Illinois (with a production of 390,000,000 bushels), Iowa (342,000,000), Indiana (195,000,000), Missouri (191,000,000), Nebraska, Ohio, and Kansas following in the order given, each with yields of over 150,000,000 bushels of corn. The entire corn crop for the whole United States for the year given aggregated nearly a billion and a half dollars in value.

Corn is the most variable of all cereals, both as regards the size to which it grows and the form of the kernel of the different varieties. "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." (Henry.)

There are six different races of Indian corn, but only three of these are of importance for feeding farm animals, viz., dent, flint, and sweet corn. The average composition of these races is as follows:

Average Chemical Composition of Indian Corn, in Per Cent

	Ash	Crude protein	Fiber	Nitrogen-free extract	Fat
Dent corn	1.5	10.3	2.2	70.4	5.0
Flint corn	1.4	10.5	1.7	70.1	5.0
Sweet corn	1.9	11.6	2.8	66.8	8.1

The main difference in the composition of these three races lies in the higher fat, protein, ash, and fiber contents of sweet corn, and its lower nitrogen-free extract, than that of the other races. Of the differences given those in the protein, fat, and carbohydrate contents are the most important; the high percentages of fat and sugar in sweet corn are probably responsible for the fondness of stock for this corn.

Characteristics of Corn.—Although fairly rich in protein, corn is especially a carbohydrate grain, containing nearly 70 per cent of pure starch. Its high fat content (about 5 to 8 per cent) increases its value as a fattening and heat-producing feed and adds to its palatability to farm animals. Corn is low in ash (less than 2 per cent), and this contains only a small proportion of lime and phosphorus; hence corn is less valuable than other cereals for feeding young stock and for milk-producing animals and poultry, all of which require considerable mineral matter for building up their bone structure, or for ash in milk or egg-shells. By feeding corn as a sole feed to pigs, farmers in the corn belt and elsewhere have sustained large losses through overfattened, weakly swine, with poor bone, that fall an easy prey to disease (p. 301).

As shown elsewhere, corn can be supplemented for best results with feeds rich in protein and mineral substances in feeding the classes of live stock mentioned. Corn is fed either whole as ear corn, or shelled or ground. The best method of feeding varies according to the kind and age of the animal, and will be considered under the respective classes of live stock, along with the adaptability and general value of corn in each case. Instead of grinding the shelled corn, the ear corn is sometimes ground "cob and all." This feed, known as corn and cob meal, has been found to be of value in making a lighter feed than corn meal, and makes a good feed for horses, steers, and milch cows. Experiments have shown that it has a similar value to corn meal, pound for pound, for these animals.

Ear corn contains varying proportions of cob, according to the race, variety, and maturity of the corn, an average ratio for dent corn being 14 pounds of cob to 56 pounds of shelled corn. The cob is very low in valuable feed materials and contains about 30 per cent fiber; the carbohydrates are composed largely of pentosans (31 per cent) and substances of lower feeding value than starch. The cob therefore adds but little to the value of the ground corn in itself, but the benefit from grinding the corn and cob together comes from the mechanical effect, rendering the ground meal lighter and insuring a more complete action of the digestive juices on the same.

Corn Proteins.—The proteins of corn, according to Osborne, are composed of about 40 per cent zein (a characteristic alcohol-soluble protein), 30 per cent glutelin, 22 per cent albumen, globulin and proteose, and 6 per cent protein insoluble in alkali.[2] While little is known so far regarding the specific nutritive properties of the different protein substances, it seems evident that the special corn proteins possess important advantages over those of the wheat or the oat plant. Investigations conducted during a series of years at the Wisconsin station have shown that corn is the only one of the three cereals which can properly nourish dairy cows for long periods and keep them in a strong, healthy condition so that they will give birth to normally-developed, vigorous calves.[3] It has not been established that this difference in the nutritive effects of the three plants fed by themselves is due to differences in the composition of the protein compounds, but, with our present incomplete knowledge of this subject, it seems most likely that the phenomena brought to light in the important investigations referred to must be explained by differences in the inner constitution of the proteins in these crops.

Oats are a highly-prized feed for farm animals, especially horses, cows, sheep, and young stock. Next to corn, they are the most important cereal for feeding livestock in the United States. Their cost frequently makes them rather expensive for feeding other stock than horses, but, when not too costly, there is no better concentrated feed for the animals mentioned. Oats vary greatly in their percentage of hulls; a good quality of oats contains, on the average, about 30 per cent hulls, while light oats may contain considerably over 40 per cent hulls (or 16 per cent fiber). Oats contain more fiber and protein and nearly as much fat as corn, as will be seen from the analyses given below:

Composition of Oats and Oat Hulls, in Per Cent

	Protein	Fat	Fiber	Ash	Digestible	
					Protein	Carbohydrates and fat
Oats..........	11.4	4.8	10.8	3.2	8.8	58.9
Oat hulls......	3.4	1.3	30.7	6.7	1.3	39.9

[2] *Science*, 1913, p. 185; *Journal Biological Chemistry*, 1913, xxxi, No. 2.
[3] Wisconsin Research Bulletin 17.

The hulls serve a similar purpose as corn cobs in grinding the grain, making the meal lighter and more easily digested. Oats are generally fed whole, however, except in the case of old or very young animals that cannot masticate their feed thoroughly. Ground or rolled oats are to be preferred for feeding such animals. The favorable effect of oats on horses has long been known, and it has been held that no other grain or feed is equal to oats for them. It has been stated by various scientists that oats contain a special stimulating principle not found in other grains, but the matter has not yet been fully settled. In 1883 Sanson, a French chemist, claimed to have discovered a characteristic nitrogenous alkaloid in oats called "avenin," having a stimulating effect on the motor nerves of the horse, but subsequent investigators have been unable to verify the presence of such a compound. The careful and exhaustive studies by Osborne have shown that the proteins of the oat kernels are made up of glutenin (about 11 per cent) and a small amount of a globulin called avenalin (1.5 per cent). It is very likely that the digestive ferments found in oats are of importance in the digestion of this grain. The mechanical effect of oats in inciting a free flow of digestive juices may also be a factor in bringing about the favorable results which oats doubtless produce in the feeding of horses.

New oats must be fed with care to horses, as they have a decided loosening effect on the bowels. The change in this respect that takes place in oats in storage also, in all probability, comes as a result of the action of the oat enzymes on some of the constituents of the oats.[4]

Digestibility of Oats.—The following summary of digestion coefficients shows the extent to which the different classes of farm animals can digest oats:

Average Digestion Coefficients for Oats, in Per Cent

Animals used	Number of trials	Dry matter	Protein	Fiber	Nitrogen-free extract	Fat
Ruminants	6	70	77	31	77	89
Horses	4	74	84	22	82	81
Poultry	13	63*	71	..	90	88

* Organic matter.

Horses are evidently able to digest the dry matter of oats, as well as the protein and nitrogen-free extract, better than do rumi-

[4] Farmers' Bulletin 420.

nants, while these animals digest the fiber and fat better than do horses.

Oats do not have quite as high digestibility as Indian corn, so far as fiber and nitrogen-free extract are concerned, due to the higher percentage and the more woody character of the fiber in oats than in corn. The coefficients for protein and fat in the two grains, on the other hand, are about similar. The high fat contents of these two grains are doubtless important factors in making them palatable stock feeds. Oats, as a rule, have a somewhat lower feeding value than corn, although this depends largely on the combination in which they are fed. In general, a mixture of the two grains gives better results than either fed alone. This rule does not hold good, however, in the case of oats for horses (p. 287).

Corn and Oats ("Ground feed").—Mixtures of corn and oats are ground together and sold in immense quantities in eastern and central States as "ground feed" or "ground corn and oats." This is used for feeding horses and dairy cows, especially the former, for which purpose it is well adapted. A good grade of corn and oats makes a valuable horse feed, but low-grade materials, like oat hulls, refuse from oatmeal factories, ground corn cobs, etc., are often added in making the feed, and its purchase cannot be recommended outside of States which have feed inspection laws on their statute-books, where the feed may be bought on definite guarantees of protein, fat, and maximum fiber contents. The wholesome effect of feed inspection laws has been strikingly illustrated in the quality of the ground feed sold in a State before and after the passage of such protective laws.[5]

Ground oats and corn are generally sold on a guarantee of 9 to 10 per cent protein, 3 to 4 per cent fat, and 7 to 9 per cent maximum fiber, according to the proportions of the two grains entering into the feed. These may vary from one of corn to three of oats by weight to three of corn and one of oats. The market prices of the two grains determine largely the proportions used of each, more corn being used when this grain is the cheaper, and *vice versa.* Since corn contains only about 2 per cent fiber, and oats, on the average, about 10 per cent, mixtures of the two grains will not be likely to contain over 7 per cent fiber. A fiber content of over 9 per cent is conclusive evidence that the ground feed is either adulterated, or that a very poor grade of light oats was used in its manufacture.

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[5] Wisconsin Circular 30, p. 83, January, 1912.

Barley is mainly used for stock feeding on the Pacific coast in this country, but in middle and northern Europe it is one of the common grain feeds for farm animals. It makes an excellent feed for horses and dairy cows, and, fed with dairy by-products, produces a fine quality of pork. It is generally fed ground, cracked, or rolled. The last method of preparation is considered preferable, because fine-ground barley forms a pasty mass in the mouth of animals and is more likely to give rise to digestive troubles than when rolled, as is the case with fine-ground corn or corn and oats for horses. There is a prejudice among some farmers against feeding barley to milch cows, but this is doubtless unfounded, for its value for milk production has been fully established. In an experiment at the California University Farm[6] a cow that received green alfalfa or alfalfa hay and only rolled barley in addition, 10 pounds daily as a maximum feed, produced an average of 60 pounds of milk for a period of over three months, and not only did better on this feed, but kept up better in her milk flow than during any previous lactation period.

Barley is higher in protein and carbohydrates than oats, and lower in fat, containing, on the average, 12.0 per cent protein, 1.8 per cent fat, 4.2 per cent fiber, 68.7 per cent nitrogen-free extract, and 2.5 per cent ash. It has a high digestibility, viz., on the average:

For ruminants, protein 73 per cent, fat 79 per cent, and nitrogen-free extract 92 per cent.

For horses, protein 80 per cent, fat 42 per cent, and nitrogen-free extract 87 per cent.

For swine, protein 76 per cent, fat 65 per cent, and nitrogen-free extract 90 per cent.

While it is considered that rain or foggy weather during ripening injures the quality of barley for brewing, this does not affect its feeding value in any way, and barley unfit for brewing can often be obtained for feeding purposes at a low figure.

Rye is less used for stock feeding in America than the three cereal grains considered in the preceding. Its value for this purpose is, however, well established. It is the common bread grain in northern Europe, and is also fed to stock when its price is not too high. Rye does not differ greatly from barley in the composition or feeding value. Its average composition is: 11.3 per cent protein, 1.9 per cent fat, 1.5 per cent fiber, 74.5 per cent nitrogen-free extract, and 2.1 per cent ash. Its average digestion coefficients, as determined with cows, are: Protein, 80 per cent; fat, 86 per cent, and nitrogen-free extract, 80 per cent.

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[6] **Unpublished results**

Rye makes a valuable feed for horses and fattening swine; it is often fed soaked to the latter farm animals, and is preferably fed ground and mixed with other concentrates to other classes of livestock. Rye was found to have about the same feeding value as barley in extensive Danish swine-feeding experiments, and the quality of the pork produced was satisfactory. The best results were, however, obtained with mixtures of the two cereals.

Wheat is too high-priced, as a general rule, to be used for feeding farm animals. In exceptional cases it may be advisable to use it for this purpose, however, and it is well, therefore, to understand its nutritive value and main characteristics, especially since the lower grades of wheat can generally be used for stock feeding to advantage, even at present-day market prices for grains.

Wheat stands close to barley in composition and feeding value. It is of slightly lower value as a feed for fattening animals, but is superior to this cereal in nutritive effect for young and growing animals and for dairy cows. It is lower in fat but somewhat higher in protein and carbohydrates than corn; its digestibility is as high as that of the other cereals except oats, which, as stated, have a somewhat lower digestibility than these on account of their relatively high fiber content.

Wheat is generally ground before feeding. On account of its large content of gliadin and glutenin, it forms a sticky paste when chewed, and for this reason is preferably fed in mixtures with more bulky concentrates, like oats or wheat bran.

Damaged wheat (salvage wheat from elevator fires, etc.) is at times obtainable at a low cost; the better grades make a valuable feed, only slightly inferior to an average grade of wheat.

Grain screenings are mixtures of broken or shrunken grain, weed seeds, chaff, pieces of straw, dirt, etc., which are obtained in the cleaning of grain in elevators. They vary considerably in their chemical composition and feeding value, according to their origin and the character of the impurities contained in the grain. On account of the large proportion of different weed seeds in screenings, they are expensive feeds at any price to farmers who wish to keep their land as free as possible from noxious weeds. Many of the weed seeds in screenings will pass through the animals uninjured and will germinate when the manure is put on the land,[7] thus rendering cultivation more expensive and reducing the yield of cultivated crops through the growth of weeds. Many farmers do not, therefore, wish to buy screenings under any condition, and this

[7] Vermont Bulletins 131 and 138.

is the only safe position to take towards whole screenings. Finely-ground screenings often make satisfactory and cheap feeds, and, if carefully ground, are not, as a rule, objectionable. Poisonous weed seeds, like corn cockle, are found in most screenings, but they are not ordinarily present in sufficient quantities to give rise to any

FIG. 33.—Weeds growing from seed found in a mixed "dairy feed." This contained 100,000,000 weed seeds to the ton. The soil was sterilized, so that it is certain that every plant grew from a weed seed in the feed. Most samples of whole screenings contain still larger numbers of weed seeds. (Vermont Station.)

trouble in stock feeding. Sheep and poultry appear to be able to destroy weed seeds of screenings more thoroughly than other farm animals, and do well on them (Fig. 33).

Screenings are often used in the manufacture of mixed feeds and molasses feeds, in the latter case serving as absorbent for the molasses. Both screenings and molasses feeds manufactured from them may be considered worth somewhat less than wheat bran, ton for ton.

Emmer (often incorrectly called *speltz*) is a drought-resistant cereal crop, especially valuable in the semi-arid western United States, where it is extensively grown and fed to stock. Experiment stations in that region have experimented extensively with emmer for a number of years, and have shown that it is well worthy of a trial by farmers in those States, along with oats or where oats cannot be grown. Emmer yields good crops of grain (20 to 40 bushels per acre), and compares favorably in feeding value with oats and barley. For best results, mixtures of oats or other grains and emmer are ground and fed, instead of clear emmer, which is rather fibrous and bulky. The hulls of emmer make up about 20 per cent of the grain. It resembles oats more than any other grain crop, and is largely used for feeding farm animals as a substitute for oats. The following compilation of digestion coefficients of these two grain crops and of barley shows that emmer stands between these in digestible components, and that it stands nearer oats than barley: [8]

Digestible Components in Oats, Emmer, and Barley, in Per Cent

	Protein	Fat	Fiber	Nitrogen-free extract	Nutritive ratio
Oats	10.73	3.59	3.17	51.04	1:5.8
Emmer	9.96	1.36	4.98	52.06	1:6.0
Barley	9.37	1.66	1.86	69.96	1:9.0

Buckwheat is rarely used for feeding farm animals, either whole or ground, since it is too valuable as a raw material for the manufacture of buckwheat flour. The by-products obtained in the manufacture of this flour will be considered under "Flour and Cereal Mill Feeds" (p. 183).

Sweet and non-saccharine sorghums are important bread crops for the peoples of Asia and Africa. "In India alone over 33,000,000 acres of land are annually devoted to growing the millets, including the sorghums, kafir, milos, etc., a greater area than is devoted to wheat raising, rice, and Indian corn combined.[9]

[8] Bureau of Chemistry, U. S. Department of Agriculture, Bulletin 120; Farmers' Bulletin 466.

[9] Church, "Food Grains in India," 1901; cited in Henry, "Feeds and Feeding," p. 147.

The sorghums may be divided into two classes: (1) The sweet or saccharine varieties, of which amber or orange cane is mostly grown, and (2) the non-saccharine or grain sorghums, which are smaller and have pithy stems, with but little sweet juice (Fig. 34). Sweet sorghum is grown primarily for forage and, to a limited extent at the present day, for the production of syrup. The non-saccharine sorghums are grown both for grain and for forage. The grain sorghums are represented in this country by kafir corn, durra, and milo maize, and a few other varieties of minor importance. Different strains of each of these are grown and possess different characteris-

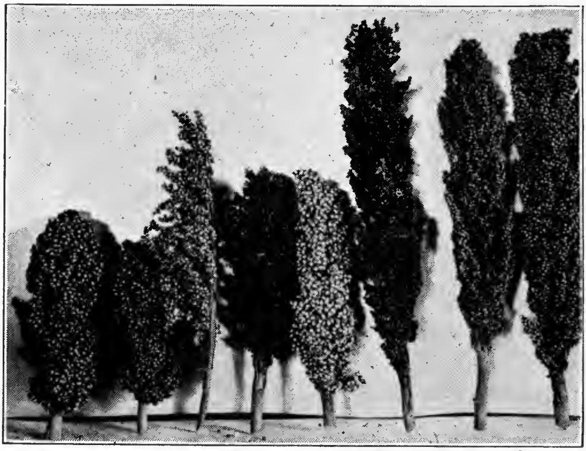

FIG. 34.—Types of grain sorghums; these crops are of increasing importance for grain and forage to farmers in the western United States. From left to right: 1 and 2, yellow Milo; 3 and 4, white and brown Kaoliang; 5, Feterita (Sudan Durra); 6 to 8, red, pink, and black-hulled Kafir corn. (*Breeders' Gazette.*)

tics that make them of special value under varying conditions. The main cultivated strains are: White and black kafir, white, brown, and Sudan durra, and yellow milo. The kafirs and milo occur in standard and dwarf varieties. White durra is also called Jerusalem corn; brown durra, Egyptian corn,[10] and Sudan durra, feterita. The grain sorghums are valuable forage and grain plants, especially suited to a dry and hot climate. The most striking characteristic of the grain sorghums is their ability to withstand drought, and to make a good growth with but little or no rainfall. After periods of protracted drought, they will resume growth as soon as water

[10] Both white and brown durras are often incorrectly called Egyptian corn.

becomes available. In this respect they differ greatly from Indian corn, which will not yield satisfactorily when once checked in its growth. This quality makes the grain sorghums especially valuable under the conditions in the semi-arid western and southwestern States. They bid fair to become of great agricultural importance in these sections of the country. The areas sown to grain sorghums in Kansas (Fig. 35), Oklahoma, and Texas have increased in a marked manner during the last ten years, and they are apparently replacing Indian corn to some extent in these States.[11]

The grain of the non-saccharine sorghums resembles corn in chemical composition; it contains a higher percentage of starch than corn, but less protein and fat, and may be considered not quite equal to corn in feeding value or palatability. The grain should be

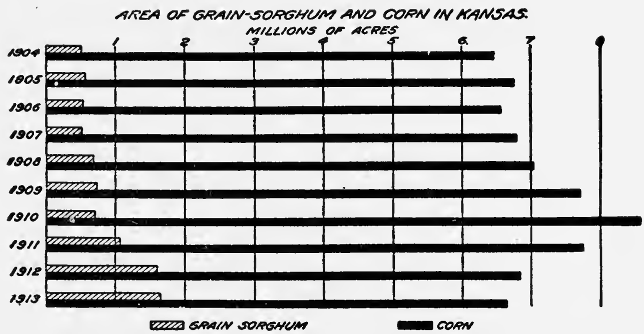

FIG. 35.—Diagram showing increase in area sown to grain sorghums in Kansas during the decade 1904–13. (Ball.)

threshed and ground for feeding to fattening cattle, while it may be fed threshed or in the head to working horses and sheep, and preferably "heads and all" to idle horses, colts, dairy cattle, and young stock. Ground grain is fed with skim milk to calves, and moistened with water or skim milk to hogs. As it is quite carbonaceous (N.R., milo 1:9.7, Egyptian corn 1:8.9), it makes a good supplemental feed for hogs fed skim milk or alfalfa, either hay or pasture.

Rice.—As in the case of many other seeds, rice is too valuable as a human food to allow of its use for feeding farm stock, and it is only used for this purpose to a limited extent in rice-growing sections. The hull or husk of the rice kernel is rough and brittle, and

[11] U. S. Department of Agriculture Yearbook, 1913, p. 221.

is usually removed before the grain is sold. The hull is not, as we shall see, suited for feeding livestock, on account of its sharp barbs and high content of ash (silica, see p. 186), but it is sometimes ground with rice for feeding purposes. The hulled rice is a very valuable fattening feed. It contains considerably more nitrogen-free extract than any other available feeding stuff, viz., nearly 80 per cent, while its protein content is low (on the average, 7.4 per cent). Owing to the high starch content and the minute amount of fiber in the hulled rice, it has the highest percentage digestibility of any vegetable feed known, its digestion coefficients being as follows, according to the German digestion trials:

Dry matter, 98 per cent; protein, 86 per cent; nitrogen-free extract, 100 per cent, and fat, 90 per cent.

According to the Louisiana station, the ground, rough rice is worth 7 per cent more than corn as a feed for farm stock, and hulled rice is worth 16 per cent more. Supplemented with cottonseed meal and other high-protein feeds, ground rice furnishes southern farmers a highly nutritious ration for cattle, sheep, or horses. The only thing that stands in the way of its general use for feeding is its cost.

II. LEGUMINOUS AND OIL-BEARING SEEDS

The leguminous seeds, like peas and beans, soybeans and cowpeas, are valuable concentrated feeds, and their use for feeding farm animals is increasing every year, as farmers come to realize their value and appreciate that they can greatly reduce their feed bills by growing high-protein forage and grain crops on their farms. At the same time the fertilizer bills may be reduced, since these crops render available for plant use the free nitrogen of the air through symbiosis with certain soil bacteria, and leave the soil richer in this expensive fertilizer element than it was before the crop was grown thereon (p. 113). These grains have a high digestibility and contain two or three times as much digestible protein as the cereal grains. With the exception of soybeans, which contain nearly 15 per cent digestible fat, the leguminous seeds are all very low in this component, containing only about 1 per cent thereof. Further information as to the character of the seeds given will be found under the discussion of the respective crops as forage plants. The chemical composition of these seeds will be seen from the following:

Chemical Composition of Leguminous Seeds, in Per Cent

	Protein	Fat	Ash	Digestible		
				Protein	Carbo-hydrates and fat	N. R.
Canada field pea	23.7	.8	2.4	19.7	50.2	1:2.5
Horse bean	26.6	1.0	3.8	23.1	51.6	1:2.2
Soybean	33.5	17.2	4.8	29.1	56.2	1:1.9
Cowpea	20.5	1.5	3.2	16.8	57.4	1:3.4

Flaxseed is used only to a limited extent for feeding purposes, viz., mostly as a calf feed, its high price being rather prohibitive for feeding to other farm animals. It is always ground for calf feeding and mixed with boiling hot water in the proportion of a pound of meal to a gallon of water. The jelly-like liquid thus formed has a laxative effect and forms a highly-prized component of calf rations. It is generally fed mixed with standard, easily-digested concentrates, as wheat middlings, ground oats, barley, etc. (p. 221). Flaxseed contains about 22 per cent protein, 33 per cent fat (oil), and 7 per cent fiber; it has a high digestibility, containing over 20 per cent digestible protein, 17 per cent nitrogen-free extract, and 29 per cent fat; owing to the large content of digestible fat, its nutritive ratio is considerably wider than linseed meal, viz., 1:4.0 (p. 363).

Cotton Seed.—Only relatively small amounts of cotton seed are now fed to stock on account of the value of the seed for the manufacture of cotton-seed oil. Formerly the seed was used quite generally throughout the South as a feed for farm animals. It is fed either raw, roasted, steamed, or boiled. The composition of the cotton seed is, on the average, as follows:

Water	9.9 per cent
Protein	19.4 per cent
Fat	19.5 per cent
Fiber	22.6 per cent
Nitrogen-free extract	23.9 per cent
Ash	4.7 per cent

It contains about 11 per cent of digestible protein, 33 per cent digestible carbohydrates, and 18 per cent digestible fat. Cotton seed possesses a high feeding value, especially as a cattle feed, but has sometimes proved injurious to stock on account of the lint and the dust that it collects. The main reason for its present limited use as a stock feed is, however, that the seed can generally be sold for a good price at the oil mills, or exchanged for cotton-seed meal at the rate of 800 pounds per ton of seed. It has, therefore, now been largely replaced by cotton-seed meal in the feeding of farm animals.[12]

Literature on Forage and Grain Crops.—Hunt, "The Forage and Fiber Crops," New York, 1907. Hunt, "The Cereals in America," New York, 1904. Voorhees, "Forage Crops," New York, 1907. Shaw, "Grasses and How to Grow Them," New York, 1908. Shaw, "Forage Crops," New York, 1907. Shaw, "Soiling Crops and the Silo," New York, 1902. Shaw, "Clovers and How to Grow Them," 1906; Wallace, "Clover Farm," 1898. Spillman, "Farm Grasses of the United States," New York, 1907. Wing, "Meadows and Pastures," Chicago. Wing, "Alfalfa Farming in America," Chicago, 1909. Coburn, "The Book of Alfalfa," New York, 1908. Myrick, "The Book of Corn," New York, 1903. Shoesmith, "The Study of Corn," New York, 1910. Montgomery, "The Corn Crops," New York. Holden, "A, B, C of Corn Culture," 1906. Bowman and Crosley, "Corn," Ames, Iowa, 1908.

Farmers' Bulletins 11, "The Rape Plant," 1893. 164, "Rape as a Forage Crop," 1903. 16, "Leguminous Plants for Green Manuring and Feeding," 1894. 18, "Forage Plants for the South," 1894. 102, "Southern Forage Plants," 1899. 300, "Some Important Grasses and Forage Plants for the Gulf Coast Region," 1907. 147, "Winter Forage Crops for the South," 1902. 436, "Winter Oats for the South," 1911. 25, "Peanuts, Culture and Uses," 1895. 26, "Sweet Potatoes, Culture and Uses," 1895. 129, "Sweet Potatoes, Culture and Uses," 1901. 31, "Alfalfa or Lucern," 1895. 215, "Alfalfa Growing," 1905. 276, "Alfalfa Culture in Eastern United States," 1907. 339, "Alfalfa," 1908. 199, "Corn Growing," 1904. 36, "Cotton Seed and its Products," 1896. 37, "Kafir Corn," 1896 (see also Bulletin 73). 552, "Kafir as a Grain Crop," 1913. 50, "Sorghum as a Forage Crop," 1897. 58, "The Soybean as a Forage Crop," 1897. 372, "Soybeans," 1909. 66, "Meadows and Pastures," 1897. 86, "Thirty Poisonous Plants," 1898. 89, "Cowpeas," 1899. 318, "Cowpeas," 1908. 101, "Millets," 1899. 168, "Pearl Millet," 1903. 108, "Salt Bushes," 1900. 110, "Rice Culture in the United States," 1900. 139, "Emmer: A Grain for the Semi-arid Regions," 1901. 466, "Winter Emmer," 1911. 167, "Cassava," 1903. 224, "Canadian Field Peas," 1905. 246, "Saccharine, Sorghums for Forage," 1906. 458, "The Two Best Sweet Sorghums for Forage," 1911. 288, "The Non-saccharine Sorghums," 1907. 322, "Milo as a Dry Land Grain Crop," 1908. 448, "Better Grain for Sorghum Crops," 1911. 356, "Peanuts," 1908. 431, "The Peanut," 1911. 361, "Meadow Fescue, its Culture and Uses," 1909. 362, "Conditions Affecting the Market Value of Hay," 1909. 508, "Market Hay," 1912. 402, "Canada Blue Grass, its Uses and Culture," 1910. 420, "Oats, Distribution and Uses," 1910. 427, "Barley Culture in the Southern States," 1910. 518, "Winter Barley," 1912. 441, "Lespedeza or Japan Clover," 1911. 455, "Red Clover," 1911. 485, "Sweet Clover," 1912. 550, "Crimson Clover, Growing the Crop," 1913. 515, "Vetches," 1912. 529, "Vetch Growing in the South Atlantic States," 1913. 483, "The Thornless Prickly Pears," 1912. 502, "Timothy Production on Irrigated Land in the Northwest." 509, "Forage Crops for the Cotton Region," 1912. 271, "Forage Crop Practices in Western Oregon and Western Washington," 1906. 331, "Forage Crops for Hogs in Kansas and Oklahoma," 1908. 534, "Durum Wheat," 1913.

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[12] Farmers' Bulletin 36.

Bureau of Plant Industry Bulletins 4, "Range Improvement in Arizona," 1902. 15, "Forage Conditions on the Northern Border of the Great Basin," 1902. 31, "Cultivated Forage Crops of the Northwestern States," 1902. 38, "Forage Conditions and Problems in Eastern Washington and Oregon, and Northwestern California and Nevada," 1903. 59, "Pasture, Meadow, and Forage Crops in Nebraska," 1904. 67, "Range Investigations in Arizona," 1904.

QUESTIONS

1. What are the main cereal grains used for feeding farm animals?
2. Give the classes of animals to which each kind is preferably fed; their average chemical composition and relative feeding values.
3. What per cent of hulls do oats generally contain, and in what way are the hulls of importance in feeding farm animals?
4. What is "ground feed," and to which classes of animals is it generally fed?
5. What are grain screenings? State under what conditions they may be safely used, and what disadvantages are incident to their use.
6. Give the different kinds of sorghums used for feeding farm animals, and the special points in their favor.
7. Name the leguminous seeds used for stock feeding, and give their average composition and relative value in comparison with the cereal grains.
8. What oil-bearing seeds are used for stock feeding, and under what conditions are they used?

CHAPTER XVII

VARIOUS FACTORY BY-PRODUCTS

I. FLOUR AND CEREAL MILL FEEDS

In the manufacture of flour or cereal products (breakfast foods) a large number of by-products are obtained that are of the highest value for stock feeding.

The flour-mill feeds are well-known by-products that have long been standard feeding stuffs in all parts of the country where live-stock are kept. These are bran, middlings or shorts, and low-grade feeding flour. A brief statement of the minute structure of the wheat kernel will make clear the characteristic differences in these by-products.

The wheat berry is covered by three different coatings of tough, thick-walled cells, which contain a considerable proportion of fiber and but little starch. Directly beneath the innermost seed-coat is a layer of cells, very rich in protein, called the aleurone layer; inside of this is the soft white portion (endosperm) of the berry, made up of cells largely filled with starch grains. These also contain protein substances, known under the name of gluten (gliadin and glutenin, see p. 9). Within the inner starchy portion of the berry is found the germ containing the embryo of the wheat plant. The following figures show the approximate proportion of the different parts of the wheat berry, according to Bessey:

Coatings or bran layers ...	5 per cent
Aleurone layer	3 to 4 per cent
Starch cells	84 to 86 per cent
Germ	6 per cent

Wheat is the main bread grain in this country. In the manufacture of flour the wheat is first passed over a series of screens which remove the impurities contained therein, such as weed seeds, chaff, etc. (p. 170). It is then scoured, and, after being heated somewhat, is run through a series of rollers, set at decreasing distances apart, so that the kernels are gradually broken into smaller and smaller pieces. The fine floury portion formed is separated after each "break," and the tough outer seed-coats are thus gradually freed from adhering flour and make up the bran. The aim of the miller is to obtain all the starch cells and gluten possible from the wheat, and to avoid the germ and the bran, including the aleurone layer, which would give an undesirable yellow tinge to the flour and lower its keeping quality. There are considerable differences in the nomenclature of mill feeds adopted by millers in different sections of the country, but the more common terms recognized by the trade are wheat bran, shorts or standard middlings, white middlings, and red-dog flour.

Wheat bran is rich in protein and fat, and also in fiber, the average percentages of these components being about 15, 4, and 10 per cent, respectively. Its digestibility is lower than that of the cereals, viz., dry matter 66 per cent, protein 77 per cent, fiber 41 per cent, nitrogen-free extract 71 per cent, fat 63 per cent, making the percentage of digestible components:

Protein 11.9 per cent,
Carbohydrates and fat 47.6 per cent (N.R., 1:4.0).

Bran is rich in mineral matter, and contains about 80 per cent of the phosphorus of the wheat berry; hence, it is very valuable as a source of this important element in feeding young, growing, or milk-producing animals. The ash is relatively poor in lime; in feeding wheat bran to the animals, it should, therefore, be supplemented by hay of legumes, which is especially rich in this component. Wheat bran also contains 6 to 8 per cent of the organic phosphorus compound phytin, to which constituent it largely owes its laxative properties.

The wheat bran on the market is of two kinds: Country mill bran and roller or flaky bran. The former kind comes from small flour mills which do not have the perfect machinery for the separation of starch-cells from the seed-coats that is found in large roller mills; this bran is, therefore, higher in starch and lower in protein and fiber than roller bran. The value of the two kinds for feeding purposes will depend largely on the combinations in which it is fed, and the kind of animals fed. While roller bran supplies more protein than does country mill bran, its digestibility is likely to be somewhat lower on account of its larger fiber content. The differences in the nutritive values of the two kinds of bran are, in general, small, however, making it advisable, in case both kinds are available, to select whichever can be obtained at the lower price.

Wheat bran is often high-priced in comparison with other desirable concentrates, and farmers should study the market prices of different feeds and the feed bulletins issued by the various experiment stations so as to be able to take advantage of low market prices for other feeds that may serve their purpose equally well.

The fact that wheat bran is a common and valuable dairy feed should not lead feeders to believe that it is indispensable and must be bought at any price. It is often possible to buy other equally valuable concentrates at a lower cost.

Bran is especially valuable for feeding stock that requires a liberal supply of protein and mineral matter in their rations and are able to digest bulky feeds; on account of its coarseness it is well adapted for use with heavy feeds like corn meal, buckwheat middlings, oil meal, etc.

Middlings or shorts are well suited to the use of young animals that do not do well on bran, like pigs and calves. They are especially valuable for feeding these classes of animals, and are always mixed with other feeds, like corn meal, ground oats or barley, oil meal, etc., when so used. They contain, as a rule, about 17 per cent protein, 5 per cent fat, and less than 8 per cent fiber.

Red-dog flour, or dark feeding flour, is rich in starch, protein, and fat, containing, on the average, about 18 per cent protein, 4.5 per cent fat, and over 60 per cent nitrogen-free extract; its fiber content is generally below 2 per cent. The high percentages of protein and fat contained in red dog are due to the presence therein of the rich wheat germs which generally go into this by-product. It is, therefore, a more valuable feed than the best grades of middlings, and is also somewhat higher in price. Besides for feeding young animals, calves, and pigs, red-dog flour is used in foundry work, to prevent the mold from adhering to the castings.

White middlings or flour middlings are composed of a mixture of standard middlings and red-dog flour, and have an intermediate composition and feeding value between these feeds.

Adulterated Wheat Feeds.—As a rule, the wheat feeds on the market are pure feeds, or free from serious adulterations, although of greatly varying quality. Adulterations with ground cornstalks, ground corn cobs, cedar sawdust, oat hulls, and weed seeds have, however, been identified in commercial samples in the past.[1] The only common adulteration of wheat bran and other wheat feeds is the admixture of whole or ground grain screenings. If finely ground, the screenings are, as a rule, rather unobjectionable, since the weed seeds contain considerable amounts of nutrients, but the whole screenings make a very undesirable adulteration, on account of the danger of fouling the farm land with weeds by their use. One of the most striking recent examples of this danger that

[1] Wisconsin Bulletin 97, p. 30; U. S. Notice of Judgment, 66, 67, and 2387.

has come to the author's notice was presented by a sample of wheat bran examined in the feed-control work in Wisconsin.[2] The analysis showed that 1413 whole seeds were found in 10 grams (or less than one-third ounce) of the bran, and the weed seeds made up over 10 per cent of the weight of the sample. The number given represents over 128,000,000 weed seeds in a ton, which would be distributed on the land with manure and, to a large extent, be ready to germinate the first season. By taking up space and plant food that should be used by farm crops, the weeds grown from the seeds would decrease the production of the land and would also increase the cost of growing the crops (p. 171).

The feed laws of the various States require that bran (or middlings) containing screenings must be sold as "wheat bran (or wheat middlings) mixed with screenings," and a statement of the percentage contained therein is also required in some cases.

Oat Feeds.—The by-products in the manufacture of oatmeal are similar to those obtained at the flour mills, except for the differences in the structure of the oat kernel. Oats consist of a kernel and a hull which are easily separated. The former is high in starch, protein, and fat; the latter is low in all those components, and high in fiber, hence has a very low feeding value. As previously shown, the hulls make up about one-third of the oat kernel, on the average, and contain 30 to over 40 per cent fiber and only about 3 per cent protein.

The hairy tips on the oats are separated in the manufacture of oatmeal, after the kernels are hulled, and make up the by-product sold as oat dust. The only other refuse feed obtained in oat mills is oat shorts or middlings (often sold as oat feed).

Oat dust contains considerable protein (13.5 per cent), fat (4.8 per cent), and other valuable feed components, with about 18 per cent fiber. It is, therefore, a feed of some importance, although its light, fluffy mechanical condition makes it difficult to feed except in mixtures with heavy concentrates.

Oat shorts or middlings are the richest of the by-products from oats, and correspond closely to wheat middlings in chemical composition, with a somewhat higher fat content than this feed.

Oat feed contains ground oat hulls with shorts or middlings; it should be bought only on a definite guarantee of its composition, including maximum fiber content. The oat feeds on the market differ greatly in composition and feeding value, according to the

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[2] Circular 30, p. 79; see also Circular 97 of the same station, and Vermont Bulletin 138.

condition of the feed market and the integrity of the manufacturer. Oat hulls are frequently ground and used as adulterants for ground corn and oats, or oat feeds (p. 168). Unless present in excessive quantities, the true quality of these feeds can be determined only by chemical analysis, and it is not safe, therefore, to buy such feeds except on a guarantee, and of reputable feed dealers or manufacturers.

Barley Feed.—In the manufacture of pearl barley or barley flour only one by-product is obtained, which is sold under the name of barley feed or meal. It resembles wheat bran closely in composition, except that it contains a somewhat higher percentage of nitrogen-free extract and less fiber. The two feeds may, in general, be considered of similar feeding value.

Rye Feeds.—Rye is used in this country mainly in the manufacture of spirits and for feeding livestock; the manufacture of rye flour is a relatively unimportant industry. The refuse from rye mills is sold either as rye feed or as two separate feeds, rye bran and rye middlings. The process of manufacture is similar to that of the wheat feeds. Rye feed contains, on the average, about 15.5 per cent protein, 0.3 per cent fat, and 5 per cent fiber. It is, therefore, considerably lower in fiber than wheat bran, but otherwise quite similar in composition to this feed. It is often sold at a lower price than wheat bran, and is then an economical feed, well worthy of a trial for feeding dairy cows or pigs. It should be fed in moderate amounts to pigs, as it will otherwise produce a soft pork of inferior quality. In Germany rye feed is considered a more valuable feeding stuff than wheat bran, as it is believed to be more easily digested and more nutritious.[3] This may be due to the fact that rye and rye feed contain a large amount of diastase, which is found in only small amounts in wheat bran. There are also marked differences in the protein substances of the two cereals, the most important one being that rye contains no glutenin, which, with gliadin, forms the main protein substance of wheat.

Buckwheat Feeds.—Buckwheat flour mills supply the feed market with three or four by-products, viz., buckwheat hulls, bran, middlings, and feed. Buckwheat hulls are the coarse, black covering of the buckwheat kernels, which are readily separated therefrom. They have practically no feeding value whatever, although, if finely ground, they may serve a purpose as dilutant of heavy feeds, like corn meal or buckwheat middlings. The hulls contain

[3] Pott, "Landw. Futtermittel," 3, ii, p. 164.

about 4 per cent protein, less than 1 per cent fat, nearly 50 per cent fiber, and 36 per cent nitrogen-free extract. Buckwheat feed means the entire refuse obtained in the manufacture of buckwheat flour, and contains ordinarily one-half to two-thirds of hulls, the balance being made up of the heavy, floury portion of the buckwheat grain immediately inside of the hulls, known as middlings or shorts. Buckwheat feed composed of one-half middlings and one-half hulls will contain about 15.7 per cent protein and 24 per cent fiber, and one containing one-third middlings and two-third hulls about 12 per cent protein and 30 per cent fiber.[4] A study of the digestible components furnished by this feed and by wheat bran would lead to the conclusion that a good quality of buckwheat feed (containing not much over one-half hulls, by weight) is worth about 20 per cent less than wheat bran. Buckwheat middlings are a very valuable and rich feed, containing about 28 per cent crude protein and 7 per cent fat, with only 4 to 6 per cent fiber. It is highly prized as a feed for dairy cows, but cannot often be obtained as a separate article of commerce; most millers sell their entire amount of refuse as buckwheat feed.

Corn Feeds.—The corn kernel (Fig. 36) consists of five different parts: An outer and an inner layer of skin or hull, a layer of gluten cells, the germ, and the main starchy part (endosperm), some of which is hard and flinty, and some soft. The New Jersey station[5] made analyses of the different parts of the corn kernel and determined the approximate proportion of each, with results as shown in the table.

Composition of Dry Substance of Corn Kernel, in Per Cent

	Ash	Protein	Fiber	Nitrogen-free extract	Fat	Proportion of parts
Entire kernel	1.7	12.6	2.0	79.4	4.3	10.0
Skin (hull)	1.3	6.6	16.4	74.1	1.6	5.5
Germ	11.1	21.7	2.9	24.7	29.6	10.2
Starchy and flinty part	.7	12.2	.6	85.0	1.5	84.3

The most striking part of the data shown in the table is the high protein, fat, and ash contents of the corn germ. This contains 65 per cent of the total fat in the kernel, 16 per cent of the protein, and 62 per cent of the ash (71 per cent of the phosphoric-

[4] Wisconsin Bulletin 170, p. 76.

[5] Bulletin 105; see also Illinois Bulletin 87.

acid content). The hulls (skin) contain very nearly one-half of the total fiber, and the starchy part about 90 per cent of the total nitrogen-free extract of the kernel.

The only by-products of corn or hominy mills used for feeding farm animals are corn bran and hominy meal. Both of these are obtained by similar manufacturing processes as those given under wheat feeds. The corn bran does not differ greatly from wheat bran in chemical composition; it is lower in ash and protein, and somewhat higher in carbohydrates and fiber, however; its digestibility is slightly higher than that of wheat bran, except for the protein it contains, which is considerably lower, viz., 54 per cent, against 77 per cent for wheat bran. The two feeds may, in general, be considered of similar feeding value, in so far as it is possible to compare the feeding values of two feeds of as different nutritive ratios.

Hominy meal, feed or chop, consists of the bran, germ, and soft floury portion of the kernel which are separated in the process of making hominy grits for human consumption. It forms a very valuable, palatable, fattening feed, of a similar composition to Indian corn, the main difference being that it is higher in fat and lower in nitrogen-free extract than is Indian corn, and also somewhat higher in fiber, as will be seen from the following average analyses:

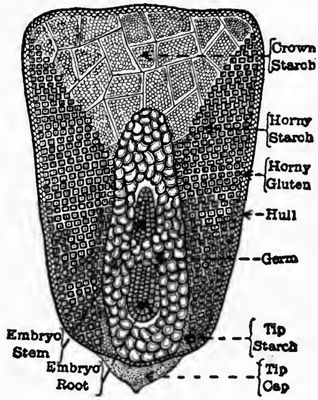

FIG. 36.—Section of corn kernel. ("Productive Farming," Davis.)

Chemical Composition and Digestibility of Hominy Meal, in Per Cent

	Dry matter	Protein	Fat	Fiber	Nitrogen-free extract	Ash
Total components.......	90.4	10.5	8.0	4.9	64.3	2.7
Digestion coefficients....	82	65	92	67	89	...
Digestible components...	74.1	6.8	7.4	60.5		...
Digestible components in corn................	81.4	7.8	4.3	66.8		...

Hominy meal is a highly valued feed for milch cows and fattening steers, and may serve a useful purpose as a substitute for Indian corn in rations for these and other farm animals. Like all corn products, it is of rather uniform quality and free from adulterations.

Rice By-products.—In the milling of rice several by-products are obtained which are used for stock feeding. The rice grains are covered by two layers: The outer coat, a hard, chaffy husk which is easily removed, and the inner coat, a closely-fitting cuticle or skin. The removal of these coatings and the manufacture of marketable rice are done by three operations: Husking, hulling, and polishing. Husking is accomplished by passing the rice between revolving millstones, which are set far enough apart to crack the hull and allow the rice to fall out without cracking it too much. The hulls are not removed completely, there being always some grains which retain their husk. The by-product from this process is rice hulls. The rice is next passed through one or more hullers, which remove the cuticle or skin. The products of this machine are rice bran, some flour, and clean rice. The final process consists in polishing the rice, which is done in a special machine and gives the rice its lustre. The by-product from this process is a finely-powdered material, known as rice polish. Three by-products used for stock feeding are thus obtained in these processes, viz., rice hulls, rice meal, and rice polish.

Rice hulls are used as a fuel at the mills and for packing eggs, etc.; they are also sometimes ground and sold as "husk meal" or "Star bran," or used as an adulterant of rice bran. They are, however, of no value as a feed, and are, in fact, injurious to stock, being provided with sharply-pointed fibers, which are strongly impregnated with silica. When taken into the stomach and intestines of an animal they provoke an intense irritation of the delicate membranes of these tracts, and may cause impaction of the bowels; fatalities are on record resulting from animals eating rice hulls or rice bran adulterated with hulls.[6]

The average chemical composition of the rice by-products is shown in the following table:

Composition of Rice By-products, in Per Cent

	Ash	Protein	Fiber	Nitrogen-free extract	Fat
Rice hulls	15.6	3.2	36.2	35.2	1.0
Rice bran	9.7	11.9	12.0	46.6	10.1
Rice polish	4.8	11.9	3.3	62.3	7.2

[6] Browne, *Louisiana Planter and Sugar Manufacturer*, June 13, 1903; Louisiana Bulletin 77.

In addition to the preceding by-products, a feed called "commercial rice bran" is obtained and sold in the South. This is a mixture of the pure bran with varying amounts of ground hulls, the quantity of the latter being sometimes as high as 50 per cent. According to the Texas station,[7] commercial rice bran may contain as low as 4 per cent of protein and 2 per cent of fat, and as high as 50 per cent of fiber. An addition of rice hulls decreases the feeding value of bran in proportion to the amount of hulls added. Adulteration of rice bran with hulls or mineral matter has been largely practised by southern mills, and has brought the feed into disrepute. In view of the danger of such adulteration, rice bran should be purchased only of reputable dealers and on guarantees of valuable components and maximum fiber content. It should contain not less than 10 per cent protein and 6 per cent fat, and not more than 20 per cent fiber.

Test for Rice Hulls.—Pure rice bran and rice meal contain considerable fat and are not moistened if placed on the surface of water. When the test is made with rice bran or meal adulterated with hulls, these will soon sink into the water.

Rice polish is a highly digestible starchy feed which is used as a feed for pigs, dairy cows, fattening steers, horses, and mules; its high price often makes it more expensive under southern conditions than, *e.g.*, cane molasses (p. 192).

Pure rice bran and rice polish are both valuable feeds which compare favorably with corn meal in feeding value and may be fed under similar conditions. At the Louisiana station rice bran was used successfully for one-half of the concentrates in rations for horses and mules, and it is also a good cow feed, if fed with high-protein concentrates and before turning rancid.[8]

The rice feeds will not keep long before they turn rancid, on account of the unstable character of the oil and the high oil content of these feeds. Rancid rice feeds are not palatable to livestock.

QUESTIONS

1. Describe the method of manufacture by which flour-mill feeds are obtained as by-products.
2. What are the differences in composition and relative feeding value of wheat, wheat bran, wheat middlings, and red-dog flour?
3. What are the common adulterations of wheat feeds, if any?
4. Describe the by-products obtained in the manufacture of cereal feeds, barley, rye and buckwheat flour.
5. Describe (*a*) the corn by-products; (*b*) the rice by-products.
6. Why are rice hulls a dangerous material to be used for feeding farm animals?

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[7] Bulletin 73. [8] North Carolina Bulletin 169; U. S. Dept. Agr., b. 330.

II. BREWERY AND DISTILLERY FEEDS

The main feeds of this class met with in the trade are wet and dried brewers' grains, malt sprouts, and dried distillers' grains. The first three feeds are essentially barley products, while the last feed is made from mixed grains, largely rye and corn.

Brewers' grains are the by-product obtained in the manufacture of beer. The barley is steeped in warm water and held at a warm temperature until it begins to sprout; by this process the starch content in the grain is converted into sugar (maltose), through the action of the ferment diastase found in barley. When the malted barley contains a maximum amount of sugar it is quickly dried. The tiny dry sprouts are then separated and form the feed called malt sprouts, while the remaining dried grains make what is known as malt. This is treated with large quantities of water to extract the sugar, ash, and other soluble components; the extracted malt makes wet brewers' grains, and these, on drying in vacuum, are changed into dried brewers' grains.

On account of their large water content (70 to 80 per cent), the wet brewers' grains must be fed in the vicinity of breweries and within a short time after they have been made. As the starch of the barley has been largely removed by the processes of malting and brewing, the brewers' grains are considerably richer in protein than the original grain and may be considered fully as valuable a feed for farm animals as these. Their digestibility is somewhat lower than that of barley, for reasons easily seen; but fed either wet or dry, the brewers' grains form a valuable feed for farm animals, wet grains being especially adapted for milch cows, brood sows, and fattening swine, and dried grains for cattle and horses. When fed in a sound, fresh condition and in moderate quantities, say twenty to thirty pounds per head daily, with dry roughage and concentrates, wet brewers' grains make an excellent feed for dairy cows, and can often be contracted for from local breweries at a low price; they may be considered worth about one-fourth as much as the dried grains for feeding stock.

Brewers' grains have been brought into disrepute by being fed in excessive quantities, without dry roughage and under unsanitary conditions, and their use as a stock feed under such conditions is prohibited in most States. When the wet grains are fed to dairy cows, care must be taken to keep the mangers and stable scrupulously clean, so as to avoid filthy conditions and foul odors around the premises, which will seriously affect the quality of the milk produced and the health of the animals.

Dried brewers' grains can be kept indefinitely and transported from the place of manufacture like other commercial feeds. They contain, on the average, 20 per cent digestible protein, 32 per cent digestible carbohydrates, and 6 per cent digestible fat, against 11.9 per cent, 42.0 per cent, and 2.5 per cent, respectively, for the same components in wheat bran; the two feeds, therefore, contain similar amounts of total digestible components. The brewers' grains have the advantage of containing about twice as much digestible protein and fat as wheat bran, but contain 10 per cent less carbohydrates. Dried brewers' grains form an excellent feed for cattle and horses, and may be fed to the former in similar quantities as wheat bran or small grains, while the rations for horses may consist of one-third to one-half of the dried brewers' grains, the balance being made up of corn and oats. Dried brewers' grains will prove cheaper than oats and quite as satisfactory, especially for hard-worked horses in need of an extra amount of protein.[9]

Malt sprouts are the tiny dried germs of barley that have been allowed to grow to about one-fourth inch in length. They form a light, bulky, and somewhat dusty feed, containing about 26 per cent protein (of which one-fourth to one-third is in amide form), 12 per cent of fiber, and less than 2 per cent fat. On account of its tendency to dustiness, the feed is either fed mixed with other concentrates or with silage, or is moistened before being fed out. It is especially valuable as a dairy feed, and may be given in amounts of two to three pounds daily per cow; on acccount of bitter principles contained therein (betaine and choline), most cows object to the feed at first, but soon learn to like it. It is a common feed in the dairy sections of the country, and, as a rule, forms a relatively cheap source of protein.

Dried distillers' grains are the dried residues obtained in the manufacture of alcohol and distilled liquors from cereals. The ground grains are treated with a solution of malt, thus converting the starch into sugar (maltose); by the addition of yeast, the sugar is changed into alcohol, which is distilled over, leaving a very watery residue, called distillers' slop; this is dried in especially-constructed driers and sold as dried distillers' grains. The distillers' grains consist of the hulls, germ, protein, and carbohydrates of minor nutritive value, and make a very rich and valuable feed

[9] Massachusetts Bulletin 94.

for farm animals. The quality of the grains will vary considerably, according to the cereals used in the manufacture of the distilled spirits; the larger the proportions of corn and the smaller that of rye and "malt" (small grain, so-called), the higher the grade of dried grains produced. The rye distillers' grains contain only 30 per cent protein or less, and are the least valuable of the distillers' grains.[10] The protein in the better grades may reach 34 to 36 per cent, with 10 to 12 per cent of fat or more. The dried distillers' grains have a high digestibility and must be classed among our most satisfactory and economical protein feeds, of a value nearly similar to oil meal when fed in rations for dairy cows. It may be fed in quantities of two to four pounds per head daily, preferably mixed with other concentrates.

III. STARCH AND GLUCOSE FACTORY FEEDS

Three feeds are obtained as by-products in the manufacture of starch and glucose from Indian corn, viz., gluten feed, gluten meal, and germ oil meal.

Starch and Glucose Feeds.—In the glucose factory the shelled corn is passed through a cleaning machine which removes pieces of cob, dirt, dust, etc. It is then immersed in large steeping tanks, where it remains for 30 to 40 hours until the corn is soft. The water is next run off and, in large factories, saved for further treatment. The softened corn is coarsely ground between large millstones placed well apart so as to break up the kernel and set free the interior starch cells. The mass is now put on sieves of fine bolting cloth; the coarse hulls and germs of the corn remain on the sieve, while starch and gluten go through—the latter two components are separated by running the mixtures through a series of long troughs and into settling tanks; the starch, being heavier, sinks to the bottom, while the gluten and fat (oil) float on top and are skimmed off and dried.

The gluten feed proper consists of the hulls and undissolved starch remaining on the sieves; it is dried and either placed on the market in this condition, or after addition of the gluten, which has been previously extracted with naphtha for removal of most of the oil found therein. The steep-water is evaporated in the larger factories, and the solids are added to the gluten feed. The ash and protein contained therein go to increase the contents of these constituents in the gluten feed; on the other hand, the palatability

[10] Massachusetts Bulletin 94.

and keeping quality of the feed may be somewhat decreased by this method of manufacture.[11]

The gluten obtained in some factories is placed on the market as a special feed called cream gluten meal. The corn germs are generally kept separate and extracted, and the residue put on the market as corn oil cake, or, if ground, as germ oil meal.

The composition of these various feeds put out by different manufacturers, as well as the nomenclature, differs somewhat. In general, the gluten feeds now on the market contain about 25 per cent protein, 4 per cent fat, and 8 per cent fiber. The ash content is about 4 per cent, in the case of feed to which the solids in the steep-water have been added; and, otherwise, less than 1 per cent. Gluten meal, on the other hand, contains about 35 per cent protein and less than 10 per cent fat. Germ oil meal has a protein content about 11 per cent and a fat content of 6 per cent. The digestibility of all these feeds is nearly as high as that of Indian corn.[12]

QUESTIONS

1. Describe the methods of manufacture by which brewers' grains, malt sprouts, and distillers' grains are obtained.
2. What are the characteristic properties of these feeds?
3. Give the method of manufacture of starch- and glucose-factory feeds.
4. State their value for feeding farm animals.

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[11] Wisconsin Circular 47, p. 72.

[12] Wisconsin Report, 1896, p. 92.

CHAPTER XVIII

SUGAR FACTORY FEEDS AND OIL MEALS

I. SUGAR FACTORY FEEDS

Sugar is manufactured on a large scale in this country from two agricultural crops, sugar beets and sugar cane. The former crop furnished the raw material for about 70 per cent of the sugar manufactured here during 1913–1914. The cane-sugar industry is located in the South, practically all cane-sugar manufactured in the United States being made in Louisiana. The beet-sugar factories, on the other hand, are located in the northern and western States, the States leading in this industry being Colorado, California, and Michigan. The by-products of importance as stock feeds are cane and beet molasses, and beet pulp, which is fed either wet or dried.

Molasses is the non-crystallizable residue obtained in the treatment and evaporation of the sweet juice of sugar beets or cane.

The beet molasses is composed of about 20 per cent moisture, 9 per cent protein (largely amides and nitrates), and 60 per cent nitrogen-free extract, which is almost wholly sugar, and at least two-thirds sucrose, the rest being composed of glucose, raffinose, organic acids, pentosans, etc. Beet molasses contains about 10 per cent of ash, largely potash and soda. It forms a thick, salty, not particularly sweet liquid, which is very laxative on account of its content of alkali salts and organic acids, and must, therefore, be fed sparingly to farm animals. In feeding beet molasses it is generally mixed with three to four times its proportion of warm water and sprinkled on the hay, cut straw, or other roughage. It is also used in the manufacture of molasses feeds with different absorbents, such as dried brewers' grains, malt sprouts, alfalfa meal, ground grain screenings, pea meal, ground cobs, wheat bran, and other materials. The value of these feeds differs greatly, according to the character of the absorbent used. If good feed materials enter into their manufacture and the price of the feeds do not go too high in comparison with other concentrates, they may be considered well worth a trial. Beet molasses is used in some factories for the manufacture of molasses beet pulp (see p. 195). It may be fed in limited quantities to all classes of farm animals, except, perhaps, to pigs; according to reports by the Cornell[1] and Utah stations,[2] it is injurious as a swine feed and likely to produce a poor quality of pork.

Cane molasses (black-strap molasses) differs from beet molasses mainly in the composition of the non-nitrogenous constituents and in its smaller protein and ash contents. Unlike beet molasses, it has a sweet taste and is greatly relished by farm animals. It is fed largely in the South to horses, mules, and fattening steers. According to the Louisiana station,[3] horses and mules on many sugar plantations in the State are fed as much as 10 pounds black-strap daily, per head, with excellent results, both as to the cost of the ration and its effect on the health of the animals and their working capacity. The Massachusetts station found that one gallon (12 pounds) of molasses makes a good carbohydrate feed for horses; a similar amount may be fed to fattening steers as a maximum allowance.[4] Cane molasses is especially valuable on account of its high sugar content and its palatability; it serves a useful purpose as an appetizer and for utilizing low-grade materials for stock feeding. It is often used for preparing animals for shows and sales, as it gives them a thrifty appearance and a smooth, shiny coat. It should be fed only in moderate amounts for breeding animals.

Beet pulp is obtained in large quantities as a by-product at beet-sugar factories. The carefully-cleaned beets are cut into thin, V-shaped sections, and the sugar contained therein is extracted by the so-called diffusion process by treatment with warm water in a battery of especially-constructed diffusion cells. The juice thus obtained is purified with lime and sulfur dioxide and evaporated until the sugar begins to crystallize out. Molasses is obtained as a residue after the crystallizable sugar (sucrose) has been removed so far as possible. The extracted beet pulp, as it comes from the diffusion cells, contains 80 to over 90 per cent water and only a small amount of sugar (1 to 2 per cent). It is, however, relatively high in other carbohydrates, and has been found to have about the same feeding value as beets, per unit of dry matter contained in both. Its feeding value may be considered one-half that of corn silage. The Colorado station found that two tons of pulp are equivalent to one ton of roots in feeding value; this confirms the result

[1] Bulletin 199. [2] Bulletin 101. [3] Bulletin 86.
[4] Texas Bulletin 97; see also Massachusetts Bulletin 118.

of a trial at the Nebraska station showing beets to be practically of a similar value as corn silage for dairy cows. On account of its high water content, wet pulp cannot be shipped far from the sugar factories, and it must, therefore, either be fed at or near the factory as wet pulp or beet pulp silage (p. 161), or it is dried in an especially-constructed large drier at the factory and placed on the market as dried beet pulp. Ten to fourteen tons of wet pulp will make one ton of dried pulp.[5]

The wet pulp is an excellent feed for dairy cows, sheep, and steers. As it is produced in large quantities and fed at the factories, it is often fed too heavily for best results, sometimes without dry roughage or grain feed. Not more than about 100 pounds per 1000 pounds body weight should be given daily.

Siloed or cured pulp is made in large quantities near sugar factories and generally fed there. It may be fed in quantities similar to fresh pulp, and always with dry roughage, preferably alfalfa hay or other leguminous hay. In a feeding experiment conducted by the California station[6] 1000-pound steers, each eating 103.5 pounds cured pulp and 15 pounds of cut alfalfa hay, gained 2.4 pounds a day, on the average, for a period of 70 days, and steers, on a ration of 108 pounds cured pulp, 12.1 pounds rye grass hay, and 2 pounds ground horse beans, gained 2.5 pounds a day during the same period. Milch cows cannot be fed safely over one-half of this amount of siloed pulp without the quality of the milk suffering therefrom, both as to composition and as a food for infants; fed up to this limit and always with dry roughage and grain, it makes an excellent feed for dairy cows.

Dried beet pulp is a valuable feed for dairy cows, steers, and sheep, and, to a limited extent, for other farm animals as well. It is a highly starchy feed, containing about 60 per cent nitrogen-free extract, 17.5 per cent fiber and 8 per cent protein; it contains 4.1 per cent digestible protein and 64.9 per cent carbohydrates (N. R., 1: 15.8). Dried pulp may be fed safely in large quantities to fattening steers, dairy cows, and sheep, and makes a very desirable feed when it can be obtained at a relatively low cost. It may be considered nearly equivalent in feeding value to wheat bran or oats, and of slightly lower value than corn, barley, and similar feeds. According to the feed-unit system, it takes 1.1 pounds of either of the former feeds or 1 pound of the latter feeds

[5] New Jersey Bulletin 189. [6] Unpublished results.

to equal a feed unit (p. 79). Dried beet pulp is often moistened with three to five times its weight of water about six hours before feeding time, especially on dairy farms where there is no silo. Some dairymen and farmers prefer feeding the pulp in this way. In case of heavy producing cows or steers, it is possible that they are induced to eat their feed with a keener appetite and to eat more when the dried pulp is fed moistened than when fed dry, but no decided advantage has been shown by this method of feeding.

Beet molasses is sometimes added to the pulp in the factory as it goes to the drier; the resulting molasses beet pulp makes an excellent feed for dairy cows and sheep, being worth somewhat more than the plain dried pulp.[7] It was found to have about one-tenth higher feeding value of corn for fattening lambs in experiments conducted at the Colorado station; this is probably somewhat too high for an average figure.

II. OIL MEALS

The oil-bearing seeds that furnish by-products of value as stock feeds are: Flaxseed, cotton seed, coconut, soybean, and peanut, the last three to a limited extent only.

Linseed Meal (Oil Meal).—Flaxseed (Fig. 37) is grown largely in the northwestern States, the Dakotas, and Minnesota, and the linseed oil mills are located in these and the central States. There are two methods of manufacture, known as (*a*) old-process and (*b*) new-process. By the former method the cleaned and ground seeds are placed in large linen bags and subjected to heavy pressure until the residue forms cakes about 1 inch thick and about 13 by 32 inches (edges trimmed). The cakes are broken into small pieces or ground to a fine meal, usually the latter, which is generally sold as old-process linseed meal, or simply oil meal.

In the new process of manufacture the flaxseed is ground and heated to about 160° F., and is then placed in large percolators holding about 1000 bushels or more. The seed is treated repeatedly with naphtha till practically all the oil is dissolved. Live steam is then introduced into the percolators and the naphtha gradually driven out of the mass. The meal is transferred to steam-heated driers, and, when dried, elevated to the meal bins and sacked. The naphtha is evaporated from the oil solution, and commercial linseed oil remains.

[7] Wisconsin Report 22, p. 108; see also Massachusetts Bulletin 99, Michigan Bulletin 220.

Old-process meal is generally preferred by feeders on account of its forming a jelly with warm water, and because of its favorable influence on the health and appearance of farm animals. Owing to its relatively high oil content (6 to 8 per cent), it is somewhat more laxative than new-process meal, which contains only about 3 per cent fat, and it gives a thrifty appearance to stock, producing a fine, shiny coat, soft to the touch, which is of special importance in the case of exhibition stock. The nutritive effect of the two kinds of meal may, in general, be considered nearly similar. The old-process meal has some advantage as a feed for fattening animals,

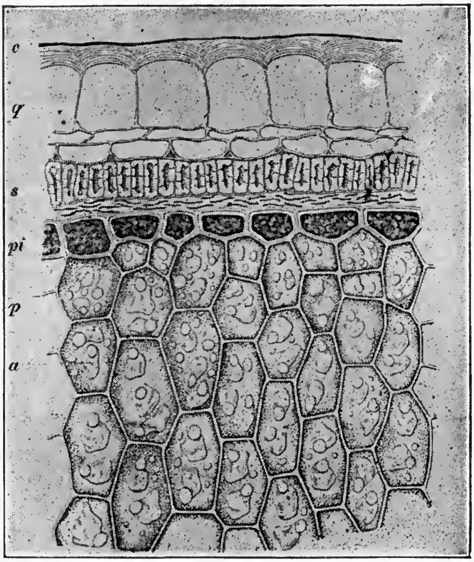

Fig. 37.—Cross-section of flaxseed showing the different layers of cells: *c*, cuticle; *q*, mucilage cells; *s*, stone cells; *pi*, pigment cells; *p*, protoplasm and oil; *a*, aleurone (protein) grains; when soaked in water the mucilage cells well and form the peculiar flaxseed jelly.

for show stock, and in combination with dry feed or feeds of constipating tendencies; when given with feeds of a laxative influence, such as green fodders, roots, and silage, or where a large supply of protein is important, as is often the case in feeding milch cows, the new-process meal may be preferred.

The Swelling Test.[8]—It is of interest to determine at times whether an oil meal is old- or new-process. The following simple test can be made at any farm by means of a tumbler and a teaspoon: Pulverize a small quantity

[8] Wisconsin Report, 1895, p. 64; "Examination of Oil Meals," by the author.

of the meal and place a level teaspoonful of it into a tumbler (Fig. 38); then add ten teaspoonfuls of boiling hot water to the meal; stir thoroughly and leave to settle. If the meal is new-process it will settle in the course of an hour, and will leave about one-half of the water clear on top. Old-process meal will remain jelly-like.

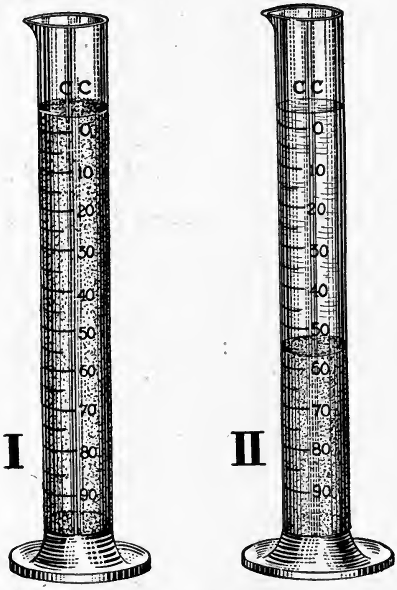

FIG. 38.—The swelling test. I, old-process oil meal; II, new-process oil meal. In case of the former, the meal stirred in water remains in suspension on standing, while the new-process meal soon settles so as to leave a clear yellowish solution on top, only about half the quantity of water added being absorbed.

Composition of Linseed Meal.—The chemical analysis and digestibility of old- and new-process oil meal will be seen from the following table:

Chemical Composition and Digestibility of Linseed Meals, in Per Cent

	Total components		Digestible components	
	Old-process	New-process	Old-process	New-process
Moisture	9.8	9.0	....	....
Ash	5.5	5.5	....	....
Protein	33.9	37.5	30.2	31.5
Fiber	7.3	8.9 }	32.0	35.7
Nitrogen-free extract	35.7	36.4 }		
Fat	7.8	2.9	6.9	2.4
Nutritive ratio, 1:	....	....	1.6	1.3

Linseed meal may be fed safely to all classes of farm animals; generally speaking, it is one of the most desirable stock feeds available. Flaxseed contains a glucoside, linamarin, which, with ferments, may yield prussic acid; but it is, as a rule, present in only minute quantities, and but few cases of ill effects from its use as a stock feed are on record. The cost of the more starchy factory by-products makes them, in general, relatively cheaper sources of protein than oil meal, but the latter may be fed to advantage in smaller quantities even under these conditions, on account of the medicinal properties as a regulator of the system, and for its stimulating effects on the appetite of the animals and their general feeling of well-being.

The quantities to be fed daily will depend on the relative cost of oil meal and other concentrates. If the market prices of the latter feeds are such as to admit of economical feeding of large quantities of oil meal, the following amounts may be fed per head daily without injurious effects: Horses, 1 pound; milch cows and fattening steers, 3 pounds; fattening sheep and hogs, 1 pound, the quantities fed being increased toward the end of the fattening period; calves and lambs, ½ pound or less. Where the production of high-grade butter is the object sought, not more than one pound of oil meal should be fed, since the quality of the butter is apt to suffer when larger quantities are fed, especially if given with corn or other feeds having a similar softening effect on the butter. Calves are generally fed boiled flaxseed rather than oil meal, especially until they are about two months old, unless the price of the seed is almost prohibitive, as sometimes happens. Oil meal may advantageously be fed to swine as a slop, a pailful of meal being stirred into a barrel of skim milk and left over night; the mixture will form a thick, almost solid mass in the morning, which will be greatly relished by swine. Fed to poultry in small quantities, a tablespoonful to each hen a few times per week, it will brighten the plumage, invigorate the system, and promote laying.

Cotton-seed meal is the ground residue obtained in the manufacture of cotton-seed oil; the oil is expressed by pressure as in old-process linseed meal. The cake is generally ground into a fine meal for the trade in the eastern and central States, while for the western States and Europe it is broken into pieces of about nut or pea size, which are readily eaten by cattle; for sheep the cake is, as a rule, coarsely pulverized. There are two kinds of cotton-seed meal on the market, viz., decorticated, made from seed the hulls of which are largely removed before the extraction of the oil, and the undecorticated, so-called cold-pressed cotton-seed cake; this is the product obtained when the whole uncrushed seed is subjected to the cold-pressure process for the extraction of oil. The difference in the value of the two kinds of meal is readily seen from the following average analyses:

Composition of Cotton-seed Meal and Cold-pressed Cotton-seed Cake, in Per Cent

	Cotton-seed meal	Cold-pressed cotton-seed cake
Moisture	7.0	7.6
Ash	6.6	4.9
Protein	45.3	24.2
Fiber	6.3	21.1
Nitrogen-free extract	24.6	32.5
Fat	10.2	9.7
	100.0	100.0

Recent analyses of cotton-seed meal appear to run considerably lower in protein than given above, viz., about 42 or 41 per cent, with fat likewise lower (about 8 per cent), and fiber higher (10 per cent). The trade recognizes three grades of cotton-seed meal: *Choice, prime,* and *good.* The former " must be finely ground, not necessarily bolted, perfectly sound and sweet in odor, yellow, free from excess of lint, and must contain at least 41 per cent protein." The protein limits for prime and good cotton-seed meal are 38.6 per cent and 36 per cent, respectively. The analyses given above indicate the difference in the value of the decorticated and cold-pressed cotton-seed cake. The high fiber content of the latter feed is important, and the result is shown by the lower digestibility of this feed compared with cotton-seed meal.[9]

Average Per Cent Digestibility of Decorticated and Cold-pressed Cotton-seed Cake

	Protein	Fat	Nitrogen-free extract
Decorticated cotton-seed meal	86	93	77
Cold-pressed cotton-seed cake.	74	90	55

It is evident, from the differences in the protein and fiber contents of the two feeds, that cotton-seed meal is a much more valuable seed than cold-pressed cake, although the latter ordinarily

[9] Pott, " Handb. tier. Ernährung," iii, 2, p. 102.

sells for only a few dollars per ton below cotton-seed meal; hence the wisdom of buying only the best grades of cotton-seed meal. This applies also to so-called cotton-seed feed which has been placed on the market during late years. This is "a mixture of cotton-seed meal and cotton-seed hulls (1: 5), containing less than 36 per cent protein" (definition); as a matter of fact, it contains only 10 per cent protein, 3.4 per cent fat, and 33.1 per cent fiber.[10]

Test for Impurities.—The Vermont station has published the following simple test for impurities in cotton-seed meal:[11]

> Place a teaspoonful of the meal in a tumbler and pour over it two ounces of hot water. Stir the mass until it is thoroughly wet and all the particles are floating. Allow it to subside for from five to ten seconds and pour off. If a large amount of fine dark brown sediment has settled in this time, a sediment noticeably heavier than the fine mustard-yellow meal, one which upon repeated treatments with boiling hot water keeps settling out, the goods are a feed meal, *i.e.*, meal containing relatively large quantities of ground hulls. If, however, there is found a larger amount of this residue, one which persists in remaining after several washings, it is surely composed of hulls, and it is a feed meal or an adulterated cotton-seed meal. The results are striking when a feed meal is compared with a sample of pure cotton-seed meal.

Uses of Cotton-seed meal.—Cotton-seed meal is a very valuable feed when rightly used. In most sections of the country it is our highest protein feed and the cheapest source of protein for stock feeding. It is an excellent feed for milch cows, and may be fed in large quantities (six pounds per head daily) apparently for any length of time; ordinarily only one to two pounds per head are fed daily, however, with other concentrates, and this is, in general, the better practice, since heavy feeding of cotton-seed meal gives the butter a hard, tallowy texture, raises the melting-point of the butter fat, and decreases the percentage of volatile fatty acids (p. 23),—in short, produces a low-grade butter.[12]

Fattening steers may also receive similar heavy feeds of cotton-seed meal as milch cows, if desired, but only for a period not to exceed 90 days; if fed cotton-seed meal longer and in larger quantities, sickness and death are likely to occur, owing to the presence of certain poisonous principles in the meal. Cotton-seed meal cannot safely be fed to calves or pigs for the same reason. The poisonous properties of cottonseed meal have been ascribed by various investigators to the presence of nitrogenous bases, like cholin and betaine, to alkaloids, and to salts of pyrophosphoric acid. Withers,

[10] Pennsylvania Bulletin 28; Wyo., b. 106.

[11] Bulletin 101, Texas Bulletin 109; Experiment Station Record 20, p. 510.

[12] Proc. Soc. Agr. Science, 1889, p. 84.

of the North Carolina Station, has lately identified a toxic principle called *gossypol* in cotton-seed kernels and studied its physiological effects; he found that it may be changed to inert forms by oxidation and precipitation.[13] The latter method may be adopted by treatment with soluble iron salts. Recent investigations appear to show that the danger in feeding cotton-seed meal to pigs can be overcome by giving them in drinking water for every pound of cotton-seed meal eaten, for each 100-pound pig, one gallon of a solution of iron sulfate (made by dissolving 1 pound in 50 gallons of drinking water).[14] If further work shows that cottonseed meal can be safely fed to pigs by this method, it will prove of great importance to American agriculture, as it will tend to do away with enormous losses of pigs that occur each year through the feeding of cotton-seed meal either to pigs direct or to steers followed by pigs.

Cotton-seed hulls are also fed to cattle in the South, being used as a roughage and a cheap substitute for hay. They are dry, hard and usually covered with a fuzzy lint. The average composition of cotton-seed hulls is as follows:

Moisture	11.3 per cent
Ash	2.7 per cent
Protein	4.2 per cent
Fiber	45.3 per cent
Nitrogen-free extract	34.1 per cent
Fat	2.2 per cent
	100.0

Ten per cent of the protein has been found digestible; 38 per cent of the fiber, 40 per cent of the nitrogen-free extract, and 77 per cent of the fat, making the amounts of digestible feed constituents found therein:

Protein	0.42 per cent
Carbohydrates and fat	34.77 per cent

The hulls are used as a fuel at the oil mills and, as stated, for stock feeding, either clear or mixed with concentrates, like cotton-seed meal, wheat bran, cracked corn, etc. In the South cotton-seed meal and cotton-seed hulls are often fed as the entire ration for fattening steers, milch cows, and other stock.[15] The hulls are considered of a similar feeding value as a good quality of straw or low-grade hay. In feeding experiments with steers conducted at the Texas station they were found of nearly similar value as an equal weight of sorghum hay.

[13] Journal of Agr. Research, v, p. 261. For literature on experiments with cotton-seed meal, composition, etc., see Ga. Bul. 119.

[14] North Carolina Circular 5; Jr. Biol. Chem. 15, 161.

[15] Farmers' Bulletin 36, pp. 14–15: "Directions for Feeding Cotton-seed Meal and Hulls to Farm Animals;" Texas Bulletin 159.

Immense numbers of steers are fattened in the South on these feeds only, generally mixed in the proportions of four parts of hulls and one of meal. The fattening is continued from 90 to 120 days. Sheep and dairy cows are also fed mixed cotton-seed meal and hulls with good results. "All the information at hand indicates that this practice is both economical and profitable. The diet apparently does not injure the health of the animals, nor impair the healthfulness of the resulting products." [16]

Coconut meal is a by-product in the manufacture of coconut oil from dried broken pieces of coconut kernels (so-called *copra*). It is used very little as a stock feed in this country except on the Pacific coast. It is relatively low in protein, fat, and fiber, its composition being about as follows: 20 per cent protein, 6 to 8 per cent fat, 9 to 10 per cent fiber, and 6 per cent ash.

According to digestion experiments conducted at the Massachusetts station,[17] the protein is 90 per cent digestible, the fat wholly digestible, and the nitrogen-free extract 87 per cent digestible. As the price of coconut meal is generally but slightly higher than that of wheat bran, it is, as a rule, more economical than this feed, especially for dairy cows, but it cannot be fed in as large amounts as wheat bran, nor can it be kept more than a few weeks in warm weather on account of its tendency to turn rancid.

Fresh coconut meal has a pleasant, aromatic flavor and is greatly relished by cattle and other stock; two to three pounds daily is a fair allowance for cattle. It should always be fed mixed with other concentrates. It is also fed to some extent to horses, pigs, calves and poultry.

Soybean meal is the ground residue obtained in the manufacture of soybean oil. The meal fed in this country is imported from either Japan, China, or Manchuria; so far as is known, none is manufactured here, although soybeans are now grown quite extensively in various parts of the United States. It is a valuable concentrate for farm stock, and is one of the richest nitrogenous feeds on the market, containing about as much protein and fat as cotton-seed meal (41.4 per cent and 7.2 per cent, respectively); it has a lower fiber content (5.3 per cent) and a higher digestibility than this meal. According to Kellner, only 3.4 per cent of the protein is present in amide form, and the protein has a digestibility of 97.7 per cent. The soybean meal is, therefore, a highly digestible feed, well adapted for feeding young stock, dairy cows, steers, and other farm animals. It is fed in this country almost entirely on the Pacific coast, where it is used largely for poultry

[16] *Loc. cit.* [17] Bulletin 152.

feeding. It makes a good substitute for linseed meal, pound for pound, for dairy cows, and is one of the most promising concentrates available for stock feeding; the only objection to its use, so far as is known, is its cost, which is, as a rule, considerably above that of linseed meal or cotton-seed meal.

Peanut Meal.—This residue is obtained in the manufacture of peanut oil. It is rarely fed in this country, but it is one of the common oil meals used by European dairy farmers. The meal on the market is manufactured either from hulled or whole peanuts, the former being the more valuable. It is one of our most concentrated and digestible nitrogenous feeds, containing, on the average, nearly 50 per cent protein, 7.3 per cent fat, 5.0 per cent fiber, 24.5 per cent nitrogen-free extract, and 5.2 per cent ash. The protein substances and the nitrogen-free extract are 90 per cent digestible, and the fat 89 per cent digestible. It is, therefore, a considerably richer feed than either cotton-seed meal or soybean meal, and, like these, is well worthy of a trial or a more extended use by our dairy and stock farmers. In Europe peanut meal is fed especially to dairy cows, which receive two or three pounds thereof daily per head, generally mixed with other kinds of oil meal and grain. It is also often fed as sole concentrate, however; a common ration for dairy cows in southern Germany and Switzerland is composed of about 20 pounds meadow hay and two to four pounds peanut meal, according to the production of the cows. It is also a good feed for fattening steers, and is fed to horses as a partial substitute for oats, viz., in place of 13.2 pounds (6 kilos) of oats, 8.8 pounds oats and 2.2 pounds peanut meal, and in place of 11 pounds of oats, 6.6 pounds oats and 3.3 pounds peanut meal. This oil meal is also used with good results in feeding young stock, especially foals. On account of its high fat and protein contents, it has a rather poor keeping quality; it is sometimes adulterated with residues from other oil-bearing seeds or with peanut hulls, and should, therefore, always be bought on analysis.

QUESTIONS

1. Describe the by-products obtained in the manufacture of (*a*) cane-sugar, (*b*) beet-sugar; and give the main uses to which these are put in feeding farm animals.
2. What are the general methods of manufacturing oil meals?
3. Give the main oil meals used for feeding farm animals in this country, and their characteristic properties.
4. Give the swelling test for determining when linseed meal is old- or new-process.
5. Give a simple test for purity of cotton-seed meal.
6. Are cotton-seed meal and cotton-seed hulls used as sole feeds for farm animals; if so, under what conditions and for what purpose?

CHAPTER XIX

ANIMAL FEEDS

I. PACKING-HOUSE FEEDS

The packing-house products used for feeding livestock are dried blood, tankage, meat scraps or meat meal, and bone meal. These feeds are especially valuable for feeding pigs, poultry, and other animals that require a considerable supply of nitrogenous and mineral components in their feed, and do not object to the animal odor of these feeds. The packing-house products are high-protein feeds, and those containing much bone, like meat scraps and tankage, are rich in mineral matter, especially phosphoric acid and lime.

Dried blood or blood meal contains over 80 per cent of protein, sometimes as high as 86 per cent, of which about nine-tenths is digestible, and the small amount of fat present therein has been found wholly digestible. Blood meal (blood flour) is used to some extent in feeding calves, being given in the skim milk, about a teaspoonful per feed. This is considered an excellent source of protein for calves, and is also of value on account of its tonic effect. Other young stock may receive about one-fourth pound per day per 100 pounds, and older animals one to two pounds per head daily. The price of the blood meal stands in the way for its more general use for older animals, however. It must also be fed mixed with other concentrates to such animals, as stock object to the animal odor of both blood and meat products. Digester tankage, meat meal, beef scraps, and similar feeds vary considerably in composition, according to their origin and the amount of bone which they contain. They should always be bought on definite guarantees of protein and fat contents.

Tankage makes a valuable swine and poultry feed. It is made from fresh meat scraps, fat trimmings, and scrap bones. These are thoroughly cooked in large steel tanks under live steam pressure, by which method the tallow is separated. The steam is then turned off, and, when the mass has settled, the tallow is drawn off. The residue is kept agitated and dried till it contains about 8 per cent water, and the tankage is then taken out, allowed to cool, ground, and is ready for shipment. Tankage is generally sold under a guarantee of 60 per cent protein and 6 per cent fat, while meat meal or beef scraps contain 40 to 50 per cent protein, 8 per cent or more of fat, and about 25 per cent ash, largely phosphate of lime (bone).

An important use of meat meal and similar feeds is in poultry feeding. Experiments at Geneva (N. Y.) and other stations have established the superior value of animal proteins in feeding poultry, especially ducks. It is likely that this value depends, to a large extent, on the mineral matter supplied in these feeds, and not especially on the protein which they contain; better results are generally obtained, however, by feeding both classes of nutrients combined in the same feeding stuff rather than separately, as, *e.g.*, grain feeds with ashes or bone meal.

Fish meal, or fish meat meal, contains amounts of protein, fat, and mineral matter similar to good grades of meat meal, and may be considered of about equal value to this feed, pound for pound, for feeding poultry or swine, when manufactured from fresh fish refuse by modern sanitary methods. Besides being a valuable poultry feed, fish meal may be fed to horse and cattle in a limited way where an extra supply of protein in the rations seems desirable. In northern Europe it is occasionally fed to dairy cows in amounts of one to two pounds per head daily, mixed with other concentrates, and is considered an economical feed, well adapted for this purpose, although the cows at first object to its peculiar odor.

Bone meal or ground bone is likewise used for feeding poultry, and, in a small way, with Indian corn for pigs, in order to correct the lack of ash materials in this cereal (p. 300). One-half ounce ground phosphate rock (floats) may be given daily to calves or pigs for the same purpose.[1]

II. DAIRY FEEDS

The dairy products form a most important group of feeds for livestock. Owing to the value of whole cows' milk as a human food, and as the raw material for the manufacture of cream, butter, cheese, etc., it is only used for stock feeding in the case of beef animals, and for dairy and breeding animals during the early life of the calves. It is, therefore, not necessary to describe in this place the chemical or physical properties of all milk, beyond a few observations as to its value for young stock.

Colostrum Milk.—Immediately after calving a thick, viscous liquid, known as colostrum, is secreted by the cow; in the course

[1] Wisconsin Research Bulletin 1.

of two or three days this gradually changes to normal milk. The colostrum differs from milk in its high content of solids, albumen, and ash, while the percentages of fat and sugar which it contains are somewhat lower than those of normal milk. Owing to the high albumen content, colostrum will thicken (coagulate) on heating. The average chemical composition of colostrum and normal cows' milk and milk of other farm animals will be seen from the following table:

Average Composition of Milk, in Per Cent (König)

	Water	Fat	Casein	Albumen	Milk-sugar	Ash
Cows' colostrum....	74.6	3.6	4.0	13.6	2.7	1.6
Cows' milk (normal)	87.3	3.7	2.9	.5	4.9	.7
Mares' milk........	90.8	1.2	2.0		5.7	.3
Ewes' milk.........	80.8	6.9	6.5		4.9	.9
Goats' milk.........	85.7	4.8	4.3		4.4	.8
Sows' milk..........	82.5	5.8	6.3		4.4	1.0

The colostrum of the other milk-producing animals is correspondingly high in albumen and ash compared with that of milch cows. Whole milk is the first feed of young animals, and is a complete feed, containing all the elements necessary for the sustenance and growth of the young. On account of the relatively large fat globules in milk rich in butter fat, this is not, however, adapted for feeding young pigs and lambs; digestive disturbances are likely to occur when such milk is fed,[2] and animals do not make as satisfactory gain on such milk as on whole milk lower in fat or on skim milk. A similar harmful effect of an excess of fat in the milk has been frequently observed in feeding infants.

Calves are fed the dam's milk for only a day or two after freshening in ordinary farm practice, except in the case of beef, exhibition, or breeding stock, which often receive whole milk for several months, when they are fed skim milk, with ground flaxseed, ground grain, or mill feeds until they can eat and digest hay and concentrates (p. 221).

In the feed-unit system three pounds of whole milk are given an equivalent value to one feed unit (one pound of grain). We may assume that it will require six pounds of whole milk, on the average, for a pound of gain with young calves, or one-half the amount of skim milk required.

[2] Storrs (Conn.) Bulletin 31.

Skim milk is used extensively for feeding calves and pigs, and, properly "reinforced," makes an excellent substitute for whole milk in feeding these animals. It is also often fed to poultry. It is now, as a rule, obtained by the centrifugal method, which furnishes a by-product containing, on the average, 9.5 per cent solids, composed of about 0.10 to 0.15 per cent fat, 5 per cent sugar, 3.5 per cent casein and albumen, and 0.9 per cent ash. It is, therefore, essentially a protein feed, with a nutritive ratio of 1 : 2; hence is preferably supplemented in feeding animals with starchy or medium-protein feeds, like cereals, wheat middlings or shorts, etc. Creameries furnish their patrons enormous quantities of skim milk in the aggregate, viz., as a rule, 80 per cent of the milk delivered. The whole milk is also run through a separator on many dairy farms where cream is shipped or delivered to the creamery; the skim milk thus obtained is warm and in the best possible condition for feeding young stock.

The value of separator skim milk for feeding purposes is variously estimated at 15 to 25 cents per hundred pounds; according to the feed-unit system, six pounds of skim milk are of the same value as one pound of grain; at one cent a pound for this ($20 per ton), 100 pounds of skim milk would, therefore, be worth 16 cents, and at 1½ cents for grain it would be worth 25 cents per hundred.

Experiments conducted at the Wisconsin station showed that the best results in feeding skim milk and corn meal to pigs will be reached by feeding these in the ratio of 3 to 1. Assuming that five pounds of corn meal fed alone would produce a pound of gain, the value of 100 pounds of skim milk would be 31 cents, with corn at $20 per ton; 46 cents with corn at $30 per ton. The rule given by Gurler as to the value of the skim milk is that 100 pounds when fed with corn to fattening pigs are worth one-half the market price of a bushel of corn (56 pounds).

Unless fed perfectly sweet and under sanitary conditions, skim milk will be likely to cause scouring in calves; pasteurized skim milk is less apt to give trouble in this respect, and it is important, therefore, that creameries adopt the method of pasteurizing the skim milk before it is returned to the patrons. This will also improve the keeping quality of the milk and will serve the still more important object of removing the danger of spreading tuberculosis through the skim milk, as the tubercle bacillus is readily killed on heating to pasteurizing temperatures of 160° F. or over (Fig. 39).

Buttermilk is the by-product obtained in the manufacture of butter. It is used especially as a feed for growing and fattening pigs. It contains, on the average, somewhat less than 10 per cent solids, viz., 0.5 per cent fat, 4 per cent casein and albumen, 4.4 per cent milk-sugar, and 0.7 per cent ash. It does not, therefore, differ materially from skim milk in composition, and extensive comparative feeding experiments conducted by the Copenhagen station and elsewhere have shown that buttermilk is very nearly of the same value as skim milk for feeding pigs. It can also be fed to calves with good results, if special care is taken to feed it in fresh condition and in small amounts at the start, so as to gradually

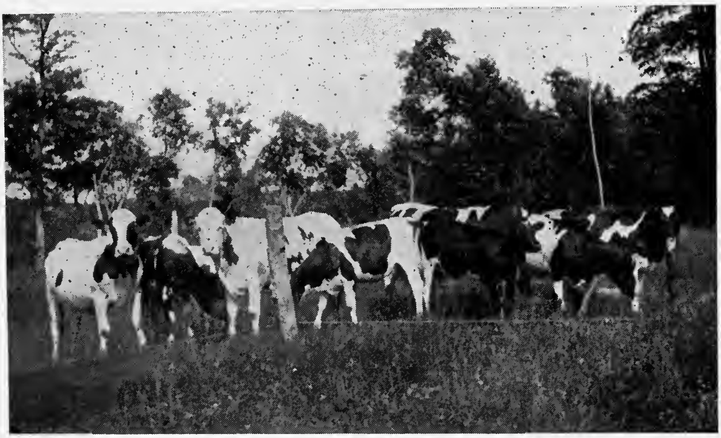

FIG. 39.—Holstein skim-milk calves—promising stock for the dairy herd.

accustom the stomach of the young animals to it. Unless it can be fed in the manner suggested and with the most scrupulous cleanliness, the attempt had better not be made to feed buttermilk to calves, as disastrous results are likely to follow.

Whey is obtained as a by-product at cheese factories, and is supplied to patrons in large quantities. It contains only about 6.6 per cent solids, viz., 0.3 per cent fat, 0.85 per cent albumen (with a little casein in suspension), 4.8 per cent milk-sugar, and 0.65 per cent ash. Whey is a more dilute and more carbonaceous feed than either skim milk or buttermilk (nutritive ratio, 1:9, against about 1:1.5 for skim milk and buttermilk); hence it may be better supplemented by protein feeds than these, like wheat bran, small grains, and oil meal. Whey is fed to pigs almost entirely; its value for this purpose has been found to be about one-half of that of skim milk or buttermilk. This would make 12 pounds of whey equal to one pound of grain feed in feeding value. It has also occasionally been used as a calf feed, but the preceding remarks as to feeding buttermilk to calves apply with still greater force to whey. It must be fed fresh and sweet, if used for this purpose, and with the utmost care as to the various factors that make for successful calf feeding (p. 220).

QUESTIONS

1. What packing-house feeds are used for feeding farm animals? Give the characteristic properties and uses of each.
2. What is colostrum milk?
3. Name the dairy by-products used for feeding farm animals.
4. What are the characteristics of each? Name their uses.
5. What is the average composition of (*a*) cows' milk, (*b*) mares', ewes', goats', and sows' milk? In the case of the latter kinds, give fat contents only.
6. What is the relative feeding value of whole milk, skim milk, buttermilk, and whey for feeding calves or pigs?

CHAPTER XX

MISCELLANEOUS FEEDS

I. Proprietary Feeds.—A large number of different kinds of mixed feeds, mostly proprietary feeds, are on the market and are sold for feeding different classes of farm animals. The names under which they are sold often indicate the purpose for which they are intended, like dairy feeds, horse, calf, swine feeds, etc. Some of these feeds possess considerable merit and may be bought at prices that render them economical in comparison with standard stock feeds; others may likewise have merit, but are sold at excessive prices, and others, again, are neither desirable nor economical feeds and may safely be left alone. Unfortunately, the majority of the proprietary feeds belong to the last class. The farmer should aim to be relatively independent of feed manufacturers by raising his own feed so far as practicable, and to supplement these through the purchase of standard feeds of the kind required for the special feeding operations in which he is engaged. The mixed feeds on the market, as a rule, are bought by farmers who are either so situated that they cannot raise much of their own feed or who have not posted themselves sufficiently on the subject of feeding stuffs to know that these mixed feeds do not necessarily possess any merit above that of ordinary well-known feeding stuffs, and that statements on the advertising circulars of feed manufacturers must often be considerably discounted.

There are, however, as suggested, many proprietary feeds on the market which may be purchased at reasonable prices and under definite guarantees of minimum contents of protein and fat, and maximum fiber contents, which are, moreover, made by reliable manufacturers who value their business reputation and furnish feeds of at least the value suggested by the guarantees. Where such feeds can be bought at fair prices and fit into the system of feeding practised by the farmer, there is no reason for not giving them a trial. Among these feeds are a number of alfalfa molasses feeds, the brewery molasses feeds, mixed grain or mill feeds, etc.; also some of the calf meals (if not too high priced) and poultry feeds.

II. Feeds of Minor Importance.—Besides the feeding stuffs mentioned in the preceding, a large number of materials find a limited use for feeding farm animals in different parts of the world; a few of these will be briefly considered in the following.

Leaves and twigs of brush and trees are a favorite feed for goats, and also used for feeding cattle and sheep in the northern part of the Scandinavian countries and Finland, being harvested and tied in bundles in the summer and fed during the winter months as a partial substitute for hay, which often cannot be obtained in sufficient quantities to carry the animals through the season. Birch, ash, and linden are commonly harvested for this purpose. The dried leaves and small twigs of these trees, fed in a limited amount, make a fair feed for the animals mentioned, as well as for goats, and have about similar nutritive value as the lower grades of hay or straw. Brush feed has been recommended as a carrier for molasses in feeding farm stock, and is used for this purpose to a limited extent.[1] It consists of leaves, twigs, and small stems of underbrush, which are run through a cutter and crusher, and molasses is afterwards mixed with the material. Enthusiastic reports of such molasses feeds are on record, but their feeding value has not yet been determined by means of carefully-conducted experiments.

Acorns and beechnuts are used as a swine feed on the Continent in Europe, and in a small way in this country in the South and in California, the animals being driven to the woods in the fall and fattened upon the nuts that they pick up from the ground. According to the Tuskegee, Alabama, station,[2] acorns and kitchen slop make a good feed for swine, about five pounds of acorns being fed per head daily. The tendency of beechnuts to make soft pork of inferior quality may be partially overcome by feeding peas, horse beans, or grain for several weeks prior to slaughtering time. The effect of acorns on the quality of the pork is similar to that of beechnuts; hogs fed exclusively on acorns furnish pork of a very low grade and are generally discriminated against by buyers.[2] Both these nut and brush feeds contain considerable quantities of tannin which renders them bitter and less palatable to stock than ordinary feeding stuffs.

Icelandic moss is another material that is sometimes used for feeding cattle in extreme northern countries. It may be inferred that this possesses considerable feeding value from the fact that it forms the main and often sole feed of the reindeer in these northern regions. Its digestibility and nutritive effects[3] have been studied

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[1] Wisconsin Circular 30, p. 94.
[2] Bulletin 93.
[3] Pott, "Futtermittellehre," ii, 1, p. 569.

by Isaachsen, of the Agricultural College of Norway.[4] It is essentially a starchy feed, containing about 50 per cent nitrogen-free extract, 42 per cent fiber, and only 3 per cent protein.

III. Condimental Stock Feeds.—Condimental stock feeds, stock tonics, etc., are sold everywhere and in large quantities in the aggregate. In so far as these materials claim to be feeds and to possess actual nutritive properties, they can be dismissed at once, as they are not fed in sufficient quantities to be of any importance whatever as feeds, and are, furthermore, too expensive to be used for this purpose. As regards their value as tonics and medicine, on the other hand, the examinations made of the materials have shown that they do not contain sufficient amounts of substances possessing medicinal properties to have any influence on stock one way or the other. A large bulk (one-half or more) of the stock feeds are made up of some common feeding stuffs, like mill feeds, corn meal, oil meal, ground screenings, etc., and the balance generally consists of salt, charcoal, or sulfur, with a small amount of mild drugs or condiments, like gentian, fenugreek, sassafras, ginger, pepper, etc. The doses of these condiments which an animal receives in an ounce or two of the stock feed, fed as directed, are too small to have any medicinal effect whatever, as they make only a small fraction of the dose recognized by veterinary science, on account of the small proportions in which they are present in the stock feeds.

The preceding remarks are largely based on theoretical considerations, which, however weighty they are, may not settle the matter in the minds of many people. The stock feeds have, however, been tried out at more than a dozen different experiment stations, and the results obtained in the trials are given in the publications of these stations and may be studied by all interested. The author made an investigation of the main stock feeds on the American market several years ago and compiled the results obtained on all experiments that were conducted with them up to that time in this and foreign countries. In these experiments 992 farm animals were included in all, viz., 78 steers, 81 dairy cows, 604 sheep, 112 pigs, and 117 hens. Out of the 23 different trials compiled, only two showed the stock feed to possess any merit, and the interpretation of the results of the two exceptions is open to question. The evidence is, therefore, practically unanimous against the use of condimental stock feeds, and goes to show that, when fed under condi-

[4] *Ber. Norges Landbrukshöjsk,* 1905–6, p. 202; *Tidsskr. norske Landbr.,* 1910, No. 10.

tions similar to those that prevailed in these experiments, the addition of a stock feed to the ration is a positive disadvantage, both with reference to the production of the animals and the relative cost of the production.

Home-made Stock Tonics.—If a farmer considers it necessary to use stock feeds for animals in poor condition of health, off feed, or ailing in one way or another, that is not plainly a case for a veterinarian to attend to, it would seem that the better plan would be to buy the separate ingredients at a drug store and mix them in the proportions indicated below. He will save money thereby and will have the satisfaction of knowing just what he is feeding his stock and of feeding it in a much more concentrated form than in the case of commercial preparations. The following three mixtures of drugs, etc., have been suggested by the Vermont station [5] and the Iowa station (Formula 3):[6]

Formula 1.—Ground gentian, one pound; ground ginger, ¼ pound; powdered saltpeter, ¼ pound; powdered iron sulfate, ¼ pound. Mix and give one tablespoonful in feed once daily for ten days, omit for three days, and feed as above for ten days more.

Formula 2.—Fenugreek, ½ pound; ginger, ½ pound; powdered gentian, ½ pound; powdered sulfur, ½ pound; potassium nitrate, ½ pound; resin, ½ pound; cayenne pepper, ¼ pound; ground flaxseed meal, 3 pounds; powdered charcoal, 1½ pounds; common salt, 1½ pounds; wheat bran, 6 pounds.

Formula 3.—Powdered gentian, 1 pound; powdered ginger, 1 pound; fenugreek, 5 pounds; common salt, 10 pounds; bran, 50 pounds; oil meal, 50 pounds.

Summary.[7]—The evidence at hand with regard to condimental stock feeds shows that there is practical unanimity of opinion among scientific men who have given the subject special study, in regard to several points connected with these so-called feeds or tonics.

1. They are of no benefit to healthy animals when fed as directed, either as to increasing the digestibility of the feed eaten or rendering it more effective for the production of meat, milk, wool, etc.

2. They are of no benefit as a cure-all for diseases of the various classes of live stock; neither do they possess any particular merit in case of specific diseases, or for animals out of condition, off feed, etc., since only a small proportion of ingredients having medicinal

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[5] Bulletin 104.

[6] Bulletin 87.

[7] Condensed from Wisconsin Bulletin 151, "Condimental Stock Feeds," by the author (May, 1907, 40 pp.). Bibliography on stock feeds up to 1907 is given in this bulletin.

value is found therein, the bulk of the feeds consisting of a filler which possesses no medicinal properties whatever.

3. Exorbitant prices are charged for these feeds, as is natural, considering the extensive advertising the manufacturers are doing and the liberal commissions which they pay agents and dealers. The large sales of stock feeds are doubtless mainly to be attributed to these facts.

4. By adopting a liberal system of feeding farm animals and furnishing a variety of feeds, good results may be obtained without resorting to stock feeds of any kind. If a farmer considers it necessary to give stock feeds at times, he can purchase the ingredients at a drug store and make his own at a fraction of the cost charged for them by the manufacturers.

The preceding conclusions may be said to give the case against the condimental stock feeds. It is only fair to state, as the other side of the case, that the suggestions for better care and feeding of stock which have come from the advertising matter issued by stock feed manufacturers, or from their agents, have doubtless been of value to many farmers and have been productive of results. As many people are not disposed to heed advice that is given without cost, it may be that indirectly the money spent for condimental stock feeds has not in some cases been wholly wasted.

QUESTIONS

1. What is a proprietary feed, and to what extent is it wise to use such a feed?
2. Name three miscellaneous feeds of minor importance for feeding stock.
3. State how and for what class of farm animals each is used.
4. What is a condimental stock feed?
5. State the main conclusions to which experiments with these materials have led.
6. Is it necessary to feed condimental stock feeds to farm animals? If not, what would you use in their place?

PART III
PRODUCTIVE FEEDING OF FARM ANIMALS

CHAPTER XXI

CALF FEEDING

Feeding Standards for Calves.—The following tables give the feed requirements for growing cattle, according to the standards of Wolff-Lehmann and of Armsby:

I. Wolff-Lehmann Standards for Growing Cattle—1000 pounds live weight

	Age, months	Live weight, pounds	Dry matter	Digestible		N. R.
				Protein	Carbohydrates and fat*	
For dairy breeds.......	2–3	150	23	4.0	17.5	1:4.5
	3–6	300	24	3.0	15.1	1:5.1
	6–12	500	27	2.0	13.6	1:6.8
For beef breeds........	2–3	165	23	4.2	17.5	1:4.2
	3–6	330	24	3.5	16.2	1:4.7
	6–12	550	25	2.5	14.8	1:6.0

* Given separately by Wolff-Lehmann.

II. Armsby Standards Per Day and Head

Age, months	Live weight, pounds	Digestible protein, pounds	Energy value, therms
3	275	1.10	5.0
6	425	1.30	6.0
12	650	1.65	7.0

Birth Weights and Gains made by Calves.—New-born calves weigh from 40 to over 100 pounds each, according to the size of the parents. Beach gives the average birth weight of calves of the dairy breeds as follows:[1] Ayrshire, 77 pounds; Guernsey, 79 pounds; Holstein, 107 pounds; Jersey, 67 pounds. These weights were 7 to

[1] Connecticut (Storrs) Report, 1907.

9 per cent of the average weights of their respective dams, which were all mature cows. According to Eckles, the average birth weights of calves in the University of Missouri dairy herd were: Ayrshire, 64 pounds; Holstein, 89 pounds; Jersey, 53 pounds, and Dairy Shorthorn, 76 pounds, these weights being 6 to 8 per cent of the weight of the dam.[2] The records show that bull calves average about ten pounds heavier than the females at birth; the maturity of the cow is also of importance, the birth weight of calves from heifers and young cows being, on the average, about five pounds lower than that of calves from cows that had given birth to three or more calves.

Gains Made by Calves.—In experiments at the Kansas station, calves reared on skim milk, grain and pasture from birth until one year old made the average gains during the successive months shown in the following table:[3]

Weight of Calves from Birth till One Year Old, in Pounds

Age, months	Average weight	Average gain made	Number of calves	Age, months	Average weight	Average gain made	Number of calves
Birth	77	..	23	..	...	..	..
1	111	34	45	7	403	54	38
2	144	33	56	8	455	52	28
3	181	37	60	9	515	60	21
4	229	48	60	10	578	63	20
5	287	58	54	11	626	48	20
6	349	62	43	12	669	43	19

The gains made during the respective months were lowest during the first three months and higher toward the end of the year, with gains of about one pound per head daily during the first months, and about two pounds per head daily during the fifth to the tenth month; the average daily gain during the entire year was 1.6 pounds per head.

The method of feeding the calf will vary according to the purpose in view: Whether it is to be added to the dairy or beef herd, or is to be vealed. After considering some general phases of the subject of calf feeding, we shall take up separately the feeding of calves for the various purposes mentioned (Fig. 40).

Feeding Stuffs for Calves.—The number of different feeds used for feeding calves is not as large as in the case of mature

[2] "Dairy Cattle and Milk Production," p. 174.
[3] Bulletin 126; see also Illinois Bulletin 164.

animals. The more important calf feeds are: Whole milk and dairy by-products, milk substitutes, hay, and various concentrates.

Whole milk is the natural feed for calves, both as to the character of its nutrients and the proportion in which these occur. It forms their sole feed for a period of a week or two to several months, according to the purpose in view, whether the calf is to be added to the breeding herd or to be vealed.

FIG. 40.—Dairy calves in the pasture—an old-country scene.

Only the fourth stomach (abomasum) of the new-born calf is fully developed; the other three compartments are small and do not take part in the digestion of the feed until the calf is old enough to eat solid feed. The lining of the fourth stomach of the young calf contains a considerable amount of the ferment rennin, and large numbers of such calves are killed annually in Europe, especially in Bohemia, to supply the demand for rennet stomachs used in the manufacture of cheese. As the calf learns to eat solid feed, the other compartments of the stomach gradually develop, and the digestive processes become similar to those of grown animals.

The amount of whole milk required for one pound of gain will vary considerably, according to the age of the calves. During the first few weeks, 4 to 6 pounds will make one pound of gain under favorable conditions, while with older calves it will require 8 to 12 pounds to produce a pound of gain.

Whole milk will produce larger gains in live weight than skim milk or other feeds, but this is made at considerably higher cost, on account of the high value of whole milk as a human food. If we assume that it will take 6 pounds of whole milk to make one

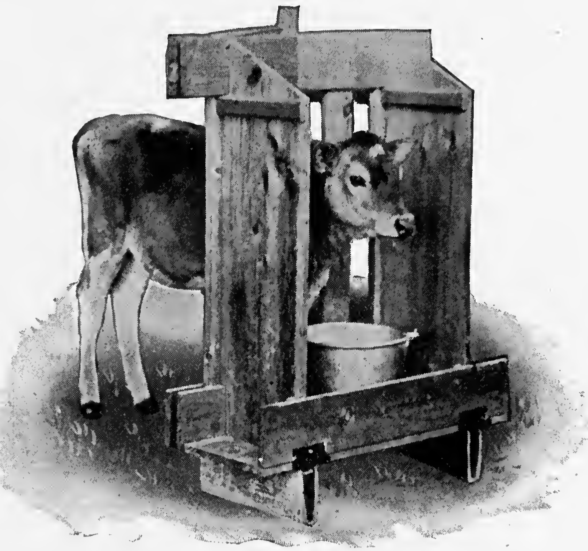

FIG. 41.—At meal time the calf is fed warm, sweet milk in a clean pail, while securely fastened in a comfortable stanchion. (Wisconsin Station.)

pound of gain in a young calf and 12 pounds of skim milk (p. 206), the cost of the ration will be 6 cents in the former case, and 1.8 cents in the case of skim milk at ordinary creamery prices—$1.00 per hundred pounds for whole milk and 15 cents per hundred pounds of skim milk. In experiments at the Kansas station it cost four times as much to produce a pound of gain with calves on whole milk as on skim milk, although the whole-milk calves gained an average of 1.86 pounds daily, against 1.51 pounds for the skim-milk calves.[4]

Looking at the problem from another point of view, Otis found that two pounds of grain, when fed with the proper amount of skim milk, were equivalent for calf feeding to one pound of butter

[4] Bulletin 126; Wisconsin Bulletin 192.

fat in whole milk. With butter fat at 25 cents per pound, 100 pounds of grain (worth $1.00 to $1.50) will take the place of $12.50 worth of butter fat, and at 30 cents for butter fat it will take the place of $15 worth of butter fat. Feeding whole milk or poorly-skimmed milk to calves is, therefore, generally speaking, a very expensive and wasteful method, since skim milk with only a slight fat content, fed with grain feed, will produce almost as good results.

Skim Milk.—The value of skim milk and other dairy by-products for calf feeding has already been considered (p. 207). After the second or third week skim milk may gradually take the place of whole milk, the proportion of the latter being slowly decreased and that of skim milk increased until after a week or ten days the calf will be getting only skim milk. This is fed warm and

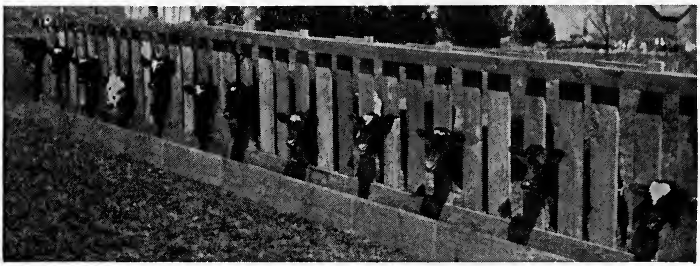

Fig. 42.—Calves in stanchions in pasture. ("Productive Farming," Davis.)

sweet, and is most conveniently fed fresh from the separator. The foam of separator skim milk should always be skimmed off before feeding the milk to calves, as it tends to cause digestive troubles and bloating; colic and scouring resulting in death may follow in aggravated cases, if this precaution is neglected. A calf may be fed from 10 to 12 pounds of skim milk daily in three feeds until about six weeks old, when the amount may be increased to 16 pounds or more, if he can handle it without scouring, and this is given in two feeds, one-half at each meal.

It requires constant care and watchfulness to raise a skim-milk calf or one fed other dairy by-products; all sudden changes and irregularities in feeding must be avoided, as well as a too liberal allowance of milk (Figs. 41 and 42). Overfeeding or injudicious feeding is a frequent cause of calf scours, and when this occurs the feed or milk must be reduced or withheld for a time, and special treatment resorted to.

Remedies for Calf Scours.—1. A teaspoonful of sterilized dried blood (so-called blood flour), thoroughly mixed with the milk at each meal, will generally remedy the trouble when it is promptly attended to. The blood meal also serves as an excellent tonic for weak calves.

2. In aggravated cases of calf scours the milk is withheld and an egg in a tablespoonful of blackberry brandy is given three times a day till improvement is noted.

3. The formaldehyde treatment is another remedy that will produce good results in most cases after a few days.[6] A teaspoonful of a 1 per cent. formaldehyde solution (prepared by adding one-half ounce of formaldehyde, 40 per cent., to a pint of water) is added per pint of milk, preferably fed immediately after the skim milk is received from the separator.

Rules for Feeding Young Calves.—The following rules epitomize the main precautions to be observed in feeding young calves.[7]

Do not overfeed. Feed sweet, preferably fresh, milk. Feed warm milk (85°–90° F.). Feed each animal individually. Feed regularly. Keep pens and calf quarters thoroughly clean, dry and free from draft. Make only gradual changes in feed. Pay strict attention to condition of the bowels.

"Where skim milk calves do poorly the blame usually rests with the feeder. The cause of the trouble will ordinarily be found in 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 become stale in the feed box" (Henry).

Supplemental Feeds with Skim Milk.—In order to compensate for the butter fat removed in the skim milk, many different methods have been recommended, and are followed with success by different farmers. Peanut oil, cod-liver oil, corn oil, or oleomargarine heated to 110° F. and mixed thoroughly with the skim milk, is used to a limited extent, these fats being added in the proportion of one-half to one ounce per quart of milk. The most common and efficient supplemental feed for skim-milk-fed young calves is, doubtless, flaxseed. This may be added either direct, a tablespoonful of ground flaxseed per quart of milk, or the meal is boiled into a jelly with six parts of water, which is mixed with the skim milk in small amounts, the equivalent of two tablespoonfuls of the dry meal to a feed.

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[6] S. C. Bulletin 122; Farmers' Bulletin 273. *White Scours* or so-called calf cholera is a contagious disease that may attack calves when only a day or two old. Repeated applications of tincture of iodine or of a 2 per cent solution of corrosive sublimate on the navel of the newborn calf and thorough disinfection of the calf pens and barn are remedial measures. The disease is often fatal and calls for assistance by a veterinarian.

[7] Missouri Circular 47. See also Wis. Cir. 59.

The amount of skim milk required for one pound of gain in feeding calves will range from about 8 pounds to 20 pounds, the amount of milk required increasing with the age and weight of the calves. When two to three weeks old, the calf will begin to eat some grain; the best way to teach it to eat grain is to rub a little on its mouth when it is through drinking milk. From this it will soon learn to eat from the feed box.

Many experiments have been conducted with feeding calves for the purpose of determining the value of different grain feeds to be fed supplementary to skim milk. In the corn-growing states corn meal will prove the best and most economical supplementary feed with skim milk; it is also theoretically best suited for this purpose, being higher in starch than either of the other common grain feeds (N. R., 1 : 9.5), while the skim milk is essentially a protein feed (N. R., 1 : 2). Because of its constipating effects, ground kafir corn is well suited to be fed with skim milk. Some feeds cannot, on the other hand, be used for calf feeding with skim milk, or must be fed with great care, for the reason that they tend to increase the danger of scouring; examples are cod-liver oil, molasses, soybeans, and linseed meal.

Grain Feeds for Calves.—The following list, prepared by Otis, may serve as a guide in making combinations of grain feeds to be fed with skim milk to suit different conditions:

1. Corn meal, gradually changed in four to six weeks to shelled corn, with or without bran.
2. Whole oats and bran.
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 corn or sorghum.
6. Whole oats, ground barley, and bran.
7. A mixture of twenty pounds of corn meal, twenty pounds of oatmeal, twenty pounds of linseed meal, ten pounds of blood meal, and five pounds of bone meal, changed to corn, oats, and bran when calves are three months old.
8. A mixture of five pounds whole oats, three pounds bran, one pound corn meal, and one pound of linseed meal.

Roughage for Calves.—Calves will nibble at roughage at about the time they begin to eat a little grain, at two or three weeks old. Fine, bright hay of either early-cut blue-grass or mixed grasses makes the best roughage for calves. Alfalfa or clover hay of choice quality is also excellent, but must be fed with some care to young calves to prevent scouring. Hay sufficient for a day may be placed in a rack in a corner of the calf pen; any residue should be removed before a new supply is given. As the calf grows older, it will eat more roughage; at about six months old it will take about three times as much roughage as grain; a part of the former may be of succulent character. As a capacity for digesting large amounts of coarse feed is important in the case of both dairy and beef cattle, it is a good plan to develop the digestive apparatus of the calf by feeding all the fine hay it will eat, along with the grain given.

Succulent Feeds.—Corn silage of good quality made from at least nearly matured corn and free from mold may be fed to advantage in small quantities, say about two pounds a day to calves that are old enough to eat it; older calves may be fed five to ten pounds with dry feed. Roots are also excellent for calves. Pasture grass will give good results with calves four months old or over. To overcome the tendency of scouring when the calves are turned on to pasture, they may be fed some soiling crops during the first days, or may be left in the pasture only a short time daily at first, so as to gradually accustom them to the green feed.

Water and Salt.—Calves should receive both water and salt regularly. Otis states that at three months of age a calf will drink, on the average, five quarts of water daily. They like to drink often, sipping a little at a time. A half barrel, cleaned and replenished twice daily, will serve nicely as a water trough. Another good device is an automatic waterer, which may be easily cleaned, placed a little above the floor to keep out the litter. Salt is essential to the normal development of the calf, as of other farm animals, and should be given regularly or kept before the calves all the time.

Substitutes for Skim Milk.—On account of the large proportion of whole milk sold for direct consumption, to condensed milk factories, or to cheese factories, many farmers do not have skim milk to feed young stock, and numerous special calf meals have as a result been placed on the market to serve as a substitute for skim milk in calf raising.

Composition of Calf Meals.—The following table shows some of the more important of these and their chemical composition:

Chemical Composition of Calf Meals, in Per Cent

	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash
Blatchford's calf meal*	10.73	25.00	5.19	6.21	47.98	4.89
Schumacher calf meal†	9.59	19.72	7.95	1.82	58.56	2.36
Lactina Suisse‡	7.30	29.75	6.20	3.00	44.01	9.74§
Sugarota calf meal*	9.81	24.58	5.10	4.19	52.37	3.95
No-Milk calf meal*	10.49	20.05	5.26	4.86	54.92	4.42
Martin's calf feed*	10.83	27.31	5.86	6.76	44.60	4.64
Average (six brands)	9.79	24.40	5.93	4.47	50.41	5.00

* Wis. Cir. 30. † Wis. Cir. 22. ‡ Mfr.'s guarantees. § By difference.

We note that the different brands of manufactured calf meals are high in protein, fat, and nitrogen-free extract, and low in fiber. Being composed of standard feeding stuffs of unquestioned merit, such as ground cereals, mill feeds, ground flaxseed, and oil meal, they are doubtless highly digestible and possess a high feeding value; their use will, therefore, depend upon the price at which they are sold in comparison to other feeds suitable for calf feeding. On this point it must be said that the prices charged for these feeds by manufacturers and dealers are, as a rule, high, being generally $2.50 to $3.50 per hundredweight. Most dairy farmers can do better by making their own calf meals from standard and easily obtainable feeds, than to buy these manufactured feeds, unless they want to use only small amounts for individual calves that need some extra feed and care. Two of these meals (Blatchford's and No-Milk), have small amounts of mild drugs which contain aromatic principles, and, as suggested, all are palatable feeds of a high nutritive value. The question is, however, whether a dairy farmer cannot obtain as good results with less expensive mixtures made from common standard farm feeds. It seems evident that, as a general rule, he can do so. The following mixture will prove a very satisfactory calf feed and may be made by any farmer at a relatively low cost: 20 parts each of ground oats and wheat middlings, 10 parts corn meal, and 5 parts linseed meal or ground flaxseed (nutritive ratio 1:4.6).

A number of experiments have been conducted with calf feeds, the most extensive ones being, perhaps, the Cornell tests.[6] The conclusions drawn from these experiments are, briefly stated, that good, strong, healthy calves can be raised without skim milk; skim milk, hay and grain make the best substitutes for whole milk for raising calves. A calf fed on skim milk should reach a weight of 300 pounds at five months of age, and the gain should be made at the rate of one and one-half pounds per day. If skim milk is not at hand, the best substitute for it seems to be third-grade dried skim-milk powder. A calf fed on this feed should reach a weight of 250 to 260 pounds at five months of age, making an average gain of 1.25 pounds per day. The manufactured meals did not, in general, produce economical gains. The calves on the best of these gained, on the average, 1.25 and 1.10 pounds per day during two

[6] Bulletins 269 and 304; see also Ontario Agricultural College Report, 1900, 1905; and Monthly Bulletin International Institute of Agriculture, vol. 4, 1914, p. 509.

successive years. At eighteen months of age there was apparently no less constitutional vigor manifested by the animals that were in poor condition at fifteen months of age, due to feeding them substitutes for skim milk, than by the animals that received skim milk, and which were in better condition at that age.

The Dairy Calf.[7]—The main point to be borne in mind in the feeding and the development of the dairy calf is to guard against an accumulation of fat in the animal, which would seriously interfere with the usefulness of the future cow in the dairy. Feeds of a fattening tendency are, therefore, to be avoided, and only such feeds are given as will develop a vigorous muscular frame and bone structure. With this end in view, the feeding of full milk to the dairy calf is discontinued after a couple of weeks, or before, in case of milk rich in butter fat, and separator skim milk is fed in its place, the change from one feed to another being made gradually, so as not to give rise to digestive disorders. The equivalent of about two ounces of flaxseed meal, boiled into a jelly with water (one part meal to six of water), is fed daily with the skim milk. At two to three weeks of age, other feeds are given, preferably oats, wheat middlings, or a mixture of both. Some feeders report good results from feeding farm-grains with skim milk after the second week. The calves will gradually learn to eat hay, if it be placed before them; a fine quality of clover or alfalfa hay or any good early-cut mixed hay is generally reserved for this purpose. The object in view throughout the first year should be to keep calves in a healthy growing condition, and to feed plenty of hay so as to develop the digestive apparatus of the calf, along with easily digestible feeds that will cause a rapid, normal growth without deposition of unnecessary body fat. Other desirable feeds for older calves than those mentioned are mill feeds, small grains, especially barley, oil meal, brewers' and distillers' grains, and malt sprouts. Cotton-seed meal, on the other hand, should be fed only sparingly, or not at all.

Fall calves, as a rule, are to be preferred to spring calves on dairy farms, both because they can receive better care and attention during the winter months than in summer, and because they will go on pasture in the spring at an age when their digestive apparatus is developed so that the green grass may form their main feed, supplemented with some grains when pastures are scant. The time

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[7] Adapted from an article by the author, on "Feeding Dairy Cattle," in Cycl. Amer. Agr., vol. iii.

for calving of cows in a dairy herd, however, must be distributed over the year to some extent, so as to insure a fairly uniform milk supply throughout the year.

The Beef Calf.—The method of feeding beef calves differs from that of feeding dairy calves mainly in the fact that they are fed more heavily so as to make more rapid gains than the latter. The beef calf is left with the dam or fed whole milk for two or three weeks to as many months, if milk does not bring more money used for other purposes. In the latter case, the calf is gradually brought over to skim milk; when older, the calf will eat hay and grain, and is fed increasing amounts of grain from this time on until ready for the market. Suckling beef calves fed whole milk should show a gain of three pounds per day for the first month, two and one-half pounds for the second, and two pounds thereafter, according to Henry, and should weigh 400 to 500 pounds at six months old. A calf at this age will eat approximately five pounds whole corn, two pounds whole oats, and one-half pound linseed meal a day; it should have plenty of good clover or alfalfa hay in addition. The grain is increased after the calf is able to eat more with a good appetite, since the more he will eat, the faster he will gain, and the sooner he will be ready for market. If the calf is intended for "baby beef" (p. 269) and is to be marketed when sixteen to eighteen months old, the feeding is especially heavy so as to secure as rapid gains as possible. Only beef-bred bulls of a low and compact build will produce calves that are suitable for this purpose. Beef calves on whole milk or skim milk are fed chiefly corn; for fattening this is supplemented by oats, wheat bran, or linseed meal. Other important feeds for beef calves are pasture, corn silage, and roots; the two latter feeds are of the greatest value in enabling steers to stand heavy grain feeding without getting "off feed" or being subjected to digestive disorders.

The Veal Calf.—Bull calves or heifer calves that are deficient in any way and are not wanted for the dairy herd or beef herd are generally killed at once or sold to buyers that make veal of them. For the highest grade of veal, whole milk is the only feed given, and the feeding is pushed as fast as possible so as to secure rapid gains and get the calf ready for market in prime veal condition. There is a strong demand for choice veal of this kind in Europe, and calves fattened on whole milk exclusively bring fancy prices; also in this country the demand for such veal is increasing in the large cities. Calves fed whole milk only can be readily distinguished

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by experts by the white of the eye being free from any yellow tint and the inside of the eyelids, lips and nose being perfectly white.[8]

QUESTIONS

1. What is the average birth weight of dairy calves, and how is it influenced?
2. Give the main feeding stuffs used for feeding calves.
3. Discuss briefly when they are used and their relative values.
4. Give three remedies for calf scours.
5. Give the main precautions to be observed in feeding young calves.
6. Name half a dozen different combinations of grain feeds that may be fed with skim milk to calves.
7. State the general value of calf meals.
8. Outline the method of raising (*a*) a dairy calf; (*b*) a beef calf; (*c*) a veal calf.

Reference Books.—Students are referred to the following books on the general subjects of feeding farm animals:

Henry, "Feeds and Feeding," Madison, Wis., 1912.
Jordan, "The Feeding of Animals," New York, 1912.
Armsby, "Manual of Cattle Feeding," New York, 1887.
Armsby, "Principles of Animal Nutrition," New York, 1908.
Smith, "Profitable Stock Feeding," Lincoln, Neb., 1906.
Harper, "Manual of Farm Animals," New York, 1911.
Shaw, "The Feeding and Management of Live Stock," St. Paul, Minn., 1912.
Burkett, "First Principles of Feeding Farm Animals," New York, 1913.
Plumb, "Types and Breeds of Farm Animals," Boston, 1906.
Youatt-Fream, "The Complete Grazier," London, 1908.
Kellner, "The Scientific Feeding of Animals" (trans. by Goodwin), London, 1909.
Wolff, "Farm Foods" (trans. by Cousins), London.
Hall, "The Feeding of Crops and Stock," New York, 1911.
Allen, "The Feeding of Farm Animals," Farmers' Bulletin 22, 1901.
Armsby, "The Maintenance Rations of Farm Animals," Bureau of Animal Industry, Bulletin 143, 1912.
Armsby, "The Computation of Rations for Farm Animals by the Use of Energy Values," Farmers' Bulletin 346, 1909.
Savage, "Computing Rations for Farm Animals," Cornell Bulletin 321, 1912.

Literature on Calf Feeding.—Conn. (Storrs), r. 1903, b. 31; Ga., b. 90; Idaho, b. 48; Iowa, r. 1891, b. 35; Ill., b. 164, c. 118; Ind., b. 47; Kans., b. 97, 126; Ky., b. 171; b. 104; Md., b. 77; Mass., r. 1893, 1903, 1904, 1908; Mich., b. 257; Minn., r. 1894; Miss., 1894, b. 8; Mo. b. 57, c. 47; Nebr., b. 68, 75, 87; N. H., b. 58; N. C., b. 199; Penna., r. 1891, b. 60; S. C., b. 122; Utah, b. 57; Va., b. 172; Wis., b. 1, 6, 7, 192.

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[8] For descriptions of the methods of feeding adopted in making Scotch and Dutch veal, see Henry, "Feeds and Feeding," 10th ed., p. 314.

CHAPTER XXII

FEEDING DAIRY CATTLE

Feeding Standards for Dairy Cows.—In studying the best methods of feeding dairy cows, the leading standards should be kept well in mind.

I. The Wolff-Lehmann Standards for Dairy Cows—1000 pounds live weight

Daily milk yield	Total dry matter	Digestible		N. R.
		Protein	Carbohydrates and fat *	
11.0	25	1.6	10.7	1:6.7
16.5	27	2.0	11.9	1:6.0
22.0	29	2.5	14.1	1:5.7
27.6	32	3.3	14.8	1:4.5

* Given separately by Wolff-Lehmann.

II. The Armsby Standards for Dairy Cows

	Digestible protein, pound	Energy values, therms
For maintenance per 1000 pounds...............	.5	6.0
Per pound of average milk (13 per cent solids, 4 per cent fat)..................................	.05	.3

The dairy cow is kept primarily for producing milk, one of the most valuable human foods and the raw material for the manufacture of butter, cheese, and other dairy products. Through selection, liberal feeding, and careful management, the cow has gradually been developed to her present wonderful capacity for dairy production. The average production of many dairy herds at the present time exceeds one pound of butter fat per head for each day in the year, or over 360 pounds for the year. Cows holding production records for milk and butter fat have, however, exceeded this amount many times, producing, respectively, over thirty thousand pounds of milk and eleven hundred pounds of butter fat in a year.

[1] Records of yearly production: Tilly Alcartra 123459, Holstein, 30,451 pounds milk; Finderne Pride Johanna Rue 121083, Holstein, 1176.47 pounds butter fat.

While it does not lie within the scope of this book to discuss the various factors that have a bearing on this production, it seems desirable to state briefly the main influences that affect the value of a cow in the herd in order that we may see more clearly what part the feeding plays in the successful management of a dairy (Fig. 43).

FIG. 43.—Dairy cows of good breeding and well kept and cared for make excellent returns "at the pail."

Composition of Milk.—Cows' milk is composed of the following constituents: Water, butter fat, proteins (casein and albumen), milk-sugar, and ash. The amounts of these components present in milk of different origin, or even in milk from the same cow at different times, vary widely. The limits of variation for normal milk from American cows are about as follows: [2]

Composition of Cows' Milk, with Variations, in Per Cent

	Minimum	Maximum	Average
Water................	82.0	90.0	87.4
Fat..................	2.3	7.8	3.7
Casein and albumen...	2.5	4.6	3.2
Milk-sugar...........	3.5	6.0	5.0
Mineral matter.......	.6	.9	.7

[2] Farrington-Woll, "Testing Milk and its Products," 22nd edition, p 18; see also Wisconsin Research Bulletin 26, p. 62.

The fat is the most valuable single component of the milk; it determines the quality and value of the milk as a human food, and largely, also, as a raw material for the manufacture of dairy products. A high fat content is, as a rule, accompanied by a high per cent of solids other than fat, and is, therefore, of direct value in the manufacture of butter, cream, and condensed milk, and, up to a certain extent, in cheese-making as well.

Factors Influencing Milk Production.—The main factors that influence the amount and quality of milk produced by cows are: Breed, individuality, age, stage of lactation period, frequency of milking, condition, excitement, season of the year, temperature and weather, grooming, and amount and character of feed.

Breed.—The various breeds of cows yield milk in different amounts and of different quality, as is well known to all. The following compilation, giving the average production of milk and butter fat by pure-bred dairy cows, will show the extent of the differences between the various breeds in these respects. The figures were compiled from the results obtained in tests conducted for a series of years at four American experiment stations (Maine, New Jersey, New York, and Wisconsin). The cost of feed required to produce 100 pounds of milk and 1 pound of butter fat in the case of the different breeds is also given. Prices of feed have advanced from 30 to 40 per cent since these breed tests were conducted, hence the figures in the last columns should be varied accordingly.[3]

Test of Pure-bred Dairy Cows—Average Results for Four Stations

Breed	Number of cows	Lactation periods	Average yield per lactation period, pounds		Per cent fat	Feed cost for	
			Milk	Fat		100 pounds milk, cents	One pound fat, cents
Jersey	19	87	5681	302.1	5.32	77.6	15.2
Guernsey	17	67	6243	317.1	5.08	69.9	13.7
Holstein	14	43	9275	317.7	3.42	61.3	17.9
Ayrshire	10	20	6909	248.5	3.59	78.5	21.5
Shorthorn	12	55	7512	296.5	3.94	62.4	15.3
Devon	3	5	3984	183.3	4.60	94.0	20.5
Brown Swiss	2	6	6971	273.0	3.91	49.5	12.6
American Holderness	2	4	5721	213.1	3.73	76.0	20.1
Total and average	79	287	....	.....	....	71.2	17.1

Only a limited number of cows of the various breeds were included in these tests, and the conditions under which the tests were

[3] See also Wisconsin Report, 1901, p. 85.

conducted at the different stations differed more or less, as did also the breeds represented in the respective trials. The results, therefore, cannot be taken as absolute evidence of the capacity of the different breeds for dairy production, but they doubtless show in a general way the relative value of the breeds in the dairy. We note that the breeds rank as shown below in regard to: (*a*) Yield of milk, (*b*) yield of butter fat, (*c*) per cent of fat, (*d*) feed cost for 100 pounds milk, (*e*) feed cost per one pound butter fat.

	a	*b*	*c*	*d*	*e*
1.	Holstein	Holstein	Jersey	Brown Swiss	Brown Swiss
2.	Shorthorn	Guernsey	Guernsey	Holstein	Guernsey
3.	Brown Swiss	Jersey	Devon	Shorthorn	Jersey
4.	Ayrshire	Shorthorn	Shorthorn	Guernsey	Shorthorn
5.	Guernsey	Brown Swiss	Brown Swiss	Am. Holderness	Holstein
6.	Am. Holderness	Ayrshire	Am. Holderness	Jersey	Am. Holderness
7	Jersey	Am. Holderness	Ayrshire	Ayrshire	Devon
8.	Devon	Devon	Holstein	Devon	Ayrshire

Individuality.—There are wide variations between individuals within the same breed as to the capacity for milk production and the quality of the milk produced. These variations are of much greater magnitude than the average differences between the breed. The great difference between individuals of the same breed as regards the amount of production is familiar to all; an average cow produces, say, 20 pounds of milk a day, containing three-fourths pound butter fat; a very good dairy cow, on the other hand, will yield over twice this amount, and exceptional producers will give more than quadruple the figures stated. But the average quality of milk of cows of the same breeds also differs greatly. The variations are probably larger within the Jersey and Guernsey breeds than in any other breed; there are thus cows or families within these breeds that produce milk of an average fat content above 6 per cent during the entire lactation period, while individuals of other families will generally not go over 4 per cent. In the same way, we find some Holstein cows producing milk with over 4 per cent fat, and others whose milk will contain less than 2.8 per cent, on the average, for a considerable period of time.

Age of Cows.—This is not, on the whole, an important factor. As a general rule, heifers and young cows will give milk of a somewhat higher fat content than older cows, but the differences in the average quality of the milk for a long period of time, say one year, are only within a few tenths of one per cent in the fat content, and there are some individuals whose milk changes with advancing age in the opposite direction from that stated.

Stage of Lactation Period.—This is of greater importance than the age of the cow. The quality of the milk is, in general, higher during the first few weeks after parturition than later on, and remains fairly constant from this time on until toward the close of the lactation, when the milk becomes richer in solids and fat as the yield decreases (Fig. 44). The following compilation by the author of 300 cows [4] entered in the Wisconsin Dairy Cow Competition, 1909–1911, will illustrate the changes in production of dairy cows during the progress of the lactation period:

Average Daily Production of Dairy Cows by Months

Month of lactation period	Average daily production by months					Number of cows
	Milk	Solids		Fat		
	Pounds	*Pounds*	*Per cent*	*Pounds*	*Per cent*	
1	43.9	5.63	12.82	1.76	4.01	323
2	41.9	5.32	12.70	1.65	3.94	323
3	38.8	4.93	12.70	1.54	3.98	323
4	36.4	4.65	12.77	1.46	4.02	323
5	34.6	4.41	12.75	1.39	4.02	323
6	32.8	4.18	12.74	1.32	4.02	323
7	30.8	3.92	12.73	1.25	4.06	323
8	27.6	3.57	12.93	1.14	4.13	323
9	23.9	3.13	13.10	1.02	4.27	323
10	19.2	2.58	13.44	0.87	4.53	323
11	16.7	2.28	13.65	0.78	4.67	251
12	14.0	1.92	13.71	0.67	4.79	74

The normal decrease in the flow of milk in well-managed dairy herds is about 5 per cent a month during the second to seventh month of the lactation period, about 10 to 12 per cent during the eighth and ninth months, and 20 per cent for the tenth and subsequent months.

Condition.—The physical condition of a cow will influence the quality and amount of her milk secretion. A dairy cow in good flesh will give more milk and of richer quality than cows in poor condition. Where cows in a fleshy body condition are placed on official tests shortly after parturition their milk may contain 1 to 2 per cent fat above normal during the first 2 to 3 weeks, as has been shown by Eckles and the author;[5] cows in good flesh directly after parturition will also produce milk of a higher fat content through-

[4] Wisconsin Research Bulletin 26.
[5] Missouri Bulletin 100; Wisconsin Report 19, p. 117; 20, p. 114.

out the lactation period than cows that are thin and poor at the beginning of the lactation.

Frequency of Milking.—Under otherwise similar conditions, the shorter the interval between milkings, the less milk is obtained and the higher are the percentages of solids and butter fat contained therein. Where the interval between milkings is nearly equal, the differences in quality will, as a rule, be small. If the cows are milked three times a day, the noon milking is richest and the morning milking generally lowest in butter fat, while the amount of milk is least at noon and heaviest in the morning.

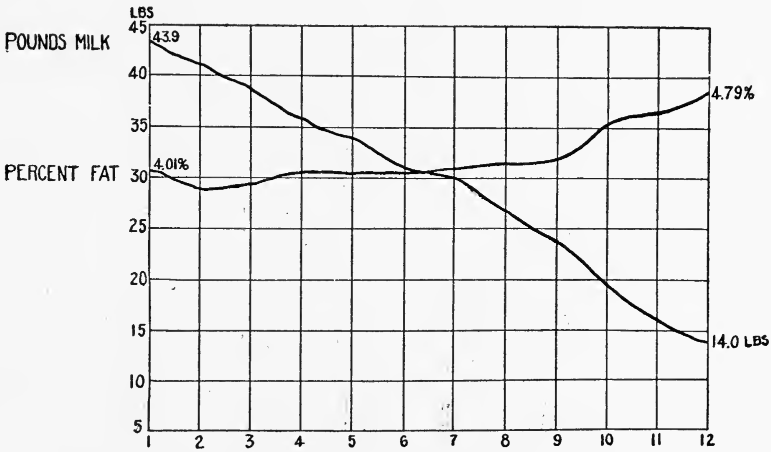

Fig. 44.—Normal changes in the monthly yield and the fat content of the milk from dairy cows with the progress of the lactation period, based on the results obtained in the Wisconsin Dairy Cow Competition, 1909–11.

Excitement.—A feverish condition is generally accompanied by a decrease in milk flow and an increase in the fat content; in cases of severe illness, the percentage of butter fat in the milk will, however, be abnormally low. Cows in heat, cows handled roughly, chased by dogs, or excited through other causes, will, as a rule, give a greatly diminished amount of milk, which will test very high.

Temperature and Weather.—Both excessively high temperatures and cold, heavy rain storms are likely to cause a marked decrease in the percentage of butter fat in the milk. Periods of drought, according to Van Slyke, cause a decrease in the flow of milk and in the contents of casein and albumen, especially the latter, while either no change or an increase in the percentage of butter fat will occur.[7]

Season of Year.—The percentage fat content of milk appears to be subject to certain seasonal influences that are independent of the stage of lactation period, the breed of cows, or the system of feeding. The lowest fat content of the milk will, in general, occur during hot weather, in June or July, and from this time on a regular increase occurs, which reaches its maximum in December or January, and a general gradual decrease then takes place until toward midsummer.[6] This seasonal influence appears to depend on the temperature of the air, and is, therefore, to be expected from what was said in the preceding paragraph.

Grooming and Exercise.—Grooming and moderate exercise stimulate the circulation and tend to cause a slight increase in the milk production and in the percentage of butter fat in the milk. Results of German experiments on this point[8] are somewhat more favorable than those of experiments conducted in this country.[9] The effects of grooming on the health of the animals and on the condition of the milk are, however, important factors. In dairies producing certified or sanitary milk the cows are curried and groomed regularly, and udders and hindquarters are washed. This, doubtless, is an effective means of promoting the health of the herd and lessening the bacterial content of the milk.

Influence of Feed on Quality of Milk.—Contrary to the opinion held quite generally by dairy farmers up to recent years, the feed does not exert any marked influence on the quality of the milk secretion, so long as the cow receives sufficient nutriment in her ration to maintain her body weight. Given a fair amount of protein and digestible nutrients in the ration, the quality of the milk is not affected by a more liberal system of feeding or by furnishing any special feed or combination of feeds. Underfed or starved cows produce milk of an abnormally low fat content, and this may be readily raised to the normal percentage for the individual cow by increasing the feed. On the other hand, by feeding rations high in protein, a cow will give milk of the highest fat content of which she is capable, but any improvement in quality that may be wrought by such feeding is small, within one or two tenths of one per cent above normal at the most. A slight improvement in the composition of the milk has been observed in some cases by feeding single feeds, notably palm-nut meal and coconut meal, and by

[6] See Eckles, *Milchw. Zentralbl.*, 1909, p. 488.
[7] Geneva (N. Y.) Bulletin 68; see also Wisconsin Report, 1895, p. 111.
[8] *Jr. f. Landw.*, 41 (1893), p. 332.
[9] Vermont Report, 1899, 1900.

feeding fat or oil, but the evidence with regard to this point furnished by different experiments is often conflicting, and in cases where greater differences were found as a result of a certain system of feeding there was a gradual return to normal after a couple of weeks or before, when the cows became accustomed to the feed. In general, both dairy farmers and scientists are now agreed that it is impossible to change materially the percentage of fat in a cow's milk by the feed; no amount of rich feeding or supplying special feeds will change the milk of a Holstein to a composition similar to that of a Jersey, or make low-testing cows or families into "high testers." The largest improvement in quality that can be hoped for would be within a few tenths of one per cent. "The quality of the milk which the cow produces is as natural to her as the color of her hair"; it is a practically fixed character that is intimately connected with the functional activity of the mammary gland.

Influence on Quantity of Milk.—The feed eaten by a cow influences in a marked manner the quantity of milk secreted, and determines the production that the cow will make, up to the capacity of her mammary glands. The feed is, therefore, of primary importance in the management of a dairy, and the problem before the dairy farmer is to provide feed for his cows that will secure the largest production of which these are capable, at a minimum cost. As it is only the excess of feed eaten over and above maintenance requirements that is used for productive purposes, it follows that the more a cow will eat without increasing appreciably in body weight, the larger returns she will yield per unit eaten (see chart, p. 236). The old saying, "Feed your cow and she will feed you," expresses the practical experience as to the relation of feed to product. With cows of the dairy type that respond to a more liberal system of feeding by an increase in milk production and not by a gain in body weight, this is a safe rule to follow in the management of a dairy. It is the heavy eaters that produce the largest yields and give the most economical production.[10]

The Value of High-producing Cows.—Results obtained in the Wisconsin Dairy Cow Competition, 1909–1911, illustrate in a striking manner the value of high-producing cows. The following table gives some of the main data for the highest, medium, and lowest producers among the 398 cows in the competition for which complete records of production for a full year were obtained. The

[10] Proc. Soc. Prom. Agr. Science, 1912, p. 23; Wisconsin Bulletin 102, p. 78, and Research Bulletin 26.

cows were separated into three groups of the same number of cows within each of the dairy breeds represented, Holstein, Jersey, and Guernsey, according to their production of butter fat; the data for the different groups have been combined and are given in the following table: [11]

Returns from Cows of Different Producing Powers

Groups	Butter fat, pounds	Cost of feed	Net returns	Feed units	Per 100 feed units: Butter fat, pounds	Per 100 feed units: Value of products
1. Highest producers (134 cows)....	529.1	$79.10	$87.72	7161	7.39	$2.33
2. Medium producers (133 cows)....	420.6	71.08	63.01	6574	6.40	2.04
3. Lowest producers (131 cows).....	338.9	65.95	42.17	6084	5.57	1.78
Differences between 1 and 3....	190.2	13.15	45.55	1077	1.82	.55
In per cent...............	56	20	108	18	32	31

While the difference in the average production of butter fat by groups 1 and 3 amounted to 190.2 pounds, or 56 per cent, calculated on the production of group 3, the cost of feed for the two groups increased only 20 per cent, and that of total number of feed units 18 per cent. The differences in net returns (the value of products above cost of feed), on the other hand, amounted to 108 per cent, and 100 feed units produced 31 to 32 per cent more butter fat or value of products in case of group 1 compared with group 3; that is, the best cows made the largest production at a relatively much lower feed cost; hence the percentage increase in the net returns secured was much greater than that in butter fat, viz., 108 per cent above that for the lowest lot. The number of feed units consumed in the rations fed was increased by only 18 per cent, and the efficiency of the rations calculated per 100 feed units was increased by over 30 per cent.

The same lesson is taught still more strikingly by the results obtained with the best ten and the poorest ten cows in the competition (Fig. 45); the feed of the former cost $114.66 per head for the year, while the net returns were $124.29, or 52 per cent; the feed of the latter cost $61.10, and the net returns were $14.89, or only 20 per cent.

The preceding results were obtained with excellent dairy cows, of families that had been bred persistently for a large milk production for many generations. Cows of this type respond to heavier feeding by an increased milk production; other cows of different breeding, or bred for beef production, would gain in body

[11] Wisconsin Bulletin 226, p. 22.

flesh by such feeding, and their milk production would be likely to suffer if forced by liberal feeding (Fig. 46). Nearly all dairy herds that have not been carefully culled will contain a considerable proportion of the latter kind of cows; in feeding a herd the in-

BEST TEN COWS POOREST TEN COWS

Fig. 45.—The areas of the circles represent the average values of the products from the best ten or the poorest ten cows in the Wisconsin Dairy Cow Competition, 1909–11. (Wisconsin Station.)

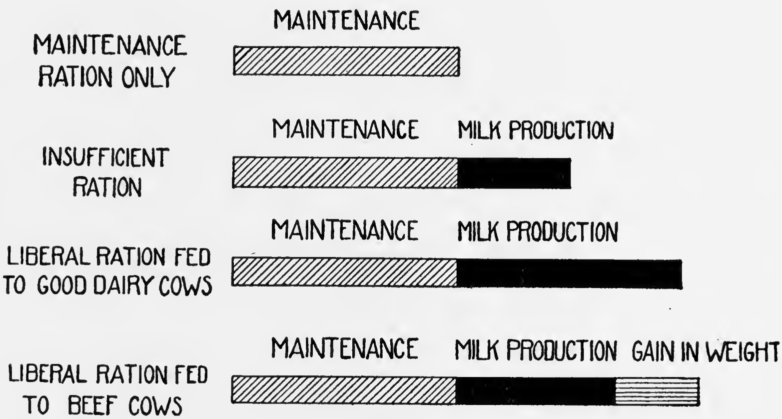

Fig. 46.—Liberal rations fed to cows of beefy tendencies produce a gain in weight; such fed to good dairy cows produce the largest production of milk of which they are capable. (Van Norman.)

dividual cows must, therefore, be carefully watched lest they be fattened by the system of feeding adopted instead of increasing in their milk production. Regular weighing of cows, say once a month or oftener, is a valuable aid in the management of a dairy herd, as it furnishes definite information as to changes in the body weight of individual cows that may occur.

Improvement of Dairy Herds.—The most important factor to be ascertained by a dairy farmer is whether the cows he is feeding are of the dairy type and capable of a good dairy production, or are what are termed "boarders"—cows whose milk production is barely sufficient to pay for the feed they eat. This can only be determined by testing the individual herds for production, by means of a milk scale (Fig. 47) and a Babcock tester (Fig. 48). This work may be done by the farmer himself or by joining a cow-testing association, or by having official tests conducted under the direction of the State Agricultural College in coöperation with the respective breed associations. Only cows that come up to a certain standard of production of milk or butter fat should be retained in the herd. This may be gradually increased from 250 to 300, 350, or even 400 pounds butter fat a year. Cows that do not reach the standard are disposed of as opportunity offers, unless they give promise of doing better in the future, as they have no place in the dairy herd.

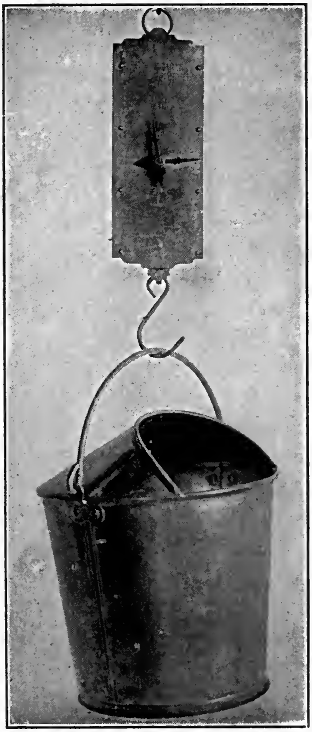

Fig. 47.—The spring milk-scale enables the farmer to keep accurate milk records of his cows with but very little extra effort. (Ottawa station).

Low producers eat considerably more feed per unit of production than high-producing cows, and are not capable of an economical production. Investigations of dairy herds at a number of experiment stations[12] have clearly demonstrated the futility of making dairying pay at present high prices for feed and labor, with cows other than of the strict dairy type, that are good individuals; they may be pure-breds, high grade, grade, or natives, according to the resources and the business ability of the farmer, but they must have inbred dairy tendencies and be able to consume large amounts of feed without growing fat. According to the experience of dairy experts, most farmers do not

[12] See Minnesota Bulletin 35; Connecticut (Storrs) Bulletin 29; Illinois Circular 106; Wisconsin Bulletins 102, 200, and 226.

feed their cows to the limit of economical production, and do not try to ascertain whether their cows are capable of making an increased production (Fig. 49). Until this is done, dairy farming, which is one of the most profitable branches of agriculture and animal husbandry, will not yield adequate returns for the labor it requires.

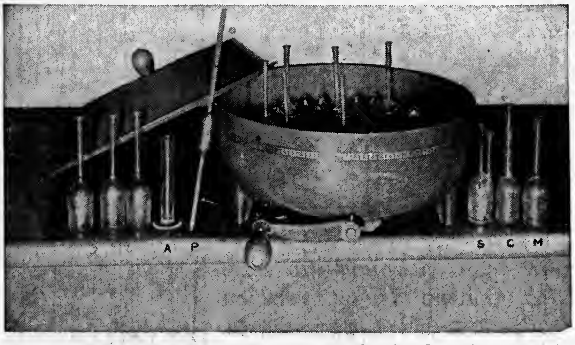

FIG. 48.—Babcock test apparatus. ("Productive Farming," Davis.)

Amount of Feed Eaten Annually by Dairy Cows.—The table given below shows the amount of different feeds eaten during the year, by cows in the dairy herds of nine experiment stations, with production of milk and butter fat as well as feed cost, according to Henry.[13] The estimated feed units have been added by the

Annual Feed Requirements of the Dairy Cow as Found by Nine Stations *

Station	Number of years	Pasture, days	Concentrates, pounds	Feed eaten: Soiling crops roots, or silage, pounds	Feed eaten: Hay, pounds	Aver-cost of feed per cow	Returns: Milk, pounds	Returns: Fat, pounds	Estimated feed units
Connecticut...	5	152	2029	8694	1830	$53.46	5498	279	5730
New Jersey....	6	168	2624	16753	1825	44.68	6165	277	7836
Michigan......	1	139	2774	3638	3986	35.96	7009	260	5964
Wisconsin.....	3	180	1914	9448	1200	37.68	7061	299	5769
Minnesota.....	1	131	3435	5306	2029	37.82	6408	301	6439
Missouri......	1	191	3027	....	4380	35.30	5927	248	6327
Utah.........	1	187	1976	3692	2347	31.61	8783	339	5635
Montana......	2	150	1169	....	6468	32.45	5993	250	5903
Nebraska.....	5	153	1305	....	4518	21.43	5601	237	5094
Average for nine herds	25	161	2250	5281	3076	$36.71	6494	277	6077

* Connecticut Bulletin 29; New Jersey Reports, 1897–1904; Michigan Bulletin 166; Wisconsin Reports, 1905–7; Minnesota Bulletin 35; Missouri Bulletin 26; Utah Bulletin 68; Montana Report, 1905; Nebraska Bulletin 101.

[13] "Feeds and Feeding," 10th ed., p. 427.

author and also the average figures for the nine stations, including, in the aggregate, twenty-five years for the herds considered.

The system of feeding adopted in the herds included in the preceding compilation varied greatly, both in kinds of feeds and intensity of feeding. The average figures give, however, quite a satisfactory statement of the actual feed requirements of dairy cows as fed in this country. We note that these herds ranged in the amount of milk produced from 5498 pounds in Connecticut (largely Jerseys and Guernseys) to 8783 pounds in Utah (grades), and in butter fat from 237 pounds in Nebraska (largely Jerseys and Holsteins) to 339 pounds in Utah; the average production for all nine herds was 6494 pounds of milk and 277 pounds of butter fat.[14] The average feed per cow for all herds was 2250 pounds of concen-

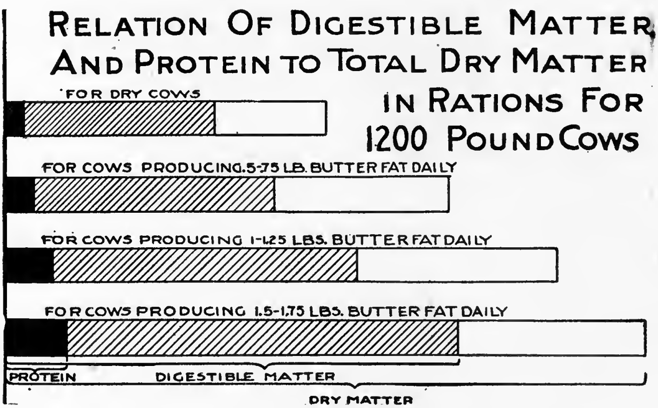

FIG. 49.—Production and size are the factors determining the feed requirements of dairy cows. The amounts of dry matter and digestible protein in feed rations should increase in proportion to the production of butter fat.

trates, 5281 pounds of succulent feeds (soiling crops, roots, and silage), 3076 pounds of hay (mixed timothy, clover, or alfalfa), and 161 pasture days, the average feed cost per cow being $36.71 (see p. 229), and the number of feed units eaten, 6077. These figures will serve as a basis for estimating the actual feed requirements of dairy cows in this country and the returns that may be expected with good cows and careful management.

Feeding Standards.—The feeding standards for dairy cows

[14] Corresponding to 323 pounds of commercial butter, obtained by adding one-sixth to the amount of butter fat, which is a safe average estimate.

according to Wolff-Lehmann and Armsby are given at the beginning of this chapter. The former standards have been modified by Haecker,[15] who has calculated the amounts of digestible protein, carbohydrates, and fat required for the production of a pound of milk testing 3 to 6.5 per cent as follows:

Requirements for Milk of Different Richness

	Digestible Protein	Digestible Carbohydrates and fat *
For maintenance per 1000 pounds	.700	7.225
Per pound of milk testing 3 per cent	.047	.238
4 per cent	.054	.287
5 per cent	.060	.334
6 per cent	.067	.383
6.5 per cent	.072	.405

* Given separately in Haecker's standards.

In addition to giving digestible protein, carbohydrates, and fat to the third decimal place, Haecker calculates the requirements per pound of milk for differences in fat contents of only 0.1 of 1 per cent between 3.0 and 6.5 per cent. In view of the great differences in the returns made by different cows from the feed eaten, and the great variations to which feeding stuffs are subject, both as regards composition and digestibility, it would seem rather unnecessary to make such fine distinctions. Eckles[16] has modified the Armsby standards according to the fat content of the milk produced, allowing 0.05 to 0.07 pound digestible protein and 0.26 to 0.45 therm per pound of milk testing 3 to 6 per cent (p. 39).

The American Practical Feeding Ration.—The author published in the nineties the following so-called "American Practical Feeding Ration" for dairy cows, as a result of studies of the methods of feeding and the experiences of more than one hundred prominent American dairy farmers with regard to the amounts and character of the feed which will be likely to give the best and most economical results under our conditions when fed to good dairy cows in full flow of milk and of an average weight of 1000 pounds:[17]

[15] Minnesota Bulletin 130.
[16] Missouri Research Bulletin 7.
[17] Wisconsin Bulletin 38.

Dry matter	24.15 pounds.
Digestible protein	2.15 pounds.
Digestible carbohydrates and fat	14.5 pounds.
Nutritive ratio	1 : 6.9

Feeding Table for Dairy Cows.—While not formulated as a standard, Professor Humphrey and the author, in 1911, published a table showing at a glance the quantities of dry matter and digestible components required daily by dairy cows of 800 to 1500 pounds body weight, and producing from less than one-half pound to over two pounds butter fat per day.[18] This table is based chiefly on the results obtained in investigations with the dairy herd of the Wisconsin station for a period of nine years.

The figures for 1000-pound cows are shown in the table:

Feed Requirements for 1000-pound Dairy Cows Producing 0.5 to 2.0 Pounds Butter Fat Per Day, in Pounds

	Dry matter	Digestible protein	Total digestible matter
Dairy cows (maintenance)	12.5	.70	7.9
Production of butter fat per day:			
Less than 0.5 pound	16.2	1.18	10.6
0.5 to 0.75 pound	18.7	1.49	12.3
0.75 to 1.0 pound	21.1	1.80	14.1
1.0 to 1.25 pounds	23.6	2.11	15.8
1.25 to 1.5 pounds	26.0	2.43	17.6
1.5 to 1.75 pounds	28.5	2.74	19.3
1.75 to 2.0 pounds	30.9	3.05	21.1

The composition of a certain combination of feeds may be readily compared with the requirements of cows of different body weight and productive capacities, as shown in this table, and rations thus formulated which will contain approximately the amounts of dry matter and digestible protein required for a certain production of butter fat. The corresponding amounts of digestible carbohydrates and fat may be readily found by subtracting the amount of digestible protein from that of total digestible matter, and the nutritive ratio by dividing this difference by the amount of digestible protein.

Example: A 1000-pound cow producing 1.3 pounds butter fat per day was fed as follows: 10 pounds alfalfa hay, 25 pounds corn silage, 10 pounds of a grain mixture composed of corn, oats, and wheat middlings, in the proportion of 2: 2: 1. This ration contains the amounts of total digestible matter and energy values as given below, on the supposition that the feeds are of average composition and digestibility.

[18] Wisconsin Bulletin 200; see also Woll, Handbook, p. 19*b*.

Composition of Ration for Dairy Cows, in Pounds

	Dry matter	Digestible		Digestible true protein	Energy values, therms
		Protein	Carbohydrates and fat		
10 pounds alfalfa hay...	9.2	1.10	4.2	.69	3.44
25 pounds corn silage...	6.6	.30	4.5	.22	4.14
4 pounds oats.........	3.6	.37	2.3	.33	2.65
4 pounds corn.........	3.6	.32	3.1	.27	3.55
2 pounds wheat middlings..............	1.8	.25	1.2	.26	1.55
Total..............	24.8	2.34	15.3	1.77	15.33

According to the Armsby standard modified by Eckles, this cow, if producing, say, 30 pounds of milk testing 4.03 per cent, should receive:

	Digestible protein, pounds	Energy value, therms
For maintenance	.5	6.0
For production	1.62	8.6
Total	2.12	14.6

The cow did not, therefore, receive as much protein or as many therms of energy values in the ratio given as called for by the standard; but the difference is very likely apparent rather than real, since it will be found, on examination, that the digestible true protein in alfalfa hay, according to the table, is very low, and probably lower than the actual content in average alfalfa hay, which contains 1.10 per cent digestible crude protein.

By the use of the table (p. 241) we find that the cow should receive 26 pounds dry matter, 2.4 pounds digestible protein, and 15.2 pounds digestible non-nitrogenous components. These amounts agree closely with the calculated composition of the ration, showing that this would furnish an ample supply of nutrients for a 1000-pound cow producing about 1.3 pounds butter fat a day. According to the Haecker standard,[19] the cow would be entitled to the following amounts of nutrients:

	Digestible protein, pounds	Carbohydrates and fat, pounds
For maintenance	.70	7.3
For production	1.62	8.7
Total	2.32	16.0

Also, in this case, there is a close agreement between the standard and the composition of the ration calculated according to the average composition of the various feeding stuffs.

Feeding the Dairy Heifer.—The practice of good dairy farmers as to the time of breeding heifers differs considerably. The best results may, however, be expected by breeding so that the heifer

[19] Minnesota Bulletin 130.

will come in between 2 and $2\frac{1}{2}$ years of age. As the time of parturition approaches, the feeding of the heifer should be plain, without stimulating feeds that may have a deleterious influence on the fœtus and cause abortion, as fermented or decayed feeds.

Good, clean hay from clover or mixed grasses, corn fodder, corn silage (made from well-matured corn and fed in moderate quantities, not to exceed 20 pounds a day), or roots should form the main reliance; preferably both dry and succulent roughage is fed, and, in addition, small amounts of ground oats, bran, shorts, gluten feed or corn, the last feed being given only when the heifer is in poor flesh. Shortly before calving, the feeding of all grain feeds, except, perhaps, about two pounds of bran, is discontinued. Directly after calving, lukewarm water only, or a warm, thin slop of oatmeal, bran, or shorts, is given for a few days until the danger of milk fever is over; the amount of feed given should be very light, and then gradually increased for two to three weeks, when the cow may be put on full feed. By this time, or before, the maximum production of butter fat, and generally also of milk, will be reached.

A heifer with her first calf should receive special care and be fed liberally, since she is growing and producing milk at the same time. A good supply of protein feeds must be furnished in her ration to meet the requirements of the body for nitrogenous components. Corn meal is especially valuable at this time for heifers that show a tendency to "milk their flesh off." The heavy feeding should be continued up to drying-off prior to the second calving. A persistent milking habit is favored by continuing to milk the heifer for about ten months during the first lactation period, if possible.

Summer Feeding of Dairy Cows.—The favorable influence of early summer pasturage on the milk secretion of cows, both as regards yield and quality, and, more especially, its fat content, has been known to observing dairy farmers so long as milk records have been kept or tests of milk have been made. Ample pasturage is one of the essentials of successful dairy farming, where the soiling system or feeding of summer silage is not practised. During the early part of the season the cows will, as a rule, find a sufficient supply of feed on pasture alone, but later it will often be necessary to supplement the pasture with soiling crops or summer silage, or, if neither is available, to feed grain feeds. The feeding of grain to cows on pasture is, in general, only profitable when there is a scarcity of pasturage (p. 94). In the case of heavy milkers it will, however, be advantageous to feed at least a few pounds of wheat bran, or wheat bran and oats, throughout the season, in order to enable them to maintain a maximum production.

The use of soiling crops or summer silage on dairy farms is an important feature of intensive dairy farming, as two to three times as much green forage may be secured per acre by this system as by pasturing; it also enables the farmer to maintain, so far as possible, the milk production of his herd during late summer, when hot weather and flies combine to reduce the production of the cows, both for the time being and for the balance of the lactation period. A variety of soiling crops is fed in different sections: Corn, alfalfa, peas and oats, rye, rape, etc. (see p. 96). Some of these crops, such as rye, rape, and oats, should be fed with care in small quantities at the start, and always after milking, so that they will not taint the milk or the products made therefrom.

Summer silage is a highly-prized feed on many American dairy farms. Generally a small, separate silo is filled in the fall for the purpose of feeding the silage in late summer, when drouth and hot weather are likely to cause serious damage to the pasture. The most common silage crops are corn, alfalfa, and red clover,—corn being of most importance in the greater portion of our dairy sections. Thirty pounds of soiling crops or silage are an average allowance for dairy cows on poor pastures; as much as sixty pounds of soiling crops or forty pounds of silage may be fed in the case of large cows during seasons of drought when pastures are scant.

Winter Feeding of Dairy Cows.—The cows are fed in the stable during one-half of the year, or more in the North, and, as the system of feeding during this period is necessarily most expensive, the profit of the dairy will depend, to a large extent, on the economy of the winter feeding. Economical feeding in cases of good dairy cows does not mean scant supplies, but the kind of feeds and feed combinations that will be likely to produce best results for the least money. Only cows that respond to liberal feeding and are fed liberally will prove profitable dairy animals.

Succulent feeds should be provided for dairy cows during their entire lactation period whenever possible; silage and roots are the main available feeds of this character during the winter period, and in corn-growing sections, at least, the former has been found to yield the largest and cheapest amounts of feed materials per unit of area. Roots are, however, valuable substitutes where there is no silo on the farm; they are fed especially in Canada and by farmers who adhere more or less to European methods of agriculture. In the case of heavy producers and cows "out of condition," roots are often fed to animals on account of their dietetic effect, as appetizers, and because of their favorable influence on the digestion.

The silo enables dairy farmers to utilize the large supply of feed materials in the corn plant with the least possible loss and expense. For this reason, and because of the advantage of having a palatable, highly nutritious and relished succulent feed conveniently at hand throughout the season, the silo is now generally regarded as next to a necessity on dairy farms, at least where corn is grown. The whole corn plant, ears and all, is, as a rule, run through a feed cutter, this having been found the most economical method of handling the crop. The corn is harvested when nearly ripe, and cut into one-half to three-fourth inch lengths in filling the silo (p. 156).

Silage is greatly relished by cows and can be fed in large quantities, if made from nearly-matured corn. Ordinarily, the best results are obtained when not over 30 to 40 pounds of corn silage are fed per head daily, according to the size of the cows, and it is always fed with some dry roughage, either hay or corn fodder. Since the corn plant is rich in carbohydrates, protein feeds like clover hay, wheat bran, or oil meal should always be fed with corn silage or corn fodder. Clover silage, or silage made from alfalfa, grain sorghums, etc., is fed in somewhat smaller quantities than corn silage, the daily allowance being less than 25 to 30 pounds per head.

Dry Roughage.—Hay from the grasses or legumes is a common coarse cow feed in this and other dairy countries. Early-cut hay is more valuable, ton for ton, than late-cut, but the yield obtained will be somewhat lower in the former case. Clover hay, or hay of other legumes, stands first in value as dry roughage for dairy cows (Fig. 50). It is preferably fed long. Pure timothy hay is a poor cow feed, especially if late-cut; mixed timothy and clover hay is the more valuable for cows the less timothy it contains. Other kinds of hay that are fed and relished by dairy stock are oat hay, millet hay, sorghum hay, pea hay, etc. Corn stover (cornstalks) and corn fodder are fed whole or are cut or shredded on the best-managed farms after having been shocked in the field (p. 129).

Straw of the small grains is not often fed to dairy cows in this country, as we have an abundant and cheap supply of roughage in cornstalks. Where a quantity of fine, bright oat straw is available, it may be fed in moderate quantities, not to exceed one-half the weight of total dry roughage fed.

Concentrates.—The common concentrates used on American dairy farms are cereals and mill-refuse feeds, starch or glucose refuse feeds, brewers' and distillers' feeds, and oil meals, especially linseed meal and cotton-seed meal. The amounts of these feeds that can be fed to dairy cows with profit will depend upon the price of the feeds, the production of the cows, and the prices obtained for the dairy products. In general, the carbohydrates of feed rations are supplied by farm-grown crops, while nitrogenous feeds are largely purchased, except when leguminous crops are grown. By the culture of crops of the latter class the amount of protein feeds that it will be necessary to purchase will be reduced to a minimum. Wheat bran may be partially replaced, nearly ton for ton, by carefully-cured alfalfa hay, or by five to six tons of pea-

FIG. 50.—Alfalfa is, as a rule, fed in racks in the corrals (feeding yards) to milch cows in the Western States.

vine silage. Roughly speaking, the cereals may be considered of equal feeding value for dairy cows, and of similar value to bran or shorts, in rations as ordinarily fed. Cotton-seed meal, gluten meal, and linseed meal likewise possess nearly equal value, with the first two feeds occasionally ahead. The comparative value of feeding stuffs depends, however, to a large extent on the combination in which they are fed, a starchy feed being of greater value to a farmer having a good supply of protein feeds than to one who has mainly starchy feeds to select from. The feed-unit system furnishes a convenient and very satisfactory method of comparing the value of different kinds of feeds for dairy cows (p. 79).

The quantities of grain feeds fed by American dairy farmers vary considerably, from a few pounds to fifteen or more pounds per head daily (Figs. 51 and 52). Only exceptionally large producers will give good returns for more than six or eight pounds of grain feed daily, with abundant roughage of good quality at hand. A common rule is to feed as many pounds of grain feeds a day per head as the cows produce pounds of butter fat during the week, and to feed as much roughage in addition as they will eat up clean.

Fig. 51.—The "meal cart" used for weighing concentrates for the individual cows in the herd. (Ottawa Station.)

Rations for Dairy Cows.—It is important, in making up rations for dairy cows, as for other classes of farm animals, to see to it that a liberal amount of easily digestible substances is supplied; nearly one-half of the dry matter of the ration should be given in the form of concentrated feeds in case of milch cows, the amount fed being governed primarily by the production of the cows. No moldy or decayed feeds should be fed, and, in the case of wet feeds, particular attention must be given to keeping clean the mangers and the premises about the stable. A variety of feeds is always fed, often as many as half a dozen different ones, so as to stimulate the appetites of the cows; the modern dairy cow is a product of special-purpose breeding and high feeding, and, unless special pains is taken to cater to her wants, she will not be able to reach and maintain the high standard of production which may be reasonably expected of her (Figs. 53, 54, 55, and 56).

The following rations for milch cows are given as samples of the system of feeding adapted to the conditions in different sections of our country:

1. Hay, 20 pounds; oats, 3 pounds; corn and cob meal, 3 pounds; linseed meal, 2 pounds.

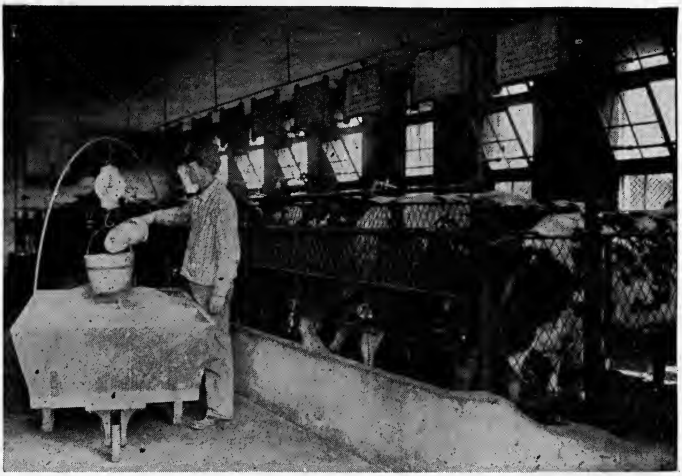

Fig. 52.—Weighing rations for the dairy herd. The cows receive seven pounds of grain per pound of butter fat produced. (Wisconsin Station.)

2. Hay, 10 pounds; cornstalks, *ad lib.;* wheat bran, 3 pounds; corn meal, 2 pounds; cotton-seed meal, 2 pounds.

3. Roots, 60 pounds; stover, *ad lib.;* oats, 3 pounds; bran, 3 pounds; gluten feed, 3 pounds.

4. Corn fodder, *ad lib.;* corn silage, 40 pounds; shorts, 2 pounds; dried brewers' grains, 2 pounds; linseed meal, 2 pounds.

5. Corn silage, 35 pounds; hay, *ad lib.;* bran, 4 pounds; oats, 2 pounds; gluten meal, 2 pounds.

6. Corn silage, 30 pounds; hay, *ad lib.;* oats, 4 pounds; linseed meal, 2 pounds; cotton-seed meal, 1 pound.

7. Corn silage, 30 pounds; clover hay, *ad lib.;* bran, oats, and corn meal, 2 pounds each.

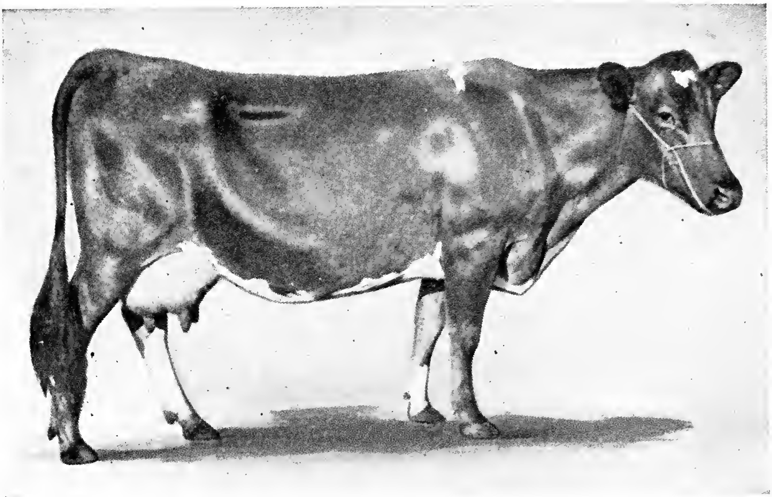

FIG. 53.—Yeksa Sunbeam, No. 15439, Guernsey. The first cow to produce the equivalent to 1000 pounds of butter in one year on a semi-official test. Record, 14,920.8 pounds milk, 857.15 pounds butter fat; average test, 4.74 per cent.

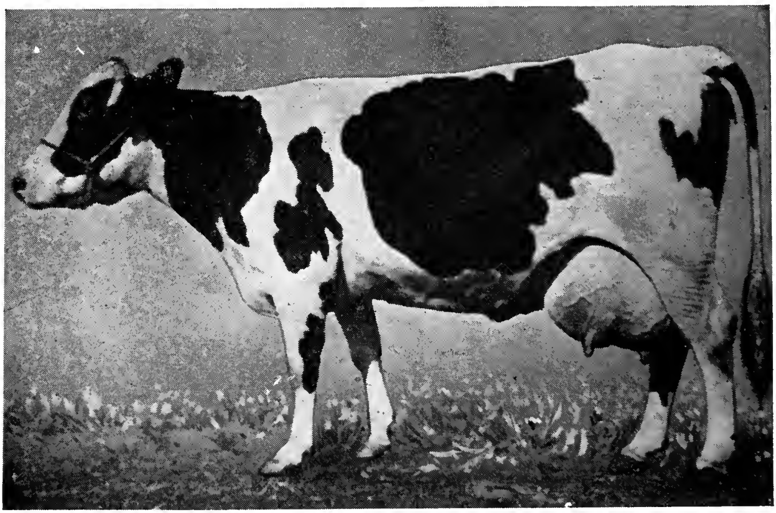

FIG. 54.—Colantha 4th Johanna, No. 48577, Holstein. The first cow to produce over 4 pounds butter fat daily in a 7-day official test and close to 1000 pounds butter fat in one year on a semi-official test. Record, 27,432.5 pounds milk, 998.26 pounds butter fat, equivalent to about 1165 pounds commercial butter; average test, 3.64 per cent.

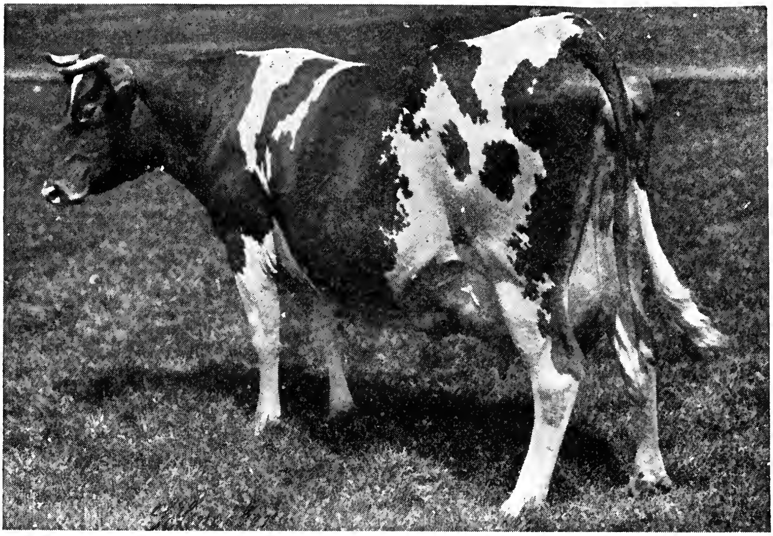

FIG. 55.—May Rilma, No. 22761, Guernsey, held the record for highest production of butter fat by a dairy cow for one year (until March, 1915, see page 227): 1073.41 pounds butter fat from 19,673 pounds milk; average test, 5.46 per cent.

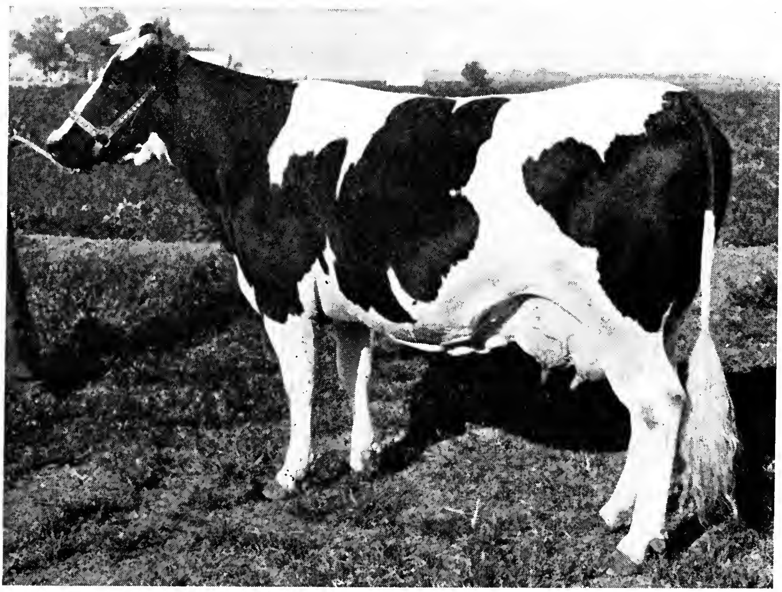

FIG. 56.—Tilly Alcartra, No. 123459, Holstein, holds the record for the highest production of milk for one year by a dairy cow: 30,451.4 pounds milk, 951.2 pounds butter fat; average test, 3.12 per cent.

8. Clover silage, 25 pounds; hay, 5 pounds; cornstalks, *ad lib.;* oats, 3 pounds; corn meal and linseed meal, 2 pounds each.

9. Clover or alfalfa silage, 30 pounds; hay, *ad lib.;* bran, 4 pounds; middlings, 3 pounds; linseed meal, 1 pound.

10. Alfalfa hay, 20 pounds; oats, 4 pounds; corn meal, 2 pounds.

11. Hay, 20 pounds; cotton-seed hulls, 10 pounds; cotton-seed meal, 4 pounds; wheat bran, 2 pounds.

12. Corn silage, 40 pounds; alfalfa hay, 25 pounds; barley, 4 pounds; dried beet pulp, 3 pounds; wheat bran, 2 pounds.

13. Corn silage, 30 pounds; cotton-seed hulls, 12 pounds; bran, 6 pounds; cotton-seed meal, 3 pounds.

The time of feeding is also important. The feeding should be as regular as the milking. Many farmers feed either hay or grain feeds directly before or during milking, but this is not, as a rule, to be recommended, both on account of the tendency it has to interfere with the letting-down of the milk, and the danger of contamination of the milk with dust and bacteria that it involves, especially when hay is fed directly before or during the milking.

A good order of the day's work in the dairy barn during the winter is as follows: Cleaning gutters, watering, feeding hay, grooming, and cleaning cows, milking, feeding grain, feeding silage, turning out in the yard (on pleasant days for one or two hours in the early afternoon), watering, cleaning stable, feeding grain, cleaning cows, milking, feeding silage, a last feed of hay if desired, and arranging bedding.

Feeding the Dairy Bull.—The bull at the head of a dairy herd should receive a large share of his feed in the shape of dry roughage, hay from the grasses or legumes, cornstalks, etc., with only limited amounts of concentrated feeds. Of the latter, wheat bran, shorts, oats, and a little corn meal are to be preferred. Roots are good as a relish, while corn silage and other kinds of silage should be fed very sparingly to breeding bulls. Fattening feeds and excessive grain feeding should be avoided, so that the animal may be kept in a vigorous, active condition. Corn and other fattening feeds are, for this reason, to be fed with care; high feeding and lack of exercise are common causes of impotency in bulls; a wrong system of feeding and management has been the cause of shortening the period of usefulness of many bulls.

QUESTIONS

1. Give the average composition of cow's milk.
2. State ten factors that influence the milk secretion of cows.
3. What is the effect of (*a*) excitement, (*b*) time of milking, (*c*) condition of the cow, on the quality of the milk secreted?

4. Name the six most important dairy breeds in this country.
5. State the relative rank of these breeds as regards (*a*) yield of milk, (*b*) yield of butter fat, (*c*) per cent of fat, (*d*) feed cost per pound of butter fat, according to experiment station trials.
6. What is the normal decrease in the production of milk and butter fat for good dairy cows due to the advance of the lactation period?
7. How does the feed influence (*a*) the quality, (*b*) the yield of milk?
8. What method would you follow for the improvement of the production of the dairy herd?
9. Give the approximate amounts of dry roughage, succulent feeds, pasture, concentrates eaten by a good dairy cow in the northern States during the year.
10. State how the Wolff-Lehmann standards for milch cows have been modified by Haecker.
11. Give the modified figures for the Armsby standard for milch cows as suggested by Eckles.
12. Describe briefly the system of feeding the dairy heifer.
13. Describe briefly the system of feeding dairy cows in your locality (*a*) during the summer, (*b*) during the winter months.
14. Criticise the following rations for dairy cows, and state how they may be changed to conform to the standards for dairy cows:
    (*a*) 20 pounds cornstalks, 10 pounds timothy hay, 6 pounds corn meal.
    (*b*) 20 pounds mixed hay, 5 pounds oats, 3 pounds corn meal.
    (*c*) 25 pounds alfalfa hay.
    (*d*) 40 pounds green alfalfa, 20 pounds alfalfa hay.
    (*e*) 50 pounds green corn fodder, 3 pounds each of wheat bran, dry brewers' grains, and oil meal.
    (*f*) 30 pounds corn silage, 10 pounds cornstalks, 4 pounds corn meal, and 2 pounds oil meal.

Literature on Feeding Dairy Cattle.—Eckles, "Dairy Cattle and Milk Production," New York, 1914. Shaw, "Management and Feeding of Cattle," New York, 1914. Murray, "The Chemistry of Cattle Feeding and Dairying," London, 1914. Housman, "Cattle, Breeds and Management," London, 1905 (see also p. 226). Alvord, "The Dairy Herd," Farmers' Bulletin 55, 1904. Haecker, "Feeding Dairy Cows," Minnesota Bulletin 130, May, 1913. Kildee, "Care, Feed and Management of the Dairy Herd," Iowa Circular 16, March, 1914.

Experiment Station Bulletins (b), *Circulars* (c), *and Reports* (r).—Alabama, b. 123, 174; Colorado, b. 73; Connecticut (Storrs), r. '04; Florida, b. 102; Georgia, b. 49; Iowa, c. 16; Kansas, b. 93, 125; r. '88; Maine, r. '95, '09; Maryland, b. 84, 98; Massachusetts (Hatch), r. '94, '05, '08, '09, '11; b. 50, 94, 95; Minnesota, 35, 67, 130, 140; Missouri res. b. 7; Mississippi, b. 60, 70; r. '91, '95, '03; Nebraska, b. 44, 76; New Jersey, r. '82, '85, '98, '03, '04, '07; b. 122, 123, 161, 174, 189, 190, 204; New Mexico r. '04; New York (Cornell), b. 13, 22, 36, 49, 183, 268, 323; New York (Geneva), b. 141; North Carolina, b. 77; North Dakota, b. 16; Ohio, c. 128; b. 155; Oregon, c. 5; Pennsylvania, b. 41, 52, 73, 80, 114; r. '81, '92, '95; Rhode Island, b. 77; South Carolina, b. 66, 117; South Dakota, b. 81; Tennessee, b. 80; vol. 17, No. 4; 15, No. 4; Texas, b. 47; Utah, b. 68; Virginia, b. 148, 156; Vermont, b. 164; r. '92, '95, '01, '03, '04, '06, '07; West Virginia, b. 109; Wisconsin, b. 33, 38, 102, 116, 117, 200, 235; r. '84, '90, '05.

CHAPTER XXIII

FEEDING BEEF CATTLE

Rations for Beef Cattle.—Feeding standards should be followed in preparing rations for beef cattle.

The Wolff-Lehmann Standards—1000 pounds live weight

	Age, months	Live weight, pounds	Dry matter, pounds	Digestible		N. R.
				Protein	Carbohydrates and fat*	
For growing cattle	12–18	750	24	2.0	13.6	1:6.8
For growing cattle	18–24	935	24	1.8	12.9	1:7.2
For fattening cattle, first period	.....	...	30	2.5†	16.3	1:6.5
For fattening cattle, second period	.....	...	30	3.0†	16.1	1:5.4
For fattening cattle, third period	.....	...	26	2.7†	16.6	1:6.2

* Given separately by W.-L. † Doubtless too high.

The Armsby Standards

	Age, months	Live weight, pounds	Digestible true protein, pounds	Energy value, therms
For growing cattle	18	850	1.70	7.5
	24	1000	1.75	8.0
	30	1100	1.65	8.0
For fattening cattle per pound gain	..	....	....	3.5

Systems of Feeding Beef Cattle.—There are two different systems followed in feeding beef cattle in this country. The cattle are either raised and fattened on the same farms, as is generally done in the farming and grain-growing districts, especially the corn belt, or they are raised and fattened in different regions. In the latter case, they are raised and fed until maturity mainly in the grazing districts of the western and southwestern States and then shipped to grain- or forage-growing regions to be fattened for market. The relative importance of the two systems may be inferred from the accompanying map (Fig. 57),[1] showing the number and value of cattle other than milch cows according to the census of 1910. The seven corn belt States had about one-third of the total

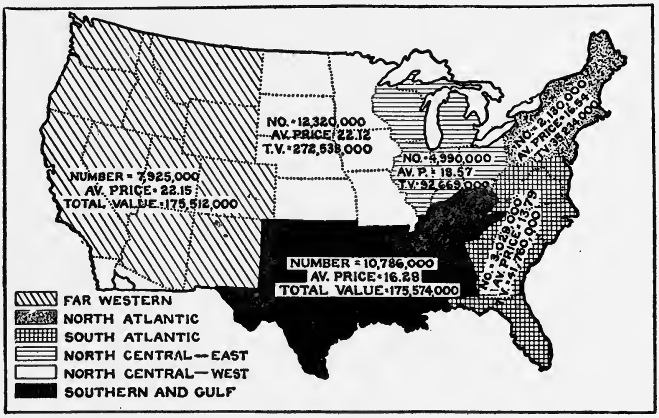

FIG. 57.—The number and value of cattle other than milch cows in the United States, April 15, 1910. (Mumford and Hall).

number of cattle other than milch cows in the United States (Fig. 58); considering the immense number of cattle brought in to be fattened there, perhaps not less than one-half of the beef cattle

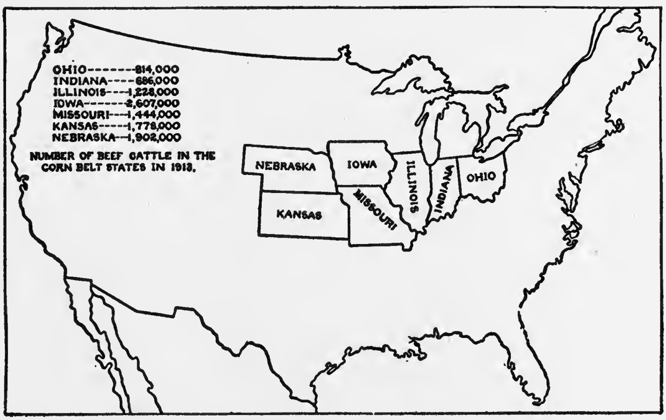

FIG. 58.—Number of beef cattle in the corn belt States, 1913. About one-third of the cattle other than milch cows in the country are kept in these States, and their value is equal to about two-fifths of the total value of such cattle in the United States. (Mumford and Hall, Illinois Circular 175.)

[1] Reproduced from Illinois Circular 169.

industry is centered in this section. The Far West section, on the other hand, furnished nearly one-fifth of the total number of cattle other than milch cows, which were largely raised and fattened by different owners.

With the passing of the public grazing domain and the gradual opening up of the range country in the western States to farmers, the second system is slowly giving way to the former; this implies, as we shall see, important changes also in the methods of feeding adopted. Farmers who raise and fatten their own cattle live in agriculturally well-developed States where land is high priced and

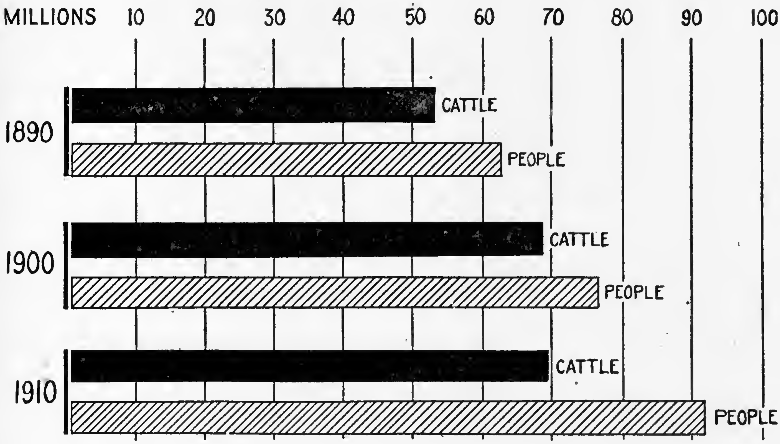

FIG. 59.—From 1890 to 1910 the number of cattle in this country increased from 53,000,000 to 69,000,000, an increase of 30 per cent., and the population increased from 63,000,000 to 92,000,000, an increase of about 46 per cent. The ratio of cattle to population was, in 1890, 100:84, and in 1910, 100:67.

feeding operations expensive, and they must, therefore, get the cattle ready for market in shorter time than is necessary for the cattle men on the western plains and ranges. The latter occupy large areas of cheap lands and can keep cattle at a relatively low cost, so that it is not so important whether they are marketed at three or four years of age. The farmer in the eastern and central States can produce beef profitably only by keeping stock of the improved beef breeds or using pure-bred beef bulls and giving the cattle good care and attention; they must also be fed with a view to being marketed at an early age, either as baby beef, yearlings, or two-year-olds (Fig. 59).

Growth and Fattening.—Before considering the method of feeding to be followed in the production of different kinds of steers, it will be necessary to discuss briefly some phases of the general laws of beef production. Beef production, as production of meat in general, includes two more or less distinct processes: Growth and fattening. The growth of animals takes place from birth to maturity, and consists essentially in an increase in the protein tissues of the body and the bone structure, etc. (p. 20). At the same time there is an accumulation of body fat that will vary according to the character and quantity of feed eaten. The production of protein tissues can be modified to a certain extent by the feed, but it appears to be mainly a function of the animal and is determined by its individuality and breeding. Growth is most active in the young, and gradually diminishes as the animal grows older, until it practically ceases in the mature animal.

Fattening, on the other hand, can take place at any age; it accompanies the production of protein tissues in the growing animal, especially if this is fed in liberal amounts with fattening feeds, but, as a rule, it goes on most rapidly from the time the animal has made its growth, when there is a greater surplus of feed materials available after the maintenance requirements of the body have been met. The fattening process is, therefore, in the main determined by the amount of feed which the animal receives and can digest in excess of that required for maintenance and growth, or for maintenance only, in the case of mature animals.

The processes of growth and fattening may, as suggested, be going on at the same time in the animal body. A calf or yearling, if gaining in weight, is always laying on fat, and a two-year-old may mature to some extent while being fattened. The fattening process improves the quality and flavor of the meat and makes it tender and juicy; this comes through a deposition of fat between the muscle tissue, and an increase of the extractives of the meat. The accumulation of fat about the internal organs and below the skin is incidental to the improvement of the meat by the fattening process and represents a certain value, but animals are fattened primarily to increase the tenderness and palatability of the meat, and not for the purpose of obtaining large amounts of internal fat and thick layers of fat about the body.

Composition of Increase in Fattening.—The results of early experiments at the Rothamsted station by Lawes and Gilbert show that an increase in body substance, even in young animals, consists, to a large extent, of pure fat. Jordan gives the following average figures for the composition of the increase in weight of young and mature fattening steers, the results shown in the first two lines being obtained in English experiments and those in the third line in American experiments:

Composition of Increase in Fattening Steers, in Per Cent

	Dry matter	Ash	Protein	Fat
Oxen fattened very young.........	63 to 68	2.25	10	50 to 55
Mature animals, final period.......	70 to 75	1.5	7 to 8	60 to 65
Well-fed steers, growth from 17 to 27 months of age..................	57.6	6.0	14.1	37.5

Even in animals that were fattened while very young, 37.5 to 50 per cent of the increase in body weight consisted of fat, 32 to 42 per cent was water, and 10 to 14 per cent consisted of protein. With mature animals, on the other hand, 60 to 65 per cent of the increase was fat, 25 to 30 per cent was water, and only 7 to 8 per cent protein. This suggests that a large supply of protein to fattening animals is not all-important, as was formerly considered the case. Practical feeding experience has shown that fattening animals require only a small amount of protein for making good gains so long as they receive plenty of digestible nutrients in their feed.

Protein Requirements.—The approximate protein requirements of cattle have been formulated by Armsby as follows, from the results of a considerable number of experiments; given in pounds of digestible protein per thousand pounds live weight.

1 to 3 months old, 4.8 to 3.5 pounds.
1 to 1½ years old, 2.0 pounds.
2 years old, 1.75 pounds.
2½ years old, 1.5 pounds.

In mature fattening animals the protein requirements are very small, as the formation of muscular tissue in these animals has practically ceased and protein is mainly required for repair of the body tissues.

Since the protein requirements for fattening animals are much lower than previously held necessary, the nutritive ratio of the rations fed may be much wider than that given by Wolff-Lehmann. Careful experiments have shown that the nutritive ratio of fattening rations may range from 1:4 to 1:10 without affecting the gain in body weight per unit of digestible matter eaten, provided the feed supplied above maintenance be furnished by easily digestible feeding stuffs (concentrates or roots). With a wider ratio than 1:10, there will be a depression in the digestibility of the nutrients, and lower results will be obtained than if the ration contained a larger amount of protein (p. 69). It was formerly believed that the protein in the feed was the source of fat in the body, but it has now being established, mainly through the investigations of German scientists, as well as by the results of practical tests, that the carbohydrates of the feed are the main sources of the body fat; protein has not, therefore, the importance in the feeding of fattening animals as was previously taught, and the Wolff-Lehmann standards for fattening cattle are now largely of historical interest only: They call for more protein and narrower nutritive ratio than necessary, as well as for excessive amounts of total dry substance and digestible nutrients, as has been shown by Jordan.[2] According to the latter authority, it seems evident that "under proper conditions 8 to 10 pounds of dry coarse feed and 15 to 18 pounds of grain are all that can generally be fed with greatest profit to a steer actually weighing 1000 pounds, and may be even more than is utilized by the animal to the best advantage. Such a ration would supply about 16 pounds of digestible organic matter."

Rate of Increase.—The rate of increase is more rapid in young than in older animals; it is also most rapid in the early stages of the fattening, and gradually diminishes toward the close of the period, when the animals reach the condition known as "finished."

The rate of gain calculated from statistics covering feeding experiments "with more than 50,000 cattle of different ages" is given as follows by Wilcox:[3]

Average Daily Gain in Young and Old Cattle.

½-year-old	2.3 pounds.
1¼-year-old	2.09 pounds.
2½-year-old	1.58 pounds.
3½-year-old	1.44 pounds.
4½-year-old	1.2 pounds.

The cost of 100 pounds gain produced with calves was $4.98; yearlings, $7.23; two-year-olds, $7.45; three-year-olds, $13.75.

The cheapest returns in gain in body weight for the feed eaten are obtained with young animals, because the nutritive processes are especially active in young life and a larger proportion of the increase is water in these animals than in mature ones. According to Professor Smith, of Minnesota Agricultural College, a two-

[2] "The Feeding of Animals," p. 345.
[3] "Country Life in America," July, 1905.

year-old steer will require approximately one-third more feed for a given gain in weight than will the yearling, and the three-year-old one-third more than the two-year-old.[4] While fattening young animals bring quicker and larger returns than older stock, under otherwise similar conditions, there are special difficulties connected with the fattening of young stock. It requires more skill and care on the part of the feeder to obtain satisfactory rapid gains with young stock. They require heavier grain feeding than older animals, and the chances for accidents are greater than with these.

Results at Smithfield Show.—The relation between the age of fattening steers, the average daily gain, and the percentage dressed weight is shown in the following table for one-, two-, and three-year-olds of seven different beef breeds slaughtered at the Smithfield, England, Fat Stock Show in 1888–1895:[5]

Average Data for Steers Slaughtered at the Smithfield Fat Stock Show, 1888–1895

	Number of animals	Daily gain, pounds	Average live weight, pounds	Per cent dressed weight
One-year-olds....	77	2.01	1329	65.5
Two-year-olds....	108	1.74	1744	67.1
Three-year-olds...	64	1.56	2055	67.9

The average daily rate of gain was higher with the yearlings than with the two-year-olds in case of all the breeds, and the daily gain made by the two-year-olds higher than that of the three-year-olds. The percentage dressed weight, on the other hand, was lowest for the yearlings, the two-year-olds being next, and the three-year-olds highest. We note that the yearlings gained 2.01 pounds, on the average, for each day of the fattening period; the two-year-olds, 1.74 pounds, and the three-year-olds, 1.56, and that the percentage dressed weights of the three classes of steers were 65.5, 67.1, and 67.9 per cent, for yearlings, two-, and three-year-olds, respectively.

Results at American Fat Stock Show.—The records of the American Fat Stock Show (precursor of the "International") for animals exhibited in the various classes have been compiled by Stewart for the years 1878–1885.[6] Summary figures are given in

[4] Cyclopedia American Agriculture, vol. iii, p. 318; these figures doubtless refer especially to the corn belt.

[5] Reported annually in the *Live Stock Journal and Agricultural Gazette*, London; from a compilation by Henry.

[6] "Feeding Animals," 3rd ed., p. 530.

the following table for gain for steers of different ages, and also for the gain for each successive group:

Relation of Age to Weight and Daily Gain of Steers

Classes of steers	Number of steers	Average age, days	Average live weight, pounds	Gain per day, pounds	Gain per period, pounds	
					Total	Daily
Calves	30	297	780	2.63	780	2.63
Yearlings	152	612	1334	2.18	554	1.76
Two-year-olds	145	943	1639	1.74	305	.92
Three-year-olds	133	1283	1938	1.51	299	.87

The figures show a decided decrease in the rate of daily gain with increasing age of the steers, and also a still more marked decrease in the gain for each period, viz., from 2.63 pounds for the calves to 0.87 pound for the last year of the three-year-olds.

The results given in the last two tables were obtained with

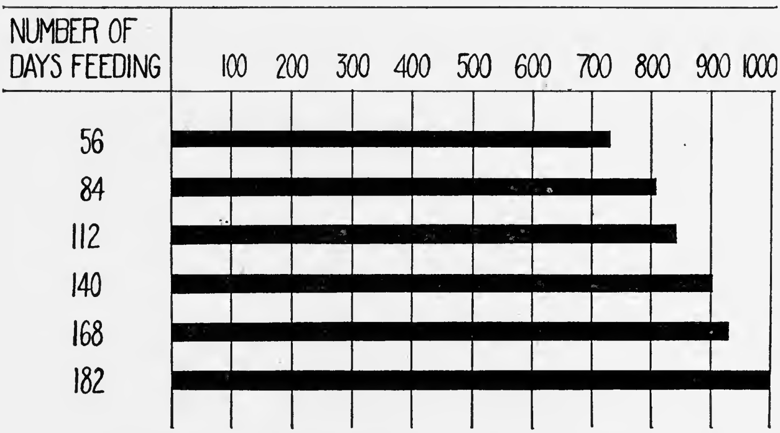

Fig. 60.—The amount of grain required to produce a hundred pounds of gain in fattening steers increases with the range of the feeding period from about 730 pounds to 1000 pounds. (Kansas Station.)

cattle of the specific beef breeds and of choice individuals within these breeds. They are, therefore, higher than are likely to obtain with steers of poorer breeding and fed less intensively (Fig. 60). The percentage dressed weight of cattle in thin body flesh will generally come from 54 to 58 per cent, and for fattening steers 58 to 65 per cent or better, according to the breed and degree of finish. The percentage dressed weight of steers but rarely exceeds 70 per cent.

Cattle Markets.—The largest central cattle markets in the country were located in 1910 as follows: Chicago (over 3,000,000 cattle received during the year), Kansas City (2,250,000), Omaha and St. Louis (both about 1,250,000), Fort Worth, Texas, New York, and St. Joseph, Mo. (decreasing, in the order given, from 1,000,000 to 500,000). Other important cattle markets are St. Paul, Sioux City, Denver, Indianapolis, Cincinnati, Buffalo, etc. The relative importance of these markets will doubtless change with the further development of our cattle industry, since cattle markets follow in the wake of the producing areas; western cattle markets have developed rapidly during the last few decades, while the eastern markets have in general declined.[7]

Shrinkage of Cattle.—When cattle are sold a certain deduction is generally made for the "shrink" in weight between the place where sold and marketed. This allows for the loss in weight that occurs during transportation, and varies according to the distance travelled and methods of transportation, as well as the system of feeding and handling of the cattle prior to shipping. The shrinkage is generally figured at 3 to 4 per cent. On a 1000-pound steer this will mean a deduction of 30 or 40 pounds for which no pay is received. The United States Department of Agriculture, in recent investigations of the shrinkage in weight of beef cattle in transit,[8] made careful studies of the various factors that influence the shrinkage. It was found that the shrinkage of range cattle in transit over 70 hours during a normal year is from 5 to 6 per cent of their live weight. If they are in transit 36 hours or less, the shrinkage will range from 3 to 4 per cent of their live weight. The shrinkage of fed cattle does not differ greatly from that of range cattle for equal periods of time. It varied from about 3 per cent with all of the silage-fed cattle and 4.2 per cent with the corn-fed cattle when both classes of these animals were in transit for less than 36 hours, to 5.4 per cent for the pulp-fed cattle which were in transit from 60 to 120 hours.

The Spread or Margin.—The profit in beef raising depends not only on the gains made by steers during fattening period, but fully as much on the price at which the steers are bought and sold. The difference in the latter two figures is known as "spread" or "margin"; this is given per hundredweight or pound. If feeding cattle are bought at, say, 6 cents a pound and sold at the end of the fattening period at 7 cents, there is a margin of 1 cent per

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[7] Illinois Circular 169. [8] Bulletin 25.

pound, or $1.00 per hundredweight. As the feed consumed by the steers frequently costs more than the value of the gain secured, it is important, in order to "break even," that there be a certain margin of profit. This may vary from ½ to 1½ cents per pound. Unless the feeder gets the benefit of the improvement in quality that occurs through the fattening process, he is not likely to come out even, and it is evident that the better he buys, the smaller margin will be required to make the feeding profitable; hence the old saying among stockmen, that "Cattle bought right are more than half sold."

The margin depends on at least five factors: The purchase price, the weight of animals bought, the gains made, the cost of the feed eaten, and the selling price. The manner in which each of these factors influences the profit of the feeding operations will be readily seen on reflection.

Cost of Feeding Beef Cattle.—The proportionate cost of the various expenses incurred in cattle feeding on twenty-four Iowa farms, as determined by the U. S. Department of Agriculture during 1909–1911, is shown in the following table. The figures given indicate in a general way the importance of the various expenses in feeding cattle, at least in the corn belt.[9]

Percentage of Various Expenses Incurred in Cattle Feeding on 24 Iowa Farms

	Purchase price*	Feed	Interest at 6 per cent	Labor	Shipping and selling†	Total
1909–1910	55.8	36.9	1.3	1.6	4.4	100
1910–1911	59.8	31.8	1.8	1.8	4.7	100
Average for both years	57.8	34.3	1.6	1.7	4.6	100

* Delivered at farm (including freight and incidental charges). † Excess in shrinkage.

It will be seen that the purchase price was more than one-half (57.8 per cent) of the total cost of the feeding, and that the feed cost came next, with about one-third (34.3 per cent) of the total expenses. These two items make up over 90 per cent of the expense of cattle feeding as practised on these farms, and the financial results of the feeding operations will, therefore, be determined largely by them and by the selling price of the steers. Waters [10] found that an average margin of $1.02 was required to cover the entire cost of

[9] Farmers' Bulletin 588.
[10] Missouri Bulletin 76; see also Purdue (Ind.) Circular 12.

fattening cattle in summer, in case of feeders in the Mississippi valley, and that a margin of $1.50 per hundredweight is necessary for six months' winter feeding with two-year-olds. Data obtained by the Purdue (Indiana) station in the same way showed that an average spread of $1.07 was required to break even under Indiana conditions, and that it cost cattle men in that State $4.80 per hundredweight gains in summer and $7.20 for gains in winter.

Length of Feeding Period.—This will vary from sixty days to a year, according to a number of conditions, as kind of stock, cost of feed, and market conditions. The various factors affecting the length of the fattening period are succinctly stated as follows

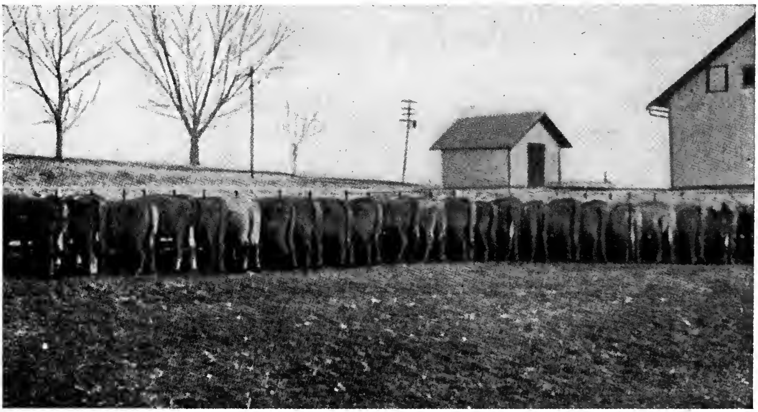

FIG. 61.—Tennessee steers in the feed lot. (Tennessee Station.)

by Mumford.[11] "The principal factors affecting the length of the feeding period are: Method of feeding, grade, condition, and age of feeding cattle used.

"*Method of Feeding.*—Where it is desired to feed a ration in which there is a large proportion of roughage to grain, the fattening process is slow. On the other hand, the feeding of large proportions of grain to roughage, or, in other words, the feeding of a highly-concentrated ration, usually shortens the fattening period. Forced feeding on highly-concentrated rations required for quick finish is, of course, more hazardous than the longer feeding period with the more bulky ration. A compromise between the two somewhat radical methods has been practised with excellent results. This compromise method is as follows: For winter fattening

[11] "Beef Production," p. 100.

1000-pound feeders in a six months' period, use thirty to sixty days for getting cattle to full grain ration, allowing free access to all the roughage the cattle will take at the beginning, and gradually decreasing the amount of roughage as the grain is increased. With two- and three-year-old cattle that are finished on grass, 120 days of full feeding are usually sufficient to put such cattle in satisfactory marketable condition after they have been carried sixty to ninety days on light grain rations.

"*Grade and Condition of Feeding Cattle Used.*—The quality or breeding of the cattle has a direct bearing upon the proper length of the fattening period. Common cattle of the lower grades and plainer sorts are not susceptible to the same high finish that can be given well-bred cattle, hence it is useless to feed them for it. Low-grade feeders finish quicker than those of high grade at the same weights and in the same condition, because they are older (Fig. 61).

"*Age of Feeding Cattle Used.*—In ordinary practice it takes three to four months to finish mature feeders, five to seven months for two-year-olds, eight to ten months for yearlings, and ten to eighteen months for calves."

Returns for Feed Eaten.—Information secured from cattle men in the corn belt by the Illinois station shows that the amounts of grain (corn or its equivalent) and hay required to produce 100 pounds gain in case of steers of different ages in winter and summer are, on the average, as follows:[12]

Feed Required for 100 Pounds Gain with Steers of Different Ages

	Pounds gain produced from one bushel corn	Per 100 pounds gain	
		Hay, pounds	Grain feed, pounds
Calves, winter	8.9	378	630
Calves, summer	10.0	267	577
Yearlings, winter	6.5	517	857
Yearlings, summer	7.6	219	734
Two-year-olds, winter	5.4	473	1036
Two-year-olds, summer	6.8	129	818

According to a common rule of feeders, it takes 1000 pounds grain and 500 pounds rough feed per 100 pounds gain in the feed lot; the averages of the returns on which the preceding data are based are 924 pounds grain and 428 pounds of roughage, showing that this rule gives a somewhat liberal allowance of feed [13] (Fig. 60).

[12] Illinois Circular 88. [13] *Loc. cit.*

Pasture for Steer Feeding.—The profit made in feeding steers will depend largely on the kind and quality of the available pasture. Steers make their cheapest gains during the summer on grass, but grass-fed cattle do not bring the prices that those fed corn or other concentrates command, and if they are to be sold on the large markets they should receive grain in addition, especially later in the season, when the pastures no longer furnish abundant feed. It is important not to overstock the pastures, so that they will not be eaten too closely to furnish ample feed for the steers. On an average, one and one-half to two acres should be allowed per head to secure sufficient feed supply throughout the season. When grain is fed to cattle on pasture, the area of land for each steer may be reduced to one or one and one-half acres. On irrigated alfalfa or mixed pasture 2 steers may be allowed to the acre; while on poor hill or range pastures, it will take 20 to 25 acres to support a steer.

The gains made on pasture are also dependent on the method of winter feeding practised. If the cattle have been wintered largely on rough feeds and have been accustomed to depend on roughage for nourishment, they will be better able to make satisfactory gains on pasture alone, but whether they should be marketed as grass-fed must depend largely on the condition of the market. The gains made by cattle on pasture will range from one and one-half to two pounds a day. Waters reports [14] that successful cattle men in Missouri, Illinois, and Iowa obtained the following gains for the season of six months: From yearlings, 270 to 288 pounds; for two-year-olds, 312 to 318 pounds. If a charge of 75 cents a month be made for yearlings on pasture, their gains cost approximately $1.60 per hundredweight; charging $1 a month for the season for the two-year-olds the gains they put on cost about $1.90 per hundredweight. Gains made on winter feeding, on the other hand, will cost at least $6 per hundredweight, and may be double this amount; the relative cheapness of pasture feeding when good gains are made is apparent from these figures.

Silage for Steers.—The number of cattle men who are feeding silage to their stock has increased greatly during late years, and in many sections silos are now as common on stock farms as they have long been on the dairy farms. The rapid growth of silage feeding on stock farms is conclusive evidence that silage is a good feed for steers. It is the consensus of opinion among feeders that it decreases the cost of beef production considerably, especially where no legume hay or protein feeds are fed. Trials have also shown that the addition of corn silage to an ordinary fattening

[14] Missouri Circular 24.

ration will result in an improvement in the rate of gain and the dressing percentage, will decrease the cost of the gain, and give better finished steers.

The value of silage for fattening steers has been demonstrated by the results of experiments at a number of our stations.[15] In experiments at the Indiana station four lots of steers were fed for 160 days on rations composed of shelled corn, cotton-seed meal, and clover hay, three of the lots receiving corn silage in addition, viz., on the average 16.0, 27.4, and 24.8 pounds per head daily. The lot receiving shelled corn, cotton-seed meal, and silage yielded an average profit of $20.96 per steer; the two lots receiving shelled corn, cotton-seed meal, clover hay, and silage yielded $10.51 and $13.59, and the fourth lot, receiving shelled corn, cotton-seed meal, and clover hay, yielded a profit of $3.37 per head.

If the value of the pork produced from the droppings and the extra corn fed the hogs be included, the profit from the three lots fed silage came as follows: $26.21, $17.09, and $19.43 per head, in the order given, and that without silage, $8.24 per head. Trials at other stations have shown that a ration of corn, cotton-seed meal, and corn silage will give equally good results in every respect for fattening steers as corn, cotton-seed meal, and clover or alfalfa hay. The testimony of experiments with silage *vs.* roots for fattening steers conducted in Canada[16] and in England[17] is also decidedly in favor of silage.

Silage is especially valuable on stock farms in times of short pastures. A silo for making summer silage is as good an investment for beef production as it is on dairy farms (p. 97).

Concentrates.—The use of concentrates in feeding fattening steers will appear from the discussions of different systems of feeding beef cattle given below. It will be noted that there are wide variations in the amounts and kinds of different grain feeds fed under different conditions. Beef cattle are finished for the market on roughage alone (blue-grass pasture, alfalfa, or alfalfa and beet pulp) in eastern and western States, respectively, and in the corn belt as much as 24 pounds of grain is often fed per day to fattening steers on full feed. The concentrates fed to fattening steers

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[15] Missouri Bulletin 112; Pennsylvania Bulletin 118; Indiana Bulletins 136, 163; Virginia Bulletins 157, 173; Illinois Bulletin 73; Ohio Bulletin 193.

[16] Ontario Agricultural College Reports, 1891, 1901, 1902.

[17] Summaries of 201 trials quoted by Henry, "Feeds and Feeding," 10th ed., p. 358.

are, in general, similar to those fed dairy cows, but the feeding of Indian corn predominates, being of far greater importance for this purpose than all other grain feeds combined. It is the great fattening feed of America, and, on account of its high starch and oil contents and high digestibility, may be considered the most important factor in both beef and pork production in this country. Corn is fed to fattening steers in the majority of cases as snapped

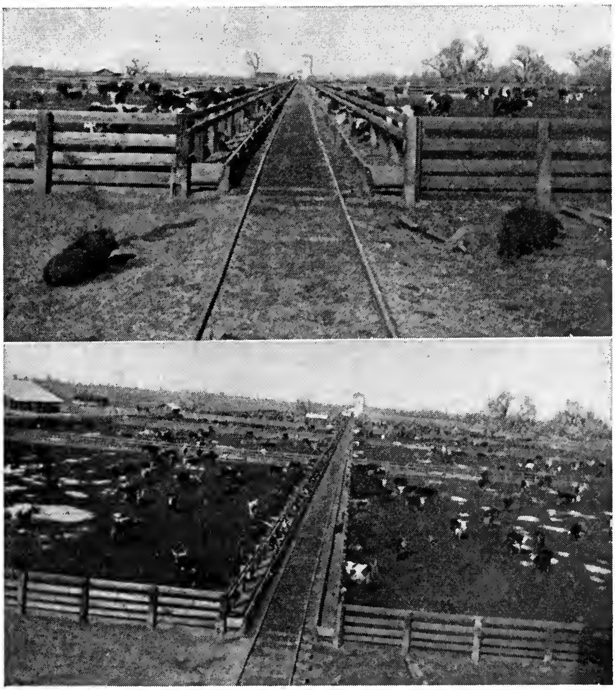

FIG. 62.—Steer feeding barns and feeding troughs on a California cattle ranch. (See also Fig. 31.) (*Pacific Rural Press.*)

(unhusked) or husked ear corn or whole shelled corn. It is crushed, ground, or soaked only in exceptional cases, viz., when very dry and hard on account of having been stored long in the crib. Being only medium or low in protein, it is supplemented to advantage in feeding steers with legume hay, or some high-protein feed, like linseed meal or cotton-seed meal, which is fed two to three pounds a day during the last sixty days of the fattening period (Figs. 62 and 63).

Use of Self-feeder.—A self-feeder is a labor-saving device for feeding grain feeds to stock (Fig. 64). It consists of a feed box that holds a considerable quantity of grain or other concentrates; the feed passes down into the feed trough below as this is emptied by the cattle, and the supply has only to be replenished at intervals. It may also be used for feeding steers a mixture of grain feeds, or cut hay mixed with grain. The self-feeder is used by cattle men in different localities with varying success; no automatic system of feeding cattle or other animals can, however, give the best results for any length of time, for "the eye of the master fattens his cattle," and the self-feeder can only be looked upon as an aid in economizing skilled labor in feeding operations. Cattle men have reported both success and failure with self-feeders. It appears that, on the whole, they may serve a useful purpose if properly constructed[18] and the cattle are put on a maximum grain feed

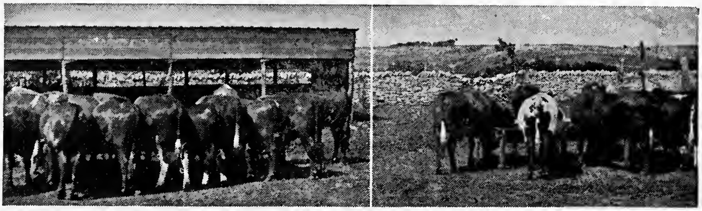

FIG. 63.—Beef cattle fattened on corn, fed in large, flat troughs. ("Productive Farming," Davis.)

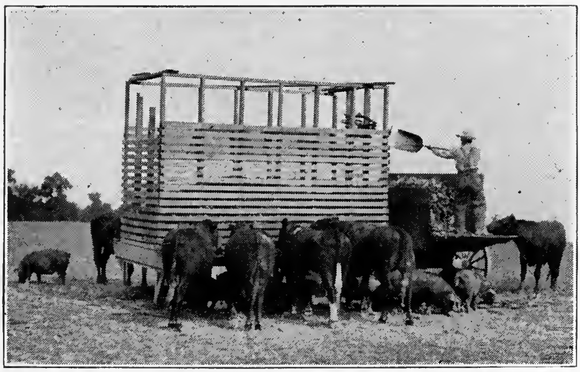

FIG. 64.—The self-feeder is used by many farmers in the corn belt States for feeding corn or grain mixtures to fattening steers. Hogs are generally kept with the steers. (*Breeders' Gazette.*)

[18] See Mumford, "Beef Production," p. 149.

slowly prior to being turned on to the self-feeder. An experienced Illinois cattle man gives as his opinion of the self-feeder that "it is more reliable than a careless man and more economical of labor than even a careful man." Under favorable conditions, self-fed steers are likely to eat more grain and make larger gains than those fed by hand, but it requires slightly more feed to produce a given gain with the self-feeder.[19]

The feeding of beef cattle will be considered under the following heads: Baby beef, yearlings, two-year-olds, and older cattle.

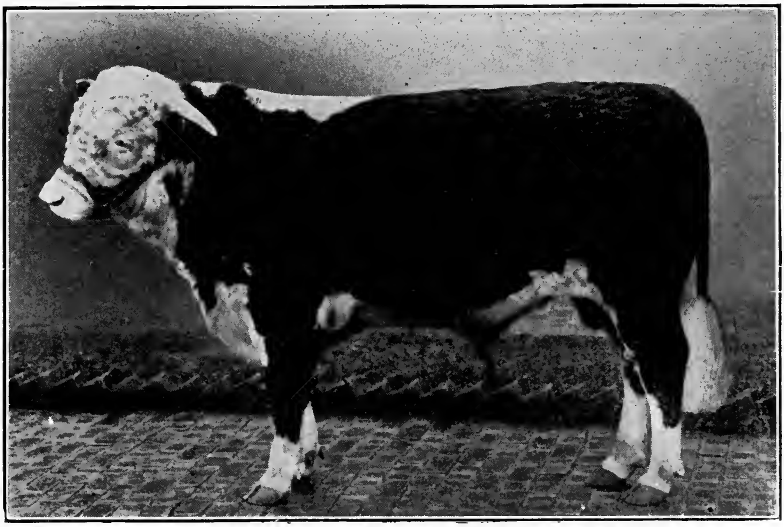

FIG. 65.—A Mississippi-raised "baby beef" calf. Note the wonderful thickness of flesh. (Ward.)

Baby Beef.—The production of baby beef (Fig. 65) is followed mainly by feeders in the corn belt. It has several advantages over feeding of older cattle; there is always a good market demand at high prices for this class of steers, weighing 1000 to 1150 pounds at an age of 16 to 18 months, and the feeder receives quick returns for his investment. Baby beeves are likely to dress somewhat lower than older cattle, but they furnish more valuable meat and have less inedible fat than the others, and have no coarseness about the neck, brisket, and chuck. To offset these advantages, it requires a higher grade of cattle and more skill and care on the part of the feeder to produce baby beef, and there is a greater chance for

[19] Illinois Bulletin 142.

accidents through sickness, like indigestion and blackleg, than in feeding older cattle.

In order to make satisfactory baby beef, calves must be of good beef type, low set and blocky, from a pure-bred, early-matured beef bull (Fig. 66). Such a bull will sire a high percentage of excellent beef calves from good grade cows, but it is not likely that calves from scrub or dairy cows can be fattened into sufficiently ripe carcasses at the age required. Calves fed for baby beef must be kept steadily gaining until they are ready for the market. They generally receive their dam's milk until weaning time, and are fed grain as soon as they learn to eat it; whole corn and oats in the

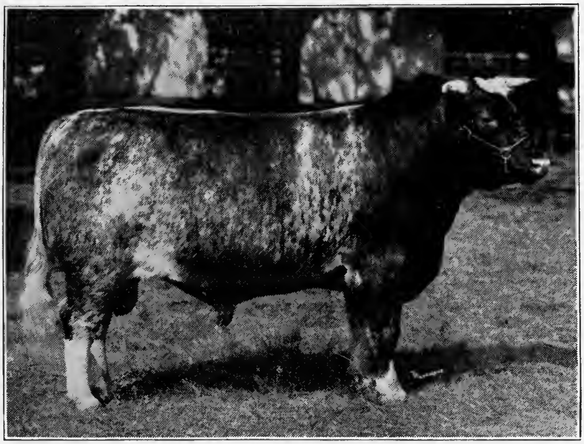

Fig. 66.—A grand champion Shorthorn bull. (*Breeders' Gazette.*)

proportion of 3 to 1, with some pea-size linseed meal, will make a very satisfactory grain mixture for calves, and with a good grade of hay or pasture will produce excellent gains. After weaning, they are gradually brought on to full feed and receive the mixture given, with some wheat bran or similar protein feed. A little cornstalks may be also fed to advantage. Baby beef calves dropped in the spring are rarely ready for market until July of the following year; they are generally marketed during the last months of the year, at about 18 months old, when they should weigh about 1100 pounds.

Calves raised on skim milk and grain are also sometimes fed for baby beef, but this requires special skill and experience because of the difficulty of keeping the calves steadily gaining by this system, as well as of selecting the kind of calves that will have the capacity for feed and individual quality necessary to make the desired rapid gains under these conditions. Inexperienced feeders are not likely to make a success of finishing skim-milk calves as baby beeves, as it takes still more expert knowledge than the production of baby beef from calves raised on whole milk.

Yearlings are cattle 18 to 23 months old. The fattening of yearlings represents a less extreme system of fattening than baby beef, but is ahead of feeding older cattle in that quicker and larger returns are obtained than in the case of these; it has the advantage over feeding calves for baby beef in that more of a gain is made on grass or rough feeds, and it requires less grain to reach the final weight. This method is especially adapted for farmers who have an abundance of good summer pasture. Calves generally receive little or no grain before they are weaned from the pail or the cow, as the case may be. They are furnished abundant pasture for the fall months, and during the winter all the good hay they will eat, with a small allowance of grain. They depend on pasture only during the following summer, and are given a full feed of grain the next fall and winter; they will be likely to consume, on the average, about 16 to 18 pounds of corn or its equivalent daily at this time, in addition to hay or fodder corn planted thick; a daily feed of alfalfa, clover, or other legume hay will furnish a variety and produce good results. The grain may be corn alone or equal weights of corn or wheat bran; if no legume hay is available, a pound of linseed meal should be fed with corn and bran. One pig is kept in the feed lot for each steer to consume the corn in the droppings. By this method of feeding the steers will be in good condition for marketing in the spring, when they will weigh 1100 to 1200 pounds at 23 months old, and will be likely to command a good price.

Two-year-olds.—The system of marketing two-year-olds (Fig. 67) is most satisfactory on farms where hay and pasturage are abundant and concentrates are expensive. These cattle are fed a light grain ration the first winter and a half grain ration the second winter. They are fed grain while on pasture, but, as a full feed of grain on grass is only two-thirds of a full feed with hay, this makes an economical method of feeding. The steers are generally fed soaked corn when on pasture, with some coarse crushed linseed cake if they are on timothy or other grass pasture. Two-year-olds are, as a rule, marketed in July during the early part of the second summer, before hot weather and fly time set in; if marketed before July, they should not be put on grass at all the second season, as the shrink that occurs during the first few weeks on grass would reduce their weight.

Two-year-olds are often also carried over to fall by feeding fodder corn (corn with ears) after the ears have hardened and when the fodder is ready to be shocked. The feeding of the corn is continued for about three months until toward December, when the steers will be sufficiently fat for the market. This method of feeding furnishes an excellent and cheap combination of grain and roughage well suited for fattening cattle. More liberal gains and marketing at an earlier date may be secured by feeding, in addition to fodder corn, bran and linseed meal in the proportion of 3 to 1,

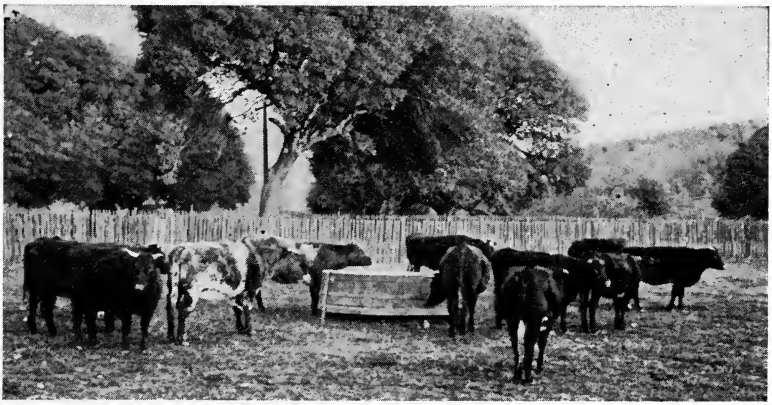

FIG. 67.—Fattening steers in California. (*Pacific Rural Press.*)

giving about four pounds of the mixture a day per steer. Gluten feed or cotton-seed meal may also be fed to advantage in the place of linseed meal, if the market price is in favor of either of these feeds.

Hogs Following Steers.—It is a common practice to keep hogs with the steers in feeding fattening steers, especially in the corn belt. The hogs eat the undigested whole and broken corn in the droppings of the steers, and a waste of feed is thus prevented. The number of pigs per steer varies according to the kind of steers and the feed they are receiving; more pigs may be put with older steers than with yearlings, and more when corn is fed whole or cracked than when corn meal is fed. Waters states[20] that two or three pigs per steer are kept when these are fed snapped corn; one

[20] Missouri Bulletin 76.

and one-half per steer on husked corn, about one per steer on shelled corn, and one pig per two or three steers on crushed or ground corn. Pigs following steers should be of good bone, in thin flesh, and of medium weight, viz., about 100 pounds; shoats put with steers may be lighter, viz., 50 to 60 pounds. When the pigs are nearly matured or fattened they should be replaced by a new set of pigs, as fat pigs are unprofitable for following steers.

The gains made by hogs following steers will vary according to the conditions of the feeding. It may be assumed that when a steer is fed about 18 pounds of shelled corn a day, about three-fourths of a pound of pork may be obtained; if ear corn is fed, greater gains will be made, while if corn meal or cotton-seed meal is fed, only a very small amount of pork will be produced, as the steers are able to fully digest the grain when finely ground.[21]

On account of the narrow margin in fattening steers and the expense of grain feeding it may happen, under unfavorable market conditions, that no profit is made on the steers, but the pigs following them, which have eaten a relatively small amount of extra grain, can, as a rule, be depended upon to bring a profit, and they often save the feeding operation from being a losing proposition.

Feeding Range Cattle.—Time was when cattle raised on western plains and mountain ranges were kept until four or five years old before they were fattened, but the large majority of range cattle now are sold as two to three years old, and are fattened for a period, varying in different sections of the country, from 60 to 180 days. The method of feeding depends on the condition and demand of the market for which they are intended. In the corn belt, where a large proportion of the range steers are fattened, the common practice is to feed snapped corn (ears with the husk) as the only grain feed at the beginning of the fattening period, giving clover or alfalfa hay as supplementary feed; after six or eight weeks, ear corn with some cob meal is gradually substituted for the snapped corn, and the corn is increased slowly until the steers are on full feed. They will then eat 20 to 25 pounds per head daily. If no legume hay is available, a couple pounds per head daily of some protein feed is fed with the grain, as wheat bran, linseed meal, cotton-seed cake, or gluten feed. Steers on full feed eat but little hay, viz., less than 10 pounds daily.

Cattle in the western States are generally fattened as three- or four-year-olds on alfalfa alone. Immense numbers of steers raised

[21] **Farmers' Bulletin 588.**

in Wyoming, Nevada, Texas, and other western and southwestern States are fattened each year in the open valleys of the mountainous States and in California, receiving no feed but alfalfa hay, fed either long or cut (chopped). The cattle do not generally get fat on this feed, but the gains made are relatively cheap. As these cattle are fed in racks in open corrals, the gains which they make are dependent, to a large extent, on the winter weather and the condition of the corrals, as well as on the quality of the steers and of the feed supply. In case of muddy corrals and feed lots the gains made by the steers will be greatly reduced; this applies with still more force to hogs with the steers. Paved or cement feed lots, or at least feed bunks with wooden platforms, make a profitable investment. The necessary equipment for cattle feeding will vary with the climate, and especially the rigor of the winter season. Steers comfortably kept and receiving good care will yield greater profits than those that have to shift more or less for themselves and are exposed to the inclemency of the weather, without shelter or protection from rains or snow, cold winds, or intense sunshine.

Steers fed alfalfa only will eat 25 to 35 pounds of alfalfa hay per head daily. Under favorable conditions good steers will gain two to two and one-half pounds a day on this feed; the average would, however, be likely to come below two pounds per head daily, rather than above this figure. The steers go on the market weighing from 1000 to 1200 pounds, and have a dressing percentage of 56 to 60 per cent. There is a preference shown on the western markets for medium steers weighing less than 1150 pounds. In the vicinity of the western sugar factories wet or cured beet pulp is fed mixed with chopped alfalfa hay. The common feeding period is 60 to 90 days, depending on the gains made and the condition of the market. Grain is rarely fed to either these or alfalfa-fed steers, as the market does not call for finished steers, that are as fat as required by the central or eastern markets. Steers fed chopped alfalfa hay and beet pulp will generally eat about 100 pounds pulp and 15 pounds alfalfa hay per head daily, and will gain about two pounds a day on this feed (p. 194).

Beef Production in Eastern and Southern States.—While the West and Southwest supply the bulk of the beef cattle in this country, a large number of cattle are being fattened every year in the eastern and southern States. The cattle industry is especially of increasing importance in the latter section. The South has many advantages for beef production, as, in fact, for animal husbandry in general. Forage crops of a great variety suited for cattle feeding can be produced cheaply and abundantly there, and the favorable winter climate reduces the cost of investment in buildings and equipment for cattle feeding. Excellent forage crops, like alfalfa, cowpeas, velvet beans, sorghum, soybeans, etc., together with cotton-seed meal, are the main feeds which will enable southern farmers to raise and fatten beef cattle cheaply and which will lead to a gradual development of the cattle industry in the South. The danger of Texas fever is one of the disadvantages. Large areas are, however, gradually being freed from the tick that causes this disease, and the time is probably not far distant when the whole South will be free of the Texas fever tick.[22]

Rations for Steers.—The following sample rations will show the kinds and amounts of feeding stuffs that may be fed to fattening steers per 1000 pounds live weight:

1. 10 pounds clover hay, 20 pounds corn, 3 pounds cotton-seed meal.
2. 5 pounds clover hay, 5 pounds corn stover, 20 pounds corn.
3. 10 pounds alfalfa hay, 15 pounds corn, 2 pounds linseed meal.
4. 10 pounds alfalfa hay, 18 pounds corn.
5. 25 pounds corn silage, 10 pounds mixed hay, 10 pounds shelled corn, 2 pounds cotton-seed meal.
6. 20 pounds mixed hay, 10 pounds snapped corn.
7. 25 pounds cotton-seed hulls, 6¼ pounds cotton-seed meal.
8. 20 pounds corn silage, 10 pounds clover hay, 10 pounds barley.
9. 15 pounds kafir corn, 12 pounds cotton-seed hulls, 3 pounds cotton-seed meal.
10. 8 pounds alfalfa hay, 12 pounds corn meal, 6 pounds oats.
11. 25 pounds alfalfa hay, 6 pounds barley.
12. 30 pounds corn silage, 10 pounds mixed hay, 10 pounds corn.

QUESTIONS

1. What are the two systems of feeding beef cattle in this country? State the advantages and disadvantages of each one.
2. What is the average composition of the increase in fattening steers?
3. Why are the Wolff-Lehmann standards for fattening steers not reliable guides?
4. What is the law in regard to the relation of age and weight of fattening steers to the (*a*) daily gains, (*b*) per cent dressed weight?
5. What does the term spread or margin mean, as used by cattle men?
6. Give the main factors on which the spread depends.
7. Give the factors that determine the length of feeding period.
8. How much grain and roughage does it take, on the average, to produce 100 pounds gain in fattening steers?
9. Why is pasture feeding for steers cheaper than feeding during the winter months?
10. Discuss briefly the value of silage for steer feeding.
11. What is baby beef?
12. Give the conditions under which it may be successfully produced.
13. Describe briefly the methods followed in the feeding of (*a*) yearling steers, (*b*) two-year-olds, (*c*) range steers.

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[22] Farmers' Bulletin 588.

14. Describe the method of keeping hogs with fattening steers.
15. Where are the main cattle markets located in the United States?
16. What do you understand by shrinkage of cattle, how is it influenced, and what are the average figures under different conditions?
17. What is a self-feeder? Under what conditions is its use advisable in beef production?

Literature on Feeding Cattle.—Mumford, " Beef Production," Urbana, Ill., 1908 (see p. 226) ; Barnes, " Western Grazing Grounds," Chicago, 1913; Ward, " Beef Production in the South," Farmers' Bulletin 580, 1914; Cotton and Ward, " Economical Cattle Feeding in the Corn Belt," Farmers' Bulletin 588, 1914;Curtis, " Some Essentials in Beef Production," Farmers' Bulletin 71, 1898; Bentley, " Cattle Ranges in the Southwest." Farmers' Bulletin 72, 1898; Armsby, " Feeding for Meat Production," Bur. Animal Ind., b. 108; Gray and Ward, " Beef Production in Alabama," Bur. Animal Ind., b. 131, 159.

Experiment Station Bulletins, Circulars and Reports.—Ala., b. 103; Ariz., b. 50; Ark., r. '99; Colo., b. 102; Fla., r. '01, b. 96 and 102; Ill., b. 9, 73, 83, 103, 142, c. 79, 169; Ind., b. 129, 130, 136; Iowa, b. 75, c. 6; Kan., b. 47, 67, 130, 132, 198; Ky., b. 108; Mich., b. 247; Mo., b. 76, c. 24; Miss., b. 136; Mont., b. 58; Neb., b. 85, 90, 93, 100, 105, 110, 116, 117; N. M., b. 57; N. D., b. 33, 73; Ohio, b. 193; Okla., r. '01; Penna., b. 118, 124; S. D., b. 97, 100, 148; Texas, b. 76, 86, 97, 110, 159; Utah, b. 90; Va., b. 157 and 173; Wash., b. 79; Ont. (Guelph), r. '91.

CHAPTER XXIV

FEEDING HORSES AND MULES

Feeding Standards for Horses.—The Wolff-Lehmann and the Kellner-Armsby standards are here given, to be followed in determining the best rations for horses.

The Wolff-Lehmann Standards for Horses, per 1000 Pounds Live Weight

	Dry matter	Digestible		N. R.
		Protein	Carbohydrates and fat*	
Light work....	20	1.5	10.4	1:7.0
Medium work.	24	2.0	12.4	1:6.2
Heavy work...	26	2.5	15.1	1:6.0

*Given separately by Wolff-Lehmann.

The Kellner-Armsby Standards for Horses

	Digestible true protein, pounds	Energy values, therms
Maintenance requirements:		
For 1000-pound horse.....	1.0	7.00
For 1250-pound horse.....	1.2	8.15
For 1500-pound horse.....	1.3	9.2
Requirements for 1000-pound horse, including maintenance:		
Light work..............	1.0	9.8
Medium work...........	1.4	12.4
Heavy work.............	2.0	16.0

Work Done by the Horse (Fig. 68).—The horse is kept for the production of work; this may be pulling a load or carrying a rider; in either case, the energy in the feed eaten over and above that necessary for the maintenance of the body is used for performing the work required, in addition to moving his own body forward. The work is done by the contraction of his muscles, and the material stored up in these from the digested and assimilated feed is oxidized in this process. If the oxidation of the materials in the muscles goes on faster than the repair of muscles from the feed supplied, the horse will lose weight. This frequently happens when a horse is working hard for a considerable period of time and does not receive a sufficient quantity of easily digestible feed (concentrates).

Character of Feed Required.—As the muscles are largely composed of proteins, it might be supposed that the decomposition of protein in the body would increase with the amount of labor performed; such is not the case, however. The oxidation of non-nitrogenous materials in the body, on the other hand, increases rapidly when hard work is done. A part of the energy thus set free appears as heat, and another part as mechanical work. The oxygen required for the oxidation processes going on in the body is

FIG. 68.—Draft horses that give a good account of themselves in the show ring, as breeding animals and for doing heavy work. (*Pacific Rural Press.*)

supplied by the blood, and the oxidation products formed, carbon-dioxide and water, are exhaled through the lungs and in the perspiration. The result of heavy work is, therefore, seen in an increased consumption of oxygen and an increasing excretion of carbon-dioxide and water. This is also what takes place when mature fattening animals are gaining weight. The carbohydrates or fat, or both, are the main sources of energy supply both in the production of body fat and muscular energy, and it is not necessary to furnish more protein to working animals than in the case of fattening animals, viz., sufficient to insure a complete digestion of the feed. For this purpose a nutritive ratio of 1:8 or 1:10 will suffice.

A growing animal that is performing work requires a special supply of protein, and the same appears to be the case with race horses or driving horses which perform heavy work within a short time; but for horses working at ordinary pace only a relatively small protein supply is required. The amounts of non-nitrogenous components of the ration, on the other hand, must be increased with the amount of work done. The standards for work horses, therefore, call for a relatively wide nutritive ratio of 1:6 or 1:7; even this ratio is narrower than that of rations ordinarily fed in this country, unless alfalfa or clover hay is fed, in which case a considerably narrower ratio is fed. Horses in the eastern and northern States are frequently given no other feeds than timothy hay and either oats or corn and oats. The nutritive ratios of these feeds are as follows: Timothy hay, 1:16; corn, 1:9.5, and oats, 1:5.5. It is evident, therefore, that rations composed of these feeds will be likely to have nutritive ratios of 1:9 or wider. American horses (outside of alfalfa sections) are rarely fed appreciable quantities of high-protein feeds, showing that they require but relatively small amounts of protein in their feed, and that they receive wide nutritive ratios even when at hard work.

Measurement of Work.—The amount of work done by a horse may be measured by one of the usual units of mechanical energy, a foot-pound or a foot-ton. A foot-pound is the amount of energy expended in raising one pound one foot high; a foot-ton is that expended in raising one ton one foot high. The horse-power is another common unit of energy, and is equivalent to 550 foot-pounds per second, or nearly 2,000,000 foot-pounds per hour. A horse's capacity for continuous work is, however, considerably smaller than this amount, and may be put at about 1,000,000 foot-pounds per hour per 1000 pounds weight. Light work done by horses, as commonly understood, will mean from 500,000 to 1,000,000 foot-pounds per hour, medium work from 1,000,000 to 1,500,000, and heavy work from 1,500,000 to 2,000,000 foot-pounds.[1] Instead of measuring the amount of work done by units of mechanical energy, this may be measured in the same way as the potential energy of feeds, by the unit of heat, a Calorie or a therm (p. 45); this is a convenient method, because these unit values are now often used in feed analyses and in statements of feeding standards. One Calorie corresponds very closely to 1.54 foot-tons or 3087 foot-pounds.

The relation of the nutrients required for the production of a certain work by the horse under varying conditions has been studied in extensive investigations by German and French scientists, especially among the former, by Wolff, Zuntz, and Kellner. These

[1] Murray, "Chemistry of Cattle Feeding," p. 153.

studies have been of fundamental importance and through them we are able to determine approximately the net energy that must be supplied in the feed for the production of different kinds of work at varying speed, on the level, or ascending certain grades, etc. Zuntz found that nearly one-third (31.3 per cent) of the total energy of feed can be converted by the horse into useful work. This is at least three times greater economy than that obtained in a modern steam engine. The energy required to masticate and digest feed by horses was also determined by Zuntz in an elaborate series of experiments; this energy was found to vary greatly with feeding stuffs of different character. In the case of hay, oats, and corn, for instance, the matter stands as follows:

	Hay	Oats	Corn
Pound total digestible matter in one pound	.391	.615	.785
Labor expended in chewing and digestion (in terms of nutrients)	.209	.219	.082
In per cent	53	35	10

In the case of coarse feeds a considerable proportion of the potential energy is consumed in the processes of mastication and digestion, and hence lost for productive purposes, while with cereals, grain feeds, and roots these processes require a smaller proportion of the energy, and more remains for production. With some kinds of straw a negative nutritive value was obtained, showing that while a certain amount of heat was liberated in the digestion of the straw which was ordinarily of benefit to the animal, there would be no excess of energy available for production; in fact, a larger portion of nutrients than found in the straw would be required to supply the energy called for by the increased internal muscular work.

Energy Requirements of the Horse.—Through the result of investigations along this line that have been conducted especially by German scientists we are able to calculate the energy requirements of horses for a certain piece of work. Armsby gives the following example:[2]

We will suppose that a horse weighing 1100 pounds is required to haul a load of one ton 20 miles a day on the level road. at a rate of 2.88 miles per hour, the draft averaging 100 pounds. The useful work will be in this case

5280 (feet per mile) × 20 × 100 equals 10,566,000 foot-pounds, or 3,421 Calories.

Since 31.3 per cent of the energy liberated in the body is utilized in draft, it will require, to perform 3421 Calories of work, 3421 divided by .313, which equals 10,929,000 Calories of energy in the body. It has been found that it calls for an expenditure of energy equivalent to 264 Calories for a 1100-pound

[2] Cyclopedia American Agriculture, vol. iii, p. 88.

horse to move his own body a distance of one mile at the speed given, and the expenditure of energy for locomotion will, therefore, be 264 × 20 equals 5280 Calories. To these amounts must be added the maintenance requirements of the animal, viz., 4356 Calories. The available energy required per day will then be

	Calories
For useful work	10,929
For locomotion	5,280
For maintenance	4,356
	20,565

If we assume 10 pounds of hay and 10 pounds of oats as the basis of the ration of the horse, the remainder of the food to be supplied in the form of corn, we have:

		Calories
Net available energy required		20,565
In 10 pounds of hay	3,270	
10 pounds of oats	8,820	
		12,090
Lacking		8,475

Corn required to complete the ration: 8,475 ÷ 1263 = 6.7 pounds.

By a similar method of calculation and the use of Kellner production values (p. 50), we arrive at 8.3 pounds of oats as the amount required to complete the ration.

The available energy in feeding stuffs for horses has not been determined directly, but is from computed data, "some of which appear of questionable validity" (Armsby), and we must, therefore, look upon calculations like the foregoing as showing only approximately the true energy requirements of horses for work. As a general guide to the feed requirements at work, Kellner recommends the amounts per thousand pounds live weight given at the beginning of the chapter under Kellner-Armsby standards.

Having now sketched in merest outline the application of some of the scientific principles that have been worked out of late years with regard to the relation of feed requirements of horses for work of different kinds, we shall consider briefly the practical feeding of horses and some important questions that have bearing on this subject.

Feeding the Mare and the Foal.—The new-born foal is always given the colostrum of the dam. This has purgative properties and serves to cleanse the alimentary tract of fecal matters. As a general rule, the foal depends wholly on the milk of his dam for his nourishment for the first couple of months, and largely so until toward weaning time. It is important to feed the mare while suckling her colt with a view to having a good supply of milk. If possible, she should receive some succulent feed; good pasture is the ideal feed, but some roots or good, bright silage are valuable substitutes, and with oats, rolled barley, or wheat bran will favor the milk secretion. If this should be too rich or abundant and cause the foal to scour, he is allowed only a portion of the milk, and the last part is milked out, as this is always high in fat content, which is generally the cause of the trouble.

In case the foal cannot have the dam's milk, he may be raised successfully on fresh, warm milk from a healthy cow, preferably one giving milk of a low fat content. This is diluted with an equal part of warm water so as to bring the fat content down to the low per cent found in mare's milk (p. 206); sugar and a little lime water are often added, but are not necessary. Raising a colt by the bottle requires a great deal of care, patience, and watchfulness, and, fortunately, is only necessary in exceptional cases. The suckling foal may be fed some sweet skim milk in five or six weeks and the amount gradually increased daily until in about three months it may be given freely three times a day in the place of new milk. At this age the foal will eat some grass, hay, or whole oats, which gradually become the more important part of his diet. Skim milk is continued so long as convenient during the first year. This, with grain and other feed that he receives, will develop his bone and muscles, which is a matter of first importance with the horse. He is kept on pasture (preferably blue-grass) and given oats mixed with wheat bran and a little cracked corn. According to Henry, the following amounts may be considered a fair allowance of grain for foals: Up to one year, two to three pounds per day; one to two years, four to five pounds; two to three years, seven to eight pounds.[3]

System of Feeding Horses.—There are great differences in the methods of feeding horses adopted by horsemen and farmers as to details in the manner of feeding, and no one method can give best results under all conditions and with different kinds of horses. The special method adopted must fit in with the working hours and the work the horse is required to do. It is generally considered necessary to feed the horse three times a day, although the noon meal is sometimes omitted without apparently impairing the working capacity of the horse. The heaviest meal, so far as hay is concerned, is given at night, the morning meal being next in amount, and the noon meal smallest, as he has then less time to eat; at least one-half hour is allowed after the morning and noon

[3] "Feeds and Feeding," 10th ed., p. 291; see also Alexander, "Care of New Born Foals," Wisconsin Circular 13.

meals. The daily grain feed is given about one-third each meal. Whatever system is followed, it is important to adopt a regular routine of feeding so that the horse may get his feed when he expects it and in the manner to which he is accustomed.

Colin has shown that the stomach of the horse will fill and empty itself two or three times during a meal; the portion of the feed first eaten will remain only a short time in the stomach, subject to the action of the gastric juice, being pushed into the intestines by the feed that follows. It has also been shown that if a horse is fed grain and then watered, much of the grain will be carried along into the intestines and will, therefore, not be fully digested; hence it would seem that the logical order of feeding is, hay and then grain; but horses are most anxious to get their grain and will be nervous and excited if it is withheld until the end of the meal. Farmers generally, therefore, feed their horses grain first and put hay before them to be eaten after the grain.

Watering.—Experiments by Sanborn[4] indicate that the best plan of watering horses is to water both before and after feeding. Tangl, however, who conducted elaborate experiments on this point,[5] concluded that it is of no great moment whether horses are watered before, during, or after meals, as it has no influence on the digestion or the absorption of the feed which they eat. It is important, however, to adopt a reasonable, convenient system of watering as of feeding, and then adhere rigidly to it, for regularity in the handling of horses has an important influence on their general health and condition. A moderate drink of water may be given horses at any time, even when hot and tired. They appreciate a good drink after meals, and especially after the evening meal is eaten, before lying down, but often do not get it. A horse will drink from 50 to 75 pounds of water a day, on warm days even 100 pounds or more. Rations of narrow nutritive ratios, like alfalfa rations, require larger amounts of water than those low in protein; this is, however, a matter of physiological interest mainly, and of but little practical importance.

Allowance of Roughage.—Owing to the relatively small capacity of the digestive apparatus of the horse (p. 30), his feed must be given to a large extent in concentrated form. Idle horses may be fed more roughage than those at work, and the latter should have their main allowance of coarse feed at night, when they have time to thoroughly masticate it and can rest after the meal. It is

[4] Utah Bulletin 9.
[5] Landw. Vers. Stat., 1902, p. 329.

a common practice to give horses all the hay they can eat, but the results of careful investigations tend to throw doubt on the wisdom of this practice. In experiments at the Montana station[6] in which timothy and clover hay were fed to work horses in different amounts, it was found that the horses receiving two-thirds as much hay as they would have eaten if given all they wanted had more life and perspired less than those that were not limited in their hay. When not more than 10 pounds of clover hay per 1000 pounds live weight was fed, it proved as satisfactory as timothy hay. It was also found that early-cut timothy hay was relished more and eaten in larger quantities than late-cut timothy, and that horses doing light work can be carried through the winter on 7½ pounds hay and 5 pounds of grain daily per 1000 pounds.

Horses should not be fed more hay than they will eat up clean at each feed; this is usually less than 20 pounds and, on an average, about 15 pounds per day per 1000 pounds live weight. The eating of too large quantities of coarse feed taxes the digestive apparatus of the horse unduly and is responsible for the disturbance of the respiration of the animals known as heaves, especially when over-ripe and dusty hay is fed. The Utah station reports[7] that there was not a single case of digestive trouble among its horses when the amount of alfalfa hay was limited, and states that "many valuable horses and thousands of dollars could be saved annually if the amount of coarse fodder fed to horses could be reduced one-half."[8]

Work horses, which are the animals primarily considered in this discussion, should, in general, receive about two pounds dry feed for each 100 pounds of live weight; of this amount, one-half should be concentrates and one-half hay or its equivalent of succulent feeds when a medium amount of work is done; as the work increases, the concentrates are increased and the amount of hay decreased.

Hay for Horses.—Among the rough feeds, *timothy hay* is considered especially valuable as a feed for horses, but other kinds of dry forage, like clover, alfalfa, prairie hay, cowpea hay, grain hay (wheat, barley, or oats), corn fodder, millet, and others, are all valuable horse feed when well cured and free from dust, and are used in different parts of the country.

Alfalfa Hay.—There is a prejudice against legume hay, and perhaps especially against alfalfa, among many horsemen, as it is believed to make the horse soft and unfit for heavy work. A number

[6] Bulletin 95.
[7] Bulletin 77.
[8] See also Illinois Bulletin 150.

of stations have carefully investigated this subject, the most extensive inquiry having been conducted at the Utah station.[9] No ill results were noted in these experiments on the health of the horses by long-continued, exclusive feeding of alfalfa. Attacks of colic and other digestive disorders can be prevented by a judicious system of feeding, giving less than the horses will clean up (see above). During these experiments, which were conducted for a period of twelve years, alfalfa formed the sole roughage of all the working and driving horses at the station, except during brief periods when they received other experimental fodders, and not a horse was lost, either directly or indirectly, as a result of feeding alfalfa during this entire period. This is not surprising when we remember that alfalfa forms the only roughage, and often the only feed, throughout the year on thousands upon thousands of farms in the western States, especially in irrigated regions, as it is also the sole feed of dairy cows among many farmers in these regions.

The Utah station found that 20 pounds of alfalfa hay were sufficient to maintain the weights of horses weighing nearly 1400 pounds when at rest; when at heavy work, 32.6 pounds were barely sufficient to maintain the weights of the same horses. Results of trials at the Wyoming station[10] showed that four farm horses required to perform light work maintained their weights on a daily ration of 13½ pounds of alfalfa hay when they had access to a stack of oat straw. In a second test made with two horses it was found that the weights were maintained on an average daily ration of 13.75 pounds alfalfa hay and 2.25 pounds oat straw per 1000 pounds live weight. A trial at the Wyoming station with six horses[11] fed during ten one-month periods on alfalfa hay showed a total gain of 203 pounds, while during an equal period on native hay there was a total loss of 84 pounds. The Kansas station concluded, from experiments conducted with work horses, that alfalfa hay, when properly fed, is a much more valuable roughage than either timothy or prairie hay, and reduces the cost of the daily ration from 25 to 35 per cent when substituted for either hay and fed with corn and oats.

It may, therefore, be considered established that alfalfa hay is a good feed for horses fed with other roughage or grain, and, if desired, it may also be fed as sole feed without any ill results. The main precautions to be observed are as follows: The hay must not

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[9] Bulletin 77.
[10] Report 12.
[11] Bulletin 98; see also Nebraska Extension Bulletin 28.

be cut until quite mature; it must be free from dust, mold, or smut, and must be fed in limited quantities, a maximum amount for work horses being one and one-fifth pounds per 100 pounds live weight.

In trials at the Illinois station it was found that when alfalfa is fed as the roughage part of a ration of farm horses at hard work less grain is necessary to prevent them from losing weight than when timothy hay is fed. In this test there was a saving of about 22 per cent grain. Though too short to be conclusive, these tests indicate that medium horses at hard work can be maintained quite satisfactorily, for a short time at least, on corn fed in conjunction with alfalfa hay at a saving in cost.

Grain hay is much used as a horse feed on the Pacific coast and in the South, and millet, sweet and non-saccharine sorghums to some extent in the western States. Millet cut at the beginning of bloom and well cured makes hay of an excellent quality that is nearly equal to timothy hay in feeding value. The danger of pasturing horses on second-growth sorghum on account of the possibility of prussic acid poisoning has been referred to in another place (p. 110). The grain sorghums are often cut and fed to horses, "heads and all," without threshing the grain (p. 174).

Silage for Horses.—Corn and alfalfa silage may be safely fed to horses in moderate quantities, provided certain precautions are taken: It must be made from at least fairly mature corn and be well preserved; silage exposed long to the air before feeding, or frozen or moldy silage, must not be fed to either horses or mules, and the latter kind of silage had better not be fed to any class of farm stock. Good silage is one of the cheapest and best kinds of feed for horses, especially for brood mares and work horses that are doing light work. It should only be fed with dry roughage and a little at first, say five pounds per head daily, increasing the allowance, as the horse becomes accustomed to it, to 10 or 20 pounds as a maximum feed per day. With plenty of grain on the cornstalks, horses are kept in good condition on a ration of 20 pounds silage and 10 pounds hay for each 1000 pounds live weight.[12]

Roots may be fed to advantage in small quantities, 10 pounds being a maximum allowance per day. "An addition of 5 or 6 pounds of carrots to the daily feed ration of ordinary working horses will almost always be of benefit; and 3 pounds a day will not be too much for race horses, even in a high state of training. It is safest

[12] Farmers' Bulletin 578; see also Pennsylvania Bulletin 117.

to give carrots sliced longitudinally, so that they may not stick in the animal's gullet and thus choke him" (Hayes). Roots, especially carrots, are greatly relished by horses, and are fed quite extensively in Europe. Sliced potatoes, 10 to 12 pounds as a maximum feed, may also be given, preferably mixed with cut hay or straw.

Concentrates.—Among the concentrates *oats* are, in general, considered of a higher value in feeding horses than any other grain feed. They are eminently adapted for this purpose, and are relished better by horses than other cereals. Oats can be fed safely to horses, since the digestive tract of these animals does not hold a sufficient quantity to produce serious disorders. Owing to the presence of the hull, oats form a light and loose mass in the stomach, which makes it easy for the digestive fluids to permeate the mass and insures a more complete digestion. Oats should be fed whole to horses, or, at least, crushed or rolled, except in the case of old horses with poor teeth. If corn and oats are fed, as is a common practice in the East and central States, the feed should be coarsely ground, as it may otherwise give rise to colic and indigestion when swallowed fast by hungry animals. While oats form the common cereal fed to horses in most parts of the country, other grains are used in different sections and countries: Indian corn largely in the corn belt and the southern States, barley on the Pacific coast, in European countries, and North Africa. Barley is the common horse feed in Arabia, world-famous for its fine breed of horses.

Corn is the main substitute for oats as a horse feed; a large number of stations[13] have studied the question of the relative value of the two grains for this purpose. The general result of this work is to the effect that corn is a safe and satisfactory horse feed, and that the best method of feeding is to give a mixture of the two grains. This gives better results than corn alone and, in general, makes a cheaper ration than oats as a sole concentrate. In discussing concentrates for horses, Gay says:[14] "When its general use in the corn belt States is considered, much of the prejudice of the eastern feeders loses weight. The average Iowa horse, for instance, is produced by a dam which was raised on corn, and had no other grain during the period of carrying and suckling her foal. The foal receives a little cracked corn or even cob corn for his first bite, with the amount

[13] Ohio Bulletin 195; Kansas Bulletin 186; N. Dakota Bulletin 45; Missouri Bulletin 114; also Exp. Sta. Rec., vol. 12, p. 4: E. Lavalard, "Notes on Horse Feeding."

[14] "Productive Horse Husbandry," p. 235.

gradually increased until he is allowed from 20 to 40 ears per day at maturity. In spite of this fact, when these very horses come East, top our markets, and pass under the management of the city stable boss, corn is absolutely prohibited as dangerous to feed; yet it requires a long time to induce and teach some of these horses to eat anything else."

Other Concentrates.—Dried brewers' grains with shelled corn and wheat bran, in amounts of 8, 4, and 2 pounds, respectively, were found to give good results fed to street-car horses, in experiments at the New Jersey[15] and Massachusetts stations.[16] About one pound of linseed meal per head daily with corn and oats gave satisfactory results with farm horses in trials at the Iowa station,[17] maintaining their weights and spirits and willingness to work. On account of its laxative tendencies, it should be used in only small amounts (less than one pound per head daily, especially in summer). Cotton-seed meal, beet and cane molasses, dried distillers' grains, dried beet pulp, etc., are other concentrates used regularly in rations for horses in different parts of the country. There is, therefore, a great variety of feeds to choose from in feeding horses in almost all sections; evidently there is no so-called one ration for horses any more than for other classes of farm animals. "Any feeding stuff or combination of feeding stuffs that furnishes the necessary and desirable nutrients at least cost should be the important consideration in preparation of rations for farm horses and mules."[18]

Wintering Farm Horses.—Farm work is comparatively light in winter time in northern States, and the horses then often stand idle for a considerable period. If they are fed expensive feeds, like timothy hay and oats, at this time, they will soon "eat their heads off," and it is impossible to keep them in good working condition at a low feed cost. Cornstalks or corn fodder furnishes an excellent roughage for winter feeding of horses; cereal straws are also valuable; a few ears of corn are often all the grain the horses receive with this roughage.

The question of cheap substitutes for oats and timothy for wintering farm horses was studied in an experiment with twelve horses at the Michigan station;[19] six of these were fed a regular

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[15] Report 1892.
[16] Bulletin 99.
[17] Bulletin 109.
[18] North Carolina Bulletin 189.
[19] Bulletin 254.

ration of timothy hay and oats, while the others received shredded cornstalks, oat straw and hay for roughage, and ear corn, oats, and a mixture of dried beet pulp, bran, and oil cake in the proportion of 4 : 1 : 1; 8 pounds of carrots were also fed to the horses receiving this ration, which was composed of these various feeds in order to furnish a variety to the animals and insure a good appetite throughout the feeding trial. The cost of the two rations, based on average prices, was 19.4 cents per head daily for the regular ration and 12.3 cents for the cheaper ration. The horses fed the latter gained, on the average, 14 pounds during the ten weeks of the trial, while those fed the regular ration, doing about 8 per cent more work, lost, on an average, 11 pounds in weight. It is recommended to use a small part of the corn field to raise a supply of corn fodder for wintering horses, "planting the corn in drills thick enough to

FIG. 69.—Horses on the western range. (*Pacific Rural Press.*)

produce moderate-sized stalks, an abundance of leaves, and from one-half to two-thirds of a crop of ear corn, the whole to be in bundle form."

Horses that have been idle or doing but little work during the winter should be started on a small grain ration with light work about six weeks before spring work commences, so as to be put in condition for this work; the grain is increased gradually in order to avoid digestive disorders (Fig. 69).

Fleshing Horses for Market.—Horses are collected from all over the country in small numbers every fall, and are fattened during the winter months and shipped to the large markets to be sold. This business is one of considerable magnitude in the middle West. The gains made and the profit secured depend on a number of factors, similar to those that condition the profitableness of steer fattening (p. 261). The Illinois station conducted two experiments with different rations for horses of this kind:[20] One with 18 horses for 24 days and the other with 24 horses for 112 days. The following are some of the conclusions to which these led:

1. A mixed grain ration of corn and oats, when fed with clover hay, was more efficient than a single grain ration of corn for producing large gains.

2. A ration of corn, oats, and timothy proved satisfactory for producing finish in fleshing horses for market, but was materially improved by the addition of linseed meal.

3. A ration of one-fourth oats and three-fourths corn proved more economical than one of half oats and half corn.

4. A ration of corn and bran, fed in proportions of 4 to 1 by weight, was superior to an all-corn ration for producing gains, when fed in conjunction with clover hay. There is apparently danger in feeding too much bran for best results when clover hay furnishes the roughage part of the ration. The bran and clover combined produced a too laxative condition. Exercise had a retarding effect upon the taking on of flesh, the horses receiving no exercise making 24 per cent larger gains than those having a daily walk of 2.8 miles.

The average daily gain in these trials ranged from about two to three pounds per head. According to Craig and Brettell, horses on full feed fattened for the Chicago market receive 10 to 14 ears of corn three times a day, with three quarts of oats and bran (1:2), and hay *ad lib.*, in the middle of the forenoon and again in the middle of the afternoon. Recognizing the importance of a long period of rest, no feed is given between 6 or 7 at night and the morning. Linseed meal is also given, as it aids greatly in putting on flesh and makes the skin soft. Satisfactory gains are made with good feeding and care; in several instances an average gain of 3.75 pounds per head daily was obtained with as many as a dozen horses, and in exceptional cases a gain of 5 pounds per day for a period of 90 days.[21]

Rations for Work Horses.—The following rations will show a number of combinations of different feeds and the amounts of each commonly fed in the various sections of the country:

1. 12 pounds timothy hay, 12 pounds oats.
2. 12 pounds timothy hay, 7 pounds oats, 7 pounds corn.
3. 10 pounds timothy hay, 6 pounds cracked corn, 6 pounds wheat bran, 2 pounds linseed meal.
4. 15 pounds mixed hay, 10 pounds oats, 4 pounds corn.

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[20] Bulletin 141. [21] *Breeders' Gazette*, 1899, p. 781.

5. 10 pounds clover hay, 8 pounds oats, 6 pounds corn, 2 pounds wheat bran.
6. 10 pounds alfalfa hay, 12 pounds barley.
7. 30 pounds alfalfa hay.
8. 8 pounds mixed hay, 6 pounds cornstalks, 6 pounds corn, 6 pounds wheat bran.
9. 10 pounds hay, 8 pounds oats, 4 pounds dried brewers' grains.
10. 10 pounds hay, 5 pounds corn, 5 pounds barley.

Feeding Mules.—"The work animal on the southern farm is the mule (Fig. 70). He it is that bears the brunt of the work of cultivating the growing crop, harvests it when mature, and hauls it

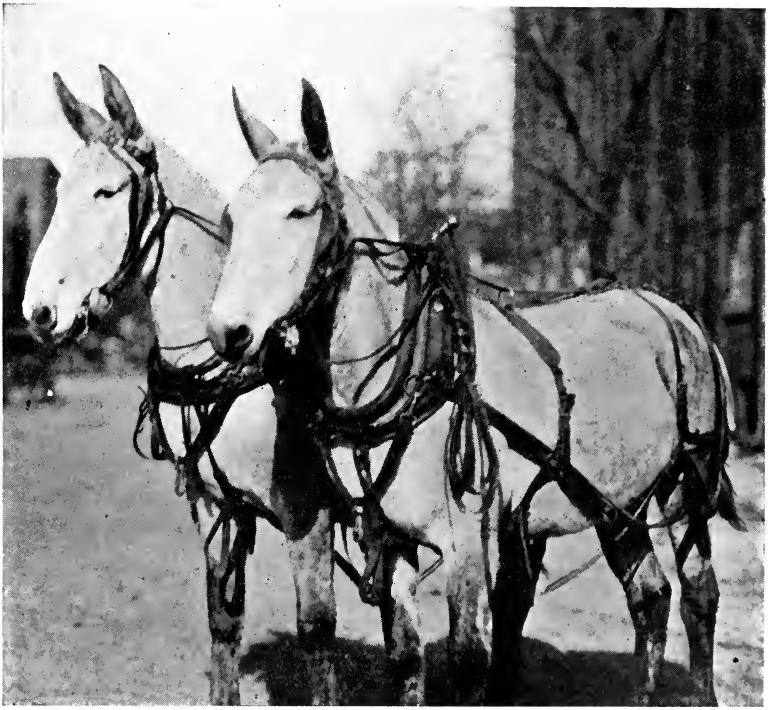


FIG. 70.—A team of farm work mules. (Missouri Station.)

to market. In the South the horses on the farm remain in field or stable until all the mules are harnessed, and are only called into use when the labor to be done is more than the mules can accomplish.

"The mule is the draft animal for the lumberman, the cotton and sugar planter, the contractor, and the miner.

"The horse may be honored for his procreative ability; he may be kept on the best in the land because of his beauty and style, but the mule is fed that he may labor."[22]

It is commonly stated that mules make more economical use of the feed they eat than horses, and that their cost of keep is, therefore, smaller. Careful investigations have failed to show, however, that there is a sound basis for this claim. After a long experience with thousands of army mules, Riley maintains [23] that a mule requires just as much feed as a horse of similar dimensions; in fact, at hard work, he says that the mule will eat more than a horse will or ever can. In general, an animal that eats little is a poor animal, regardless of its class or kind. The mule will manage to get along on poor feed given at irregular intervals, but this neglect is manifested by its condition and efficiency (Burkett).

A number of stations have conducted experiments with the two classes of animals which furnish data for a study of this question. The following summary figures were obtained at the Missouri and Ohio stations, the animals being fed oats and hay in one series of experiments, and corn and hay in another series, and the hay being figured at $10 a ton, oats at 40 cents a bushel, and shelled corn 50 cents a bushel.

	Average daily work	Average yearly cost of feed
Average for mules	4 hours 42 minutes	$58.11
Average for horses	4 hours 34½ minutes	58.01

Summarizing all available data on this point, the *Breeders' Gazette* [24] arrived at the average cost of feed for all the horses per 1000 pounds as $75.66 per year, and for the mules, $76.76. "These figures indicate that the mule has no constitutional advantage over the horse in cheapness of maintenance. In fact, the horse has a slight lead in the data presented, but the difference is so small as to be negligible. In actual practice it is probable that the mule is maintained a little more cheaply than the horse, because oats are fed to horses more commonly than to mules. The practice of feeding oats to work horses, however, is largely a whim of the feeder, since numerous tests have shown that corn may be entirely substituted with satisfactory results. The difference between the two is thus largely a matter of custom, so far as light is shed on the problem by the tests mentioned."

[22] Kentucky Bulletin 176.
[23] Burkett, "Feeding Farm Animals," p. 170.
[24] Sept. 10, 1914, p. 390.

Mules may be fed the same feeds and similar amounts of these as horses, and what has been said in the preceding about feeding this class of animals applies, in general, also to mules.

QUESTIONS

1. State the general laws governing the use of feed by horses.
2. Give a common ration for horses in your locality, and show in how far it approaches the Wolff-Lehmann and the Armsby standards.
3. How is the work done by horses measured?
4. State the main principles of feeding (*a*) foal, (*b*) the mare, (*c*) work horses.
5. When are horses preferably watered, and how many times fed daily?
6. Should horses receive all the hay they will eat? Why?
7. Discuss the value of different rough feeds for work horses.
8. State briefly the value of silage and of roots for horses.
9. Give the main concentrates fed horses, and state briefly their relative values.
10. Give the system of feeding farm horses during winter, when idle or doing light work.
11. How are horses fattened for market?
12. Which makes the more economical use of feed eaten, the horse or the mule?
13. Is a small consumption of feed a desirable point in farm animals?

Literature on Horses.—Gay, "Productive Horse Husbandry," Philadelphia, 1914. Roberts, "The Horse," New York, 1905. Johnstone, "The Horse Book," Chicago, 1908. "Heavy Horses, Breeds and Management," London, 1905. "Light Horses, Breeds and Management," London, 1904. Langworthy, "Principles of Horse Feeding," Farmers' Bulletin 170, 1903.

Experiment Station Publications on Horse and Mule Feeding: Florida, b. 72; Illinois, b. 141; Indiana, b. 97; Iowa, b. 18, 109, c. 6; Kansas, b. 186; Kentucky, b. 176; Maine, r. '91; Maryland, b. 51; Massachusetts, b. 99, (Hatch) b. 94; Michigan, b. 254; Mississippi, b. 15; Missouri, c. 27, b. 114; Montana, b. 95, 97; Nebraska, b. 130; ext. b. 28; New Hampshire, b. 82, 129; New Jersey, r. '93, b. 92; North Carolina, b. 189; North Dakota, b. 26, 45; Ohio, b. 195; Oklahoma, r. '98, '99; Pennsylvania, b. 117, 122; Utah, b. 77, 101; Virginia, b. 80; Wyoming, r. 12, b. 98; Ottawa, r .'06; Bur. An. Industry, c. 168; Farmers' B. 170; Office Exp. Stations, b. 125.

CHAPTER XXV

FEEDING SWINE

Feeding Standards for Swine.—Standards for feeding swine have been established by Wolff-Lehmann as given in the following table:

The Wolff-Lehmann Standards for Swine, per 1000 Pounds Live Weight

	Age, months	Weight, pounds	Dry matter	Digestible		N. R.
				Protein	Carbohydrates and fat*	
Brood sows, with pigs...	....	...	22	2.5	16.4	1:6.6
Fattening swine—						
First period	....	...	36	4.5	26.6	1:5.9
Second period........	....	...	32	4.0	25.1	1:6.3
Third period.........	....	...	25	2.7	18.9	1:7.0
Growing swine—						
Breeding stock......	2–3	50	44	7.6	30.3	1:4.0
	3–5	100	35	4.8	24.1	1:5.0
	5–6	120	32	3.7	22.2	1:6.0
	6–8	200	28	2.8	19.4	1:7.0
	8–12	250	25	2.1	15.8	1:7.5
Fattening stock.....	2–3	50	44	7.6	30.3	1:4.0
	3–5	100	35	5.0	24.9	1:5.0
	5–6	150	33	4.3	23.7	1:5.5
	6–8	200	30	3.6	21.4	1:6.0
	8–12	300	26	3.0	19.0	1:6.4

* Given separately by Wolff-Lehmann.

Feed Requirements of Swine.—Next to the dairy cow, the hog is the most economical producer of human food materials among our farm animals, and it stands close to the cow in this respect. Jordan has shown that 100 pounds digestible organic nutrients in the ration produce the following amount of edible solids in the form of the various animal products:

Milk, 18 pounds.
Pork, 15.6 pounds.
Veal, 8.1 pounds.
Poultry or eggs, 3.5 pounds to 5.1 pounds.
Beef, 2.75 pounds.
Mutton, 2.60 pounds.[1]

While these are only average figures, and may not hold true in individual cases, they show that the hog has a wonderful capacity

[1] "The Feeding of Animals," p. 405.

for converting feeding stuffs into human food, and he often does it under very adverse conditions as regards care and attention, and without being particular as to either the character of the feed or the quarters he occupies. No farm animal appreciates good feed and comfortable quarters, however, or responds more readily to good treatment, than do swine, but none are more abused in these respects. The pig is an omnivorous eater and can fatten on feed that other stock will not touch, but the best results in feeding pigs, as in the case of other farm animals, are secured when they receive good, wholesome feed and are given careful attention. Under these conditions, swine raising is especially profitable, and while it requires a smaller investment in animals and equipment, it will, as a rule, yield quicker and relatively larger results than any other branch of animal husbandry.

FIG. 71.—A group of young Berkshire pigs. (Iddings.)

Swine are remarkable producers of fat (Fig. 71). The composition of the increase in body weight in the case of fattening swine, as determined by Lawes and Gilbert, is as follows: Protein, 1.4 per cent; fat, 71.5 per cent; mineral matter, 0.1 per cent; water, 22.0 per cent, showing that the fattening process in the case of these animals, still more than with other fattening stock, consists largely of an accumulation of body fat (p. 20).

Birth Weight and Gains Made by Pigs.—Pigs, when farrowed, will weigh from about one and a half to three pounds each; two and a half pounds may be considered an average weight for our common, medium-sized breeds. The number of pigs in a litter will average about nine. Young pigs ordinarily gain more for every week as they grow older, but there is a gradual decrease in the rate of gain to body weight. The largest returns for the amount of feed eaten are secured from young pigs; or, to put it in another way, the amount of feed required for a pound of gain is smallest in the case of young pigs, and increases steadily with advancing age (Fig. 72). The fact is brought out in a striking manner by the following compilation by Henry[2] of over five hundred feeding trials conducted at American experiment stations with over 2200 pigs

The Relation of Weight of Pigs to Feed Consumed and Rate of Gain

Weight of pigs, pounds	Number of animals	Average live weight, pounds	Average feed eaten per day, pounds	Feed eaten daily per 100 pounds live weight, pounds	Average gain per day, pounds	Feed for 100 pounds gain, pounds
15 to 50	174	38	2.2	6.0	0.8	293
50 to 100	417	78	3.4	4.3	0.8	400
100 to 150	495	128	4.8	3.8	1.1	437
150 to 200	489	174	5.9	3.5	1.2	482
200 to 250	300	226	6.6	2.9	1.3	498
250 to 300	223	271	7.4	2.7	1.5	511
300 to 350	105	320	7.5	2.4	1.4	535

in all. In compiling the results given in the table, six pounds of skim milk and twelve pounds whey were rated equal to one pound of concentrates (one feed unit). The table shows the average weight of the pigs in each group, the feed eaten daily and per 100 pounds live weight, the daily gains made, and the feed per 100 pounds gain (Fig. 73).

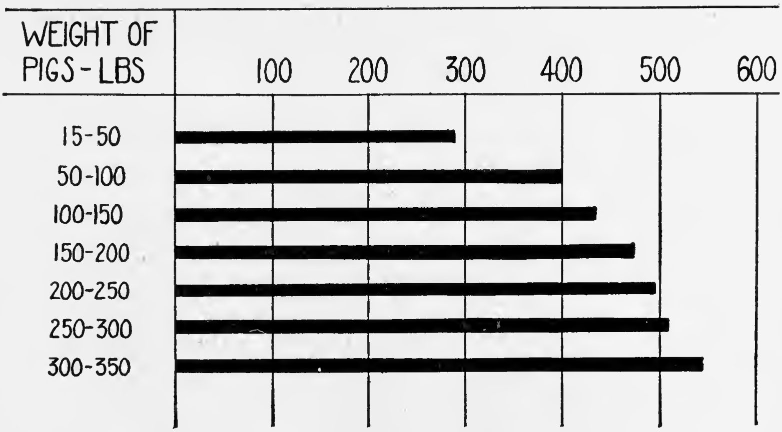


FIG. 72.—The amount of feed consumed per 100 pounds of gain for fattening pigs increases with their live weights.

[2] "Feeds and Feeding," 10th ed., p. 502.

The greater economy of young growing pigs as compared with older ones for making gains from a given amount of feed is plainly seen from this table. While pigs of less than 50 pounds live weight required only 293 pounds of feed per 100 pounds gain, pigs weighing 150 to 200 pounds required 482 pounds, and hogs weighing over 300 pounds required 535 pounds per 100 pounds gain. This difference does not represent one of actual feed value in the products, however, as the carcass of the mature hog contains more dry matter and more fat than that of young animals, but the feeder selling young animals has the benefit of the situation, as he is paid for the total weight furnished, and not only for the dry matter or edible portion of the carcass.

Fig. 73.—Well-fed, busy youngsters that will grow into good porkers. (Henry.)

Results similar to those shown in the preceding table were obtained in the extensive swine-feeding experiments conducted at the Copenhagen station during the nineties.[3] In these trials it required, on the average, 376 feed units to produce 100 pounds of gain with pigs weighing from 35 to 75 pounds each, and 639 pounds with hogs of 275 to 315 pounds weight, there being a gradual increase from the former to the latter figure with increasing weights of animals fed.

Preparation of Feed for Swine.—It has been shown that the digestibility of feeding stuffs is not, as a rule, materially altered by different methods of preparation, like cooking, cutting, grinding, rolling, etc. (p. 67). In view of the special importance of this

[3] Report 30, 1895; Exp. Sta. Record 7, p. 245.

question in feeding swine, we shall give briefly the evidence of experimental work along this line.

Grinding Grain.—Trials conducted for ten years at the Wisconsin station [4] show that an average saving of 6 per cent was secured by grinding shelled corn for pigs; in 11 out of 18 trials conducted there was a saving and in 7 cases a loss by grinding the corn. If corn is worth 50 cents a bushel, there is, therefore, a saving of 3 cents per bushel by grinding, out of which the labor and cost of grinding must be paid. It is evident from this result that grinding corn for fattening pigs in general does not pay. In these trials the pigs fed ground corn ate more feed and gained more rapidly in a given time than those receiving whole corn. This is doubtless the reason why some farmers believe that pigs do better on ground than on whole corn. According to a summary by Rommel [5] of 19 trials

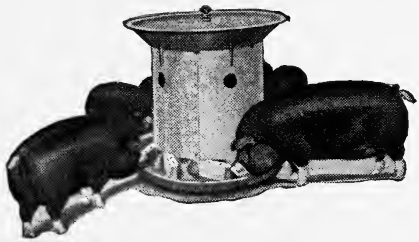


FIG. 74.—The "hog motor," a device for making pigs grind the corn they eat. (Hog Motor Company, Minneapolis.)

with 297 pigs, it required 524 pounds whole corn or 479 pounds meal to produce 100 pounds gain, a saving of 8½ per cent, or a little higher than found in the Wisconsin trials. Similar experiments with small grains and peas have shown that there is a saving of 12.3 per cent in feed by grinding. [6] It is advisable, therefore, to grind these grains in feeding pigs or to soak them before feeding (see below). Swine may grind their own grain, as shown in Fig. 74.

Cooking Feed.—Cooking feed has now been abandoned for all classes of farm animals except occasionally for swine. The question of the advisability of cooking grain for fattening hogs was studied by a number of stations in the eighties. Henry gives a summary of 17 trials at five different stations with cooked and uncooked grain (corn, barley, peas, rye, or shorts, fed separately or in mixtures) for swine, showing that in all but one trial there was a marked increase in the feed required per 100 pounds gain when this

[4] Report 1906.
[5] Bureau of Animal Industry Bulletin 47.
[6] *Loc. cit.*

was cooked (steamed); it required, on the average, 490 pounds of uncooked feed per 100 pounds gain and 561 pounds of cooked feed—a loss of nearly 15 per cent in the efficiency of the feed, not considering the expense of cooking. This practice has now been generally abandoned, except in the case of a few feeds, like potatoes, field peas, roots, chopped musty hay, etc., which are occasionally steamed by some feeders to induce a larger consumption or improve the palatability of the feed (p. 67).

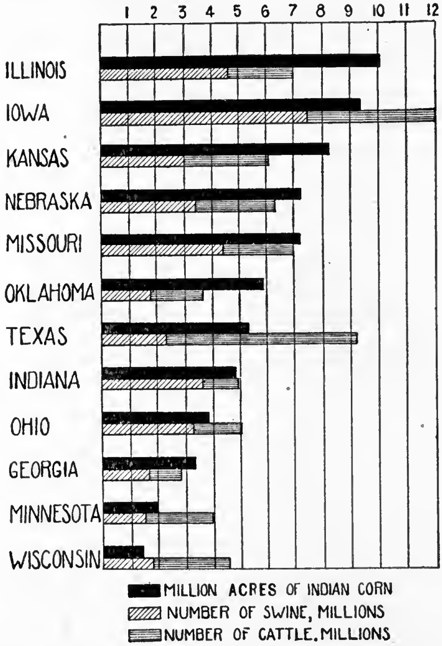


Fig. 75.—Diagram showing the acreage of corn and the number of swine and cattle listed in the twelve leading corn-growing States in the Union, according to the census of 1910.

Soaking Feed.—Soaking or wetting feed for swine is practised by some feeders who believe they obtain better results thereby. It has been shown, however, that no decided advantage is secured by this method. The average results of twelve trials conducted at eight different stations, as shown by Rommel (*loc. cit.*), came as follows: Feed required per 100 pounds gain, dry feed 444 pounds, wet feed 434 pounds, a difference of 2 per cent in favor of the latter feed. The pigs, in general, ate more soaked or wet feed than dry feed, and often made slightly better gains on the former feed, but the returns per unit of feed eaten were not, as we have seen, appreciably improved by the method of preparation; nor has it been shown that the amount of water fed in the slop of pigs has any material effect on the gains made or on the utilization of the feed.[7]

Swine Feeds.—The various feeds used in feeding swine have been previously discussed, and we shall consider here only a few of the main swine feeds, especially with reference to feeding problems in different sections of the country.

Indian corn is by far the most important single swine feed in this country. The States in the corn belt are growing more pigs than any other section, and there is, in general, a parallelism in the different States between the two industries, corn growing and pork production (Fig. 75). The corn is mostly fed on the cob, and the labor and expense of shelling and grinding are thus saved. Trials at a large number of stations have shown that it requires, on the average, about 555 pounds of shelled corn per 100 pounds gain, or that a bushel of shelled corn (56 pounds) will make very nearly 10 pounds of pork. The pigs made an average daily gain of 0.98 pound in these trials, which were conducted in more than a dozen different States and included thirty different series of experiments.

Corn is, above all, a fattening feed, and stands at the head of desirable concentrates for finishing fattening swine. Both on account of its relatively low protein content and high starch content (N. R., 1 : 9.5) and its low content of mineral matter, it is not well adapted for feeding alone to young growing pigs, and much damage has been done to our swine industry through the abuse of this grain as an exclusive feed for such pigs. The studies of this problem by Sanborn and Henry in the eighties were some of the earliest contributions of the Missouri and Wisconsin stations to the science of animal nutrition and have been of the greatest importance to American swine-breeders.

Feeding for Fat and for Lean.—Henry's striking experiments on "feeding for fat and for lean"[8] were especially adapted to bring the attention of farmers to the danger of using corn as a sole feed for young pigs (Figs. 75 and 76). In these trials one lot of pigs was fed corn meal only, and the other received skim milk, wheat middlings, and dried blood or other combinations of protein feeds. The method of feeding followed greatly influenced both the gains made by the pigs and the composition of their bodies. The corn

[7] Indiana Bulletin 86; see also Copenhagen Station Report 10, 1887.
[8] Wisconsin Reports, 1886–1890.

ration produced relatively low gains in live weight, and the bodies of the pigs were abnormal as regards the development of the skeleton, muscles, and internal organs. The amount of blood for each 100 pounds of dressed carcass of the corn-fed pigs was greatly decreased below normal. The tenderloin and other muscles were relatively light, the proportion of internal fat and that stored within

FIG. 76

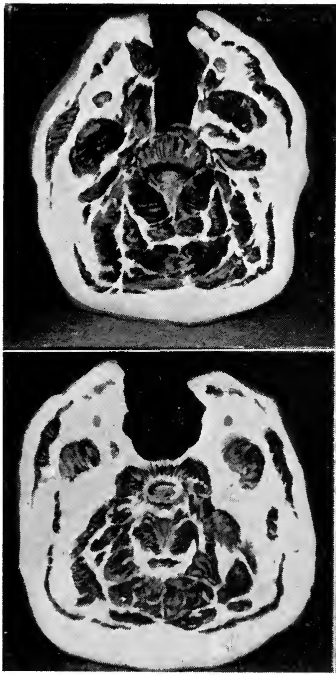
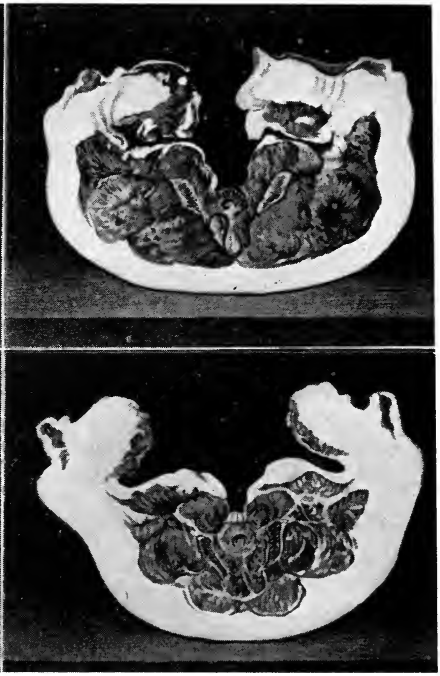


FIG. 77



A B

FIGS. 76 and 77.—Cuts of pigs fed for "fat and for lean"; Fig. 76 shows the disposition of fat and lean in the necks of the pigs, and Fig. 77 the fat and the lean of the loin or small of the back of the pigs. *A*, fed for lean; *B*, fed for fat. Note the large size of the individual muscles of the protein-fed pigs over those fed carbohydrates. Corn should be supplemented by clover, shorts, peas, skim milk, and similar feeds to bring the best results in feeding pigs. (Wisconsin Station.)

the muscular tissue was abnormally high, and the strength of the bones of the corn-fed pigs was greatly diminished, resulting, in general, in a weakly animal that would fall an easy prey to disease and accidents.

The lesson brought out by these and other experiments along this line is that young animals must receive a feed or a combination of feeds fairly rich in protein and mineral matter (N. R., 1:7 or less), that will develop a body with normal bone structure, muscles, and internal organs. As corn is deficient in both these constituents, pigs require supplementary feeds of nitrogenous character (skim milk, middlings, peas, tankage, dried blood, etc.) for a normal growth, or, at least, an addition of wood ashes, ground bone, or ground rock phosphate (floats), to build up a strong frame.

Where corn does not do well, other cereals may take its place to advantage in the feeding of pigs; wheat, barley, rye, kafir corn, field peas, cowpeas, soybeans, etc., are all valuable swine feeds when it is practicable to feed them, either in combination with Indian corn or with each other. Barley occupies a similar place to the farmers of California (and of northern Europe) as corn does in

FIG. 78.—Meal time for the swine herd. Intelligent feeding and careful management make well-bred hogs a source of profit on most farms. Note construction of individual hog houses. (Wisconsin Station.)

the corn-growing States, and has the advantage over corn in being higher both in protein and ash. It will give best results with pigs if rolled or ground before feeding. Oats are not a satisfactory swine feed on account of their high fiber content, except for breeding stock and shoats that are not being fattened. In the case of these animals they may be fed whole, scattered on the ground or on a feeding floor, so as to give the animals exercise at the same time (Fig. 78).

Dairy products form a most important group of swine feeds in dairy sections, and are used extensively as feeds supplementary to Indian corn. The results obtained in feeding skim milk and corn to pigs depend, to a large extent, on the proportions in which the two feeds are given. Skim milk alone will produce very unsatisfactory results in feeding pigs,[9] and more than five or six pounds of skim milk per pound of corn is also likely to give poor returns. The ratio of skim milk to grain to be fed will depend upon the relative price of the two feeds and on the age of the animals; fed to pigs shortly after weaning, larger proportions of milk will give better results than with older animals. The results of a large number of trials at the Wisconsin station and elsewhere showed that a ration of 3 to 1 will give most economical results in gain of live weight. Fed in the ratio of 1 to 3 pounds milk for each pound of corn meal, Henry found [10] that 327 pounds of milk were required to save 100 pounds of meal; in the ratio of 3–5 : 1, 446 pounds; 5–7 : 1, 574 pounds, and 7–9 : 1, 552 pounds, and, on the average for all trials, 475 pounds (p. 207).

Fig. 79.—Making pork on rape and oats. The average returns for three years on this pasture were $22.84 per acre. (Missouri Station.)

Corn is the best supplemental grain to feed with skim milk or buttermilk for growing pigs; with whey, on the other hand, wheat shorts, pea meal, or linseed meal as a part of the grain ration is to be preferred, being mixed with corn in increasing proportions of the latter as the animals approach maturity. [11] Trials made in this country and abroad have shown that 1000 pounds of ordinary whey,

[9] Utah Bulletin 57; Conn. (Storrs) Bulletin 39.
[10] Wisconsin Report 1895; see also Cornell Bulletin 199.
[11] Wisconsin Report 8, p. 38; Ontario Report, 1896.

when fed with grain feed, such as corn meal and barley or shorts, will save 100 pounds of grain in feeding fattening pigs, and that two pounds of whey are worth about as much as one pound of skim milk or buttermilk in feeding swine (p. 209). Canadian experiments have shown no appreciable difference in the feeding value of sweet and sour whey, but whey run through a separator or from separator skim milk is worth only 75 to 80 per cent as much as common whey obtained in the manufacture of American cheddar cheese.[12]

Pastures.—As with other farm animals, swine will make the cheapest gains when grazing or harvesting their own feed (Figs. 79 and 80); pasture only, without any supplementary grain feed, will not, however, produce satisfactory gains, whether this consists of mixed grasses, clover, or alfalfa. In trials at the Utah

Fig. 80.—Making pork on blue grass. The average returns for four years on this pasture were $15.18 per acre. (Missouri Station.)

station[13] pigs weighing 60 to 75 pounds when on pasture (alfalfa and mixed grasses, chiefly the former) gained only 0.2 pound daily; pigs receiving one-half grain ration when on pasture gained 0.7 pound; and those receiving a full grain ration gained 1.2 pounds daily. The pasturage saved about 15 per cent in the amount of grain required for the production of 100 pounds gain. The practice of feeding pastured pigs small grain rations is an econom-

[12] Ontario Reports, 1897 and 1909; Wisconsin Report 8, p. 47.
[13] Bulletin 94.

ical method of carrying pigs over summer that are to be fattened later, since such pigs will make rapid gains when put on full feed, and at a slightly less cost than those fed a full ration from the start (Utah Bulletin 94).

Alfalfa pasture alone will furnish but little more than a maintenance ration for pigs,[14] but if grain is fed, all of this can then be used for production. Two pounds of corn or more per 100 pounds of pigs have been found more profitable than a lighter ration.[15] When grain is fed, an acre of alfalfa will furnish pasture for at least 2000 pounds of pigs (15 to 20 shoats of medium weight), and will produce 500 to 800 pounds of pork, according to the kind of pigs fed, pasture and weather conditions.

Temporary Pastures.—Rape (Fig. 79), soybean, cowpeas, Indian corn, sorghum, etc., furnish excellent feed for growing pigs and brood sows and will enable the animals to make rapid gains when supplemented with grain. Pork can be produced more cheaply by feeding grain with green forage than by feeding either alone. The value of rape pasture for feeding swine, especially for breeding sows, is well understood (p. 138).

Hogging down corn is a common practice of harvesting a corn field in the corn-growing States. The method is especially adapted to sections where labor is scarce. The corn is generally allowed to nearly mature, and pigs of medium weight (80 to 120 pounds) or brood sows are turned in to gather the corn. They will eat the ear corn and leave a great deal of the coarser part of the plant, husks, cornstalks, and cobs to be plowed under, which, with the manure from the hogs, will greatly improve the humus content and the fertility of the land. Incidentally the pigs get considerable exercise and fresh air and will be less susceptible to disease than pigs fed in a dry lot. When the fat hogs are removed from the field, brood sows and pigs may be turned in; they will clean up and make good use of what is left. Hogs running at large in a field or pasture will be put in prime condition for market if they are fattened in a pen for a period of three to four months by being fed all the corn they will eat, with plenty of pure water to drink. According to Burkett,[16] a 5- to 10- acre field of good corn will carry 50 to 75 hogs from the shoat to the finished period. The total

[14] Oklahoma Report, 1899; Mississippi Report, 1905; Nebraska Bulletin 99.

[15] Nebraska Bulletin 99; Colorado Bulletin 2.

[16] "Feeding Farm Animals," p. 254; see also Farmers' Bulletin, 614. Iowa Bulletin 143.

quantity of pork produced from a given acreage, when hogged down, will be greater than when ear corn or snapped corn is fed in pens.

Feeding the Boar.—The feeding of the boar should vary according to his age and the season of the year. Thin, growing boars need more grain than older ones, but neither should be fed so that they will grow fat, since this will impair their breeding qualities, just as much as having them in a thin body condition. The boar should receive only as much grain as he will clean up readily, and should have a chance to exercise in summer time in a pasture lot, and in the winter in a small yard adjoining the pen. Succulent feed should be provided throughout the year if possible: During the summer by pasturage or cut green feed, giving enough grain to maintain a good condition of flesh; during the winter months either roots, pumpkins, or culled fruit may be supplied. An allowance not over a pound daily of grain per 100 pounds live weight will be sufficient while on the summer pasture, and during the winter, two pounds grain and four to six pounds roots. The grain should contain a considerable proportion of protein, as, *e.g.,* shorts and fine-ground oats (2 to 1 or 3 to 1). Skim milk is especially valuable for young boars as the breeding season approaches, and during this time two or three pounds grain may be fed; a mixture of equal parts of corn, ground oats, and middlings will prove an excellent combination.

Feeding the Sow and the Pigs.—The brood sow must be kept in a good body condition at all times, so far as possible, so as to be able to give birth to thrifty, vigorous pigs, and to furnish an abundance of milk for a healthy, rapid growth. Succulent feeds are an essential part of the ration both in summer and winter. A farrow, matured sow will keep in good condition on good clover or alfalfa pasture alone, but a young sow must receive about one to two pounds of grain daily per 100 pounds weight in addition; *e.g.,* a mixture of oats or barley and shorts, with a little corn so as to keep the nutritive ratio down to about 1 to 6 (p. 294). But little grain is fed for a few days before farrowing, and the sow is given cooling feeds of a laxative nature, as roots, and a slop made up largely of bran or shorts. For the first twenty-four hours after farrowing no feed is given, but all the lukewarm water she will drink; she is then given limited feed for three or four days, and is slowly brought up to full feed in the course of about ten days. A grain mixture of ground corn, ground oats, and shorts (1:1:2), mixed with three to five pounds skim milk, will give excellent results at this time; she should also be given some roots and be put on pasture as soon as possible. As much of the grain is fed as she will eat up readily.

After two or three weeks, the pigs should be given some feed in a small trough of their own, and this amount increased as rapidly as they are able to clean up more. When the sows and pigs are on pasture they will eat much less grain, but should be allowed some grain all the time as it will prevent the sow from getting too thin, and will enable the pigs to grow more rapidly; gains made at this time are much cheaper than those made later on, as has been shown before (Fig. 81). After the pigs are about three months old, they should weigh 60 pounds or better; they should get their nourishment largely from pasturage, and only one-half grain feed is given, unless feed is cheap, in which case full grain feed may be continued until they are weaned at three to four months of age. If the sow is to raise two litters a year, the

Fig. 81.—A thrifty bunch of sows and pigs crowding around the feed troughs—a familiar farm scene. (*Pacific Rural Press.*)

pigs must be weaned at a considerably earlier age, viz., from two or two and a half months old, in order to get the sow bred again in time.

To do well, pigs weaned at this age must have had grain before weaning, and must also receive skim milk with their grain feed after this period. If skim milk is not available, a slop is made of hot water and rolled or ground barley oats, and wheat shorts (1 : 1 : 2). A little digester tankage added to the slop before feeding will give good results.

The amount of grain fed to pigs on pasture should vary accordin to the kind and condition of the pasture, price of grain, thriftiness of the pigs, etc. The Oregon station [17] gives the following as

[17] Circular Bulletin 18.

a safe rule to go by with regard to feeding grain to pigs on pasture: When the price of pork on foot at the farm is more than three times the price of grain, a rather heavy ration should be given; when the price of pork is five times or less than the price of grain, a minimum amount should be fed.

The growing period of pigs will last until they are five to six months old, depending on the method of feeding practised, usually about five months old, when they will have reached a weight of nearly 100 pounds; they are then put on fattening rations.

The Dietrich Standard for Pigs.—Dietrich concludes, from careful studies of the nutrition of pigs conducted during a series of years, that one and the same pig under different conditions may maintain its live weight on distinctly different quantities of the same combinations of feed. This variation appears to be due to the plane of nutrition upon which the pigs have been maintained previous to the time of making the maintenance experiment. He gives the maintenance requirements of pigs that have been previously kept on a low nutritive plane as follows:

Dietrich Maintenance Standard for Pigs, Per Head, 100 Pounds Live Weight.

Digestible crude protein	Digestible carbohydrates	Digestible fat
0.10 pound	0.25 to 0.40 pound	0.03 pound

The energy requirements of the ration are about 1.12 therms (p. 35).[18]

The rations given in the following table have been calculated according to the rather elaborate system of feeding pigs recommended by Dietrich:

An Approximate Ration for Pigs Intended for Breeding Purposes

Feeds	Age of pigs in months						
	2	3	4	5	6	7	8
	Pounds of feed per 100 pounds live weight per day						
Corn..........	2.7	2.8	2.9	2.9	3.0	3.3	2.9
Soybeans (seed).	.4	.5	.4	.4	.4	.4	.7
Skim milk......	6.0	6.0	6.0	6.0	6.0	—	—
Water.........	7.1	6.4	5.7	5.1	4.4	9.2	8.5

In the place of corn may be substituted rye, barley, wheat, rice, etc., and in the place of soybeans, linseed meal or peas, but in the latter case the quantity fed must be increased, as peas contain

[18] Illinois Bulletin 163; Circulars 126, 133, and 153.

less protein than the other feeds. "This would also increase the carbohydrate, hence the corn would have to be correspondingly decreased. Or these may be left out and more skim milk added. Some of the protein may also be supplied in the form of clover or alfalfa. If skim milk is not available, more of some other nitrogenous feeds may be supplied, and also more water, as milk is 85 to 90 per cent water. If tankage containing 60 per cent protein is used in place of soybean meal, much less will suffice, as tankage is richer in protein.

"The above is intended for dry lot feeding (Fig. 82). If pigs are on pasture, these quantities should be reduced. If the above ration is used in a dry lot, a little bran or shorts used in place of part of the corn so as to give the ration more bulk will improve it. A greater variety of feeds will probably also make the ration better." Swine may grind their own grain, as shown in figure 74.

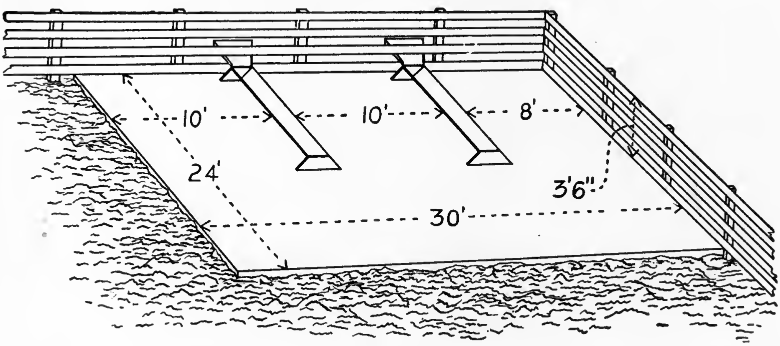


FIG. 82.—A cement feeding floor provided with sanitary substantial troughs is an essential to a well-equipped piggery. (Wisconsin Station.)

Fattening Swine.—In the corn belt States, which supply a large proportion of the hogs fattened for market, the common practice is to keep the hogs with fattening steers until three to four weeks before the end of the fattening period, when they are penned and finished for market. As previously shown, the number of hogs put with the steers will vary with the form in which corn is fed to the latter; the extra grain which the hogs receive is likewise determined by this factor, and the amount of undigested feed in the droppings of the steers (p. 273). If the steers are fed snapped ear corn or whole shelled corn, much more passes through undigested and becomes available to the hogs in the droppings than if soaked corn, ground corn, or corn and cob meal is fed. If the steers are fed protein feeds in addition to corn, they are able to digest the starchy components of the ration better than in case of wide nutritive ratios, and hogs, in that case, can glean less feed from the droppings.

Fattening Rations.—When the ration of the steers consists of whole corn, the hogs are usually fed one-fourth to one-third pound of tankage per head daily; this will be all they need in addition to the corn in the droppings for about four to five weeks, until they do not apparently gain further in weight. They are then taken out and finished on a ration of corn and tankage, cotton-seed meal,

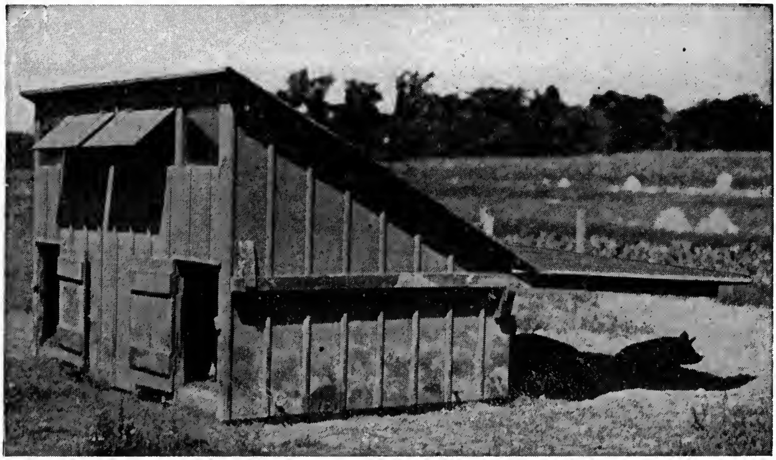


FIG. 83.—Portable hog-houses with low, flat roofs; if used for housing swine in hot weather, they should be provided with a shade at the rear under which the pigs can lie in comfort. This shade is five feet wide, made of inch stuff placed upon removable supports which rest upon cleats nailed to the ends of the house. (Wisconsin Station.)

peas, shorts, or gluten feed, in the proportion of seven parts of corn to one of tankage, or of three parts of corn to two parts of either of the other feeds. The fattening period ordinarily lasts about sixty days, at the end of which time the hogs will generally weigh about 200 pounds.

In other sections of the country hogs are either fattened on different kinds of pasture and fed grain in addition, or are fed in a dry lot until ready for the market. The latter method is less satisfactory for summer and fall feeding than pasturage, as it increases the cost of production, the hogs are less thrifty, and a larger amount of grain is required per 100 pounds gain. It is essential to furnish some green feed, as clover, alfalfa, and corn. The

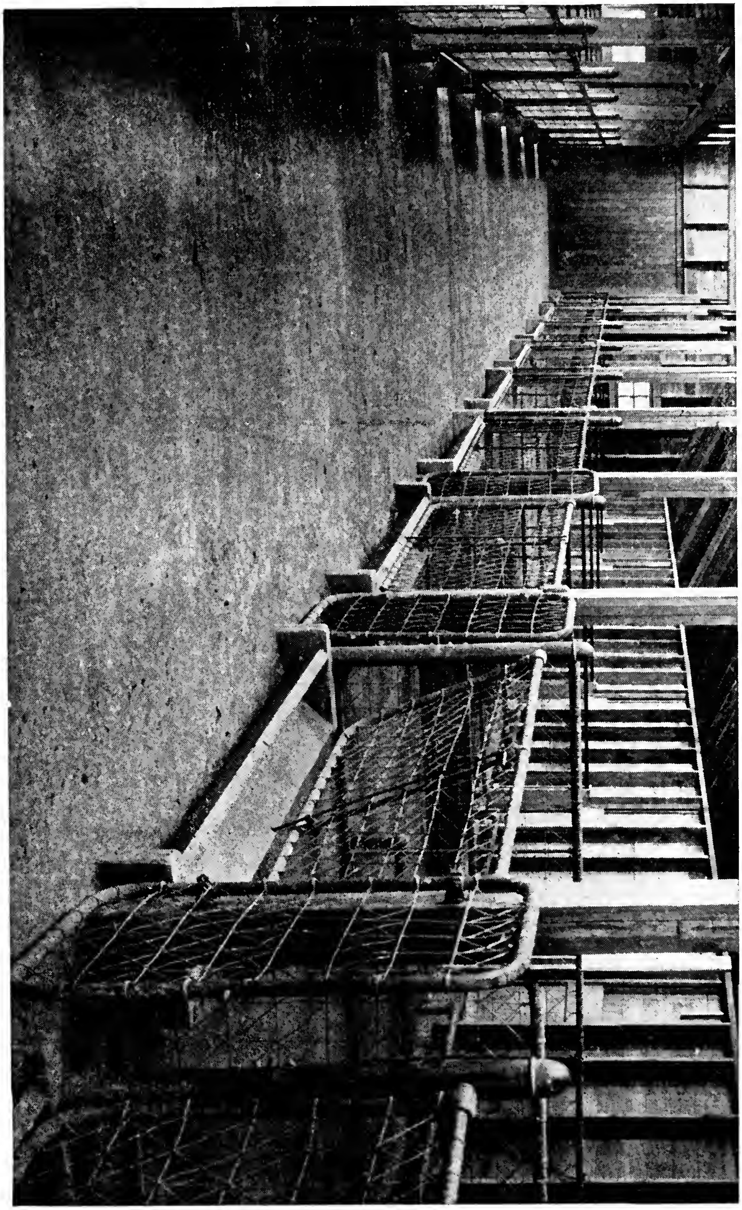


Fig. 84.—Interior arrangement of hog-houses at Illinois Station. Sanitary and practical. Note feeding troughs can be filled from the outside without entering the pens.

kind of grain fed with it will vary according to the character of the available green feed; with leguminous crops the grain may consist of corn or barley, preferably soaked or ground with a little tankage. If green corn, rape, or sorghum forage is fed, more nitrogenous feed mixtures must be supplied; skim milk and tankage are the best supplementary feeds with the cereals and mill feeds. Cotton-seed meal is fed considerably in the South to fattening hogs with corn or other grain, but fatal results often follow on account of the poisonous principles found therein (p. 200). If the animals are to be fed not more than twenty-one days in the finishing period after pasturage or running with steers, one-third of the total grain ration may be made up of cotton-seed meal; if it is likely to extend beyond twenty-one days, the proportion of cotton-seed meal must be reduced to one-fifth or one-sixth of the whole ration and the finishing period be limited to five weeks in all.[19]

Fig. 85.—The self-feeder saves labor in feeding pigs and other farm animals. The large self-feeder is used for different grain feeds, and the small one for feeding charcoal, ashes, and lime.

The Use of Self-feeder.—The self-feeder (Figs. 85 and 86) has been used to a limited extent in feeding fattening swine, for feeding grain or salt, charcoal, etc., and has given similar results, as previously stated, in the case of steers and sheep.[20] A patented "hog motor grinder," by which the pigs grind their own corn as wanted, is a special form of self-feeder. In two trials at the Maryland station [21] it produced good results, but not quite as economical gains as hopper feeding.

[19] Farmers' Bulletin 411.
[20] Maryland Bulletin 150; *Wisconsin Agriculturist*, Sept. 17, 1914.
[21] Bulletin 150; Day, "Productive Swine Husbandry," p. 208.

According to the forage conditions in different parts of the country, great variations in the methods of feeding fattening hogs, as well as swine in general, are possible. The preceding suggestions will, however, indicate in general the plan of feeding that will be likely to give best results in special cases.

Summer vs. Winter Feeding.—By far the greater proportion of the pigs in this country are fitted for the market in the summer and early fall, and depend on the summer pasturage, supplemented by grain, for cheap and rapid gains. Hogs fattened during winter, as a rule, require somewhat more feed for making a certain gain in weight than during the summer, at least in the North. No exact information in regard to this point is available for this country, but records obtained in Danish pig-feeding trials with about 2500 summer- and winter-fed pigs have a direct bearing on this question. The following summary table [22] shows the amount of feed eaten, reduced to a grain equivalent according to the feed-unit system, and the feed requirements per 100 pounds gain in weight and for each of three groups of pigs—35 to 75 pounds, 75 to 115 pounds, and 115 to 155 pounds—with averages:

Feed Required to Fatten Danish Pigs in Winter and in Summer

Weight	Grain equivalent per day per head, pounds		Grain equivalent for 100 pounds gain, pounds	
	Winter	Summer	Winter	Summer
35 to 75 pounds	2.66	2.65	371	346
75 to 115 pounds	3.96	3.92	446	397
115 to 155 pounds	5.26	5.25	516	457
Average	3.96	3.94	444	400

While the pigs ate practically the same amounts of feed in summer and winter, it required 400 pounds to make 100 pounds of gain in summer, against 444 pounds in winter, an increase of 11 per cent. The larger feed requirements in winter are explained by the fact that more body heat is lost by radiation on account of the lower air temperature. The same result was obtained in comparing the feed required by pigs weighing about 70 pounds each, kept in a well-built piggery and in individual hog-houses (Fig. 83), at the Ottawa station.[23] The trial was conducted during 60 days in winter time.

[22] Copenhagen Station Report 30, 1895; Exp. Sta. Record 7, p. 246.
[23] Report, 1904.

In the open winter quarters the pigs ate 526 pounds grain per 100 pounds gain, against 366 pounds for those in the piggery, a difference of 44 per cent in favor of the latter quarters. Brood sows in similar colony houses required only 25 per cent more, a figure which corresponds closely to that obtained in trials at the Kansas Agricultural College[24] (Fig. 84).

Feeding for Bacon Production.—Bacon hogs are kept only to a relatively small extent in the United States, but the raising of such hogs and the production of a high quality of bacon are important special industries in Canada and northern Europe, especially in Ireland and Denmark. The bacon found on the market

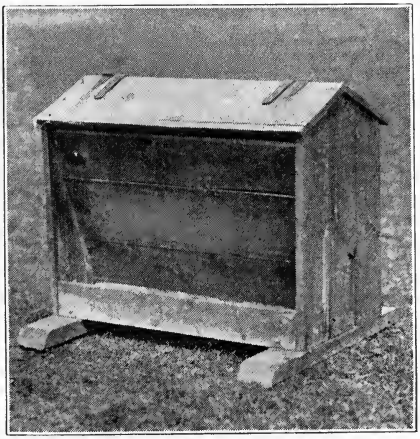


Fig. 86.—A convenient self-feeder for supplying charcoal and mineral matter to pigs on pasture. (*Breeders' Gazette.*)

in this country is largely the sides of lard hogs and has an inferior grade of meat. The special breeds of bacon hogs are best adapted to the production of good bacon, having a larger body and legs, less thickness and depth of body, and being lighter in shoulder, neck and jowl. There is less accumulation of fat and more lean and firm meat than on the lard hog. While the latter hog is essentially a product of corn, the bacon hog is produced where dairy products, small grains, and leguminous feeds are readily available; hence we find some hogs of this type in eastern and northern States where favorable feeding conditions exist for bacon production, and there is apparently an increasing home demand for all bacon that is produced in this country. Bacon hogs are marketed at about 200

[24] Report Prof. Agr., 1883.

pounds live weight; they should be only moderately fat, and a firm quality of fat is essential in a first-grade article. Soft bacon is a serious defect and is produced by a variety of causes. These have been summarized as follows by Day:[25]

"1. *Lack of Maturity.*—Generally speaking, the more immature a hog is, the greater the tendency to be soft. Almost invariably the largest percentage of softness occurs among the light sides of bacon.

"2. *Lack of Finish.*—Thin hogs have a marked tendency to produce soft bacon. Marketing hogs before they are finished is, no doubt, responsible for a great deal of softness.

"3. *Unthriftiness in hogs,* no matter what the cause may be, almost invariably produces soft bacon.

"4. *Lack of exercise* has a tendency to produce softness, but this tendency can be largely overcome by judicious feeding.

"5. *Exclusive meal feeding* is, perhaps, one of the most common causes of softness, especially when hogs are not given exercise. Some kinds of meal are more injurious than others, but wherever exclusive meal feeding is practised and the exercise is limited, more or less softness is always sure to result.

"6. *Corn.*—Of the grains in common use, corn has the greatest tendency to produce softness. Its injurious tendency can be modified by mixing it largely with other meal or by feeding skim milk, green feed, and roots, but its tendency to produce softness is so strong that it must be regarded as an undesirable food for bacon hogs. . . .

"7. *Beans* seem to have more marked effect than corn in producing softness, and should not be used for finishing bacon hogs."

Barley and skim milk make the best combination for bacon production, and may be fed in the ratio of 1 to 3 or 1 to 5. These feeds will produce large gains and a good quality of meat; other valuable feeds are peas, linseed meal, fine-ground oats and tankage. Clover, alfalfa, or rape will furnish large and satisfactory returns in summer with barley, shorts, and a small amount of skim milk. Winter feeding is also practised where roots are available—either mangels or sugar beets; they should be supplemented by skim milk and barley or wheat, with some linseed meal or tankage.

QUESTIONS

1. How do pigs rank in relation to other farm animals as producers of human food?
2. Give the average birth weight of pigs.
3. State the average amount of feed eaten daily by pigs of different weights and the feed per 100 pounds gain for pigs of different live weights.
4. What, if any, is the advantage of grinding, cooking and soaking feed for swine?
5. Describe the use of Indian corn in swine feeding.
6. How can swine be fed for fat and for lean?
7. Discuss briefly the value of dairy products and of pasture for swine feeding.

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[25] "Productive Swine Husbandry," p. 134.

8. Give briefly the method of feeding fattening swine in different parts of the country.
9. What is the difference in feed requirements per 100 pounds gain of swine in summer and in winter?
10. Give Dietrich's maintenance requirement of digestible protein and energy value for breeding pigs, and outline the method of feeding recommended by him.
11. Describe the method of feeding swine for bacon production.
12. What feeds are especially adapted for this purpose?

Literature on Swine.—Day, "Productive Swine Husbandry," Philadelphia, 1913. Lovejoy, "Forty Years' Experience as a Practical Hog Man," Springfield, Ill., 1914. Dietrich, "Swine," Chicago, 1910. Coburn, "Swine Husbandry," New York, 1888. Dawson, "The Hog Book," Chicago, 1911. Spencer, "Pigs, Breeds and Management," London, 1902. Tracy, "Hog Raising in the South," U. S. Farmers' Bulletin 100, 1899. Rommel, "Pig Management," Farmers' Bulletin 205, 1908. Gray, "Feeding Hogs in the South," Farmers' Bulletin 411, 1910. Warren, "Hog Houses," Farmers' Bulletin 438, 1911. Hunter, "Pastures and Grain Crops for Hogs in the Pacific Northwest," Farmers' Bulletin 68.

Experiment Station Publications on Swine Feeding.—Ala., b. 82, 93, 122, 143; Ark., b. 41, 54, 84; Col., b. 47, 74, 146, 165, 188; Conn. (Storrs), b. 31, 39; Fla., b. 113; Ga., b. 87; Idaho, b. 74; Ill., b. 16, 97, 163; c. 126, 133, 153; Ind., b. 79–82, 90, 108, 126, 158; Iowa, b. 2, 48, 91, 106, 113, 143, 136, ext. b. 15; Kan., b. 53, 61, 95, 124, 136, 192; Ky., b. 101; Mass., r. '84, '97, '99; Me., r. 89; Md., b. 141, 150; Mich., b. 233, 243; Minn., b. 104; Miss., r. '05; Mo., b. 14, 29, 67, 79, 110; Col., b. 1; c. 55; Mont., b. 27, 57, 89; Neb., b. 94, 99, 107, 121, 123, 124; press b. 20; N. H., b. 113; N. M., b. 90; N. C., c. 5; N. Y. (Cornell), b. 89, 199, 220; Ohio, b. 209, 268; r. '84; c. 73; Okla., r. '99–'00, p. 48; Ore., c. b. 18, 54, 80, 89, 102; Pa., b. 95; R. I., b. 152; S. Dak., b. 38, 52, 55, 63, 83, 90, 105, 136; Utah, b. 34, 70, 101, 94, r. '91; Vt., r. '91; Va., b. 167, 176; Wash., pop. b. 63; W. Va., b. 59; Wis., b. 104, 144; r. '85, '89, '90, '91, '94, '95, '02, '05, '06; Wyo., b. 74, 96; Ont., r. '96, '97, '99, '01, '05; Ottawa, b. 33, 51, 57; r. '91, '94, '01, '02, '04, '08.

CHAPTER XXVI

FEEDING SHEEP AND GOATS

Feeding Standards for Sheep.—The three following tables give the established feeding standards for sheep of different types and ages:

The Wolff-Lehmann Standards for Sheep, per 1000 Pounds Live Weight Daily

	Age, months	Live weight, pounds	Dry matter, pounds	Digestible Protein	Digestible Carbohydrates and fat*	N. R.
1. Growing sheep:						
Wool breeds	4–6	60	25	3.4	17.0	1:5.0
	6–8	75	25	2.8	15.2	1:5.4
	8–11	85	23	2.1	12.6	1:6.0
	11–15	90	22	1.8	12.1	1:7.0
	15–20	100	22	1.5	11.5	1:7.7
Mutton breeds	4–6	65	26	4.4	17.5	1:4.0
	6–8	85	26	3.5	16.6	1:4.8
	8–11	100	24	3.0	15.4	1:5.2
	11–15	120	23	2.2	13.7	1:6.3
	15–20	150	22	2.0	12.9	1:6.5
2. Sheep, coarse wool			20	1.2	11.0	1:9.1
Sheep, fine wool			23	1.5	12.7	1:8.5
3. Ewes, suckling lambs			25	2.9	16.1	1:5.6
4. Fattening sheep, first period			30	3.0†	16.1	1:5.4
Fattening sheep, second period			28	3.5†	15.9	1:4.5

* Given separately by Wolff-Lehmann. † Doubtless too high, making N. R. too narrow.

The Armsby Standards for Sheep, Maintenance Requirements, per Day and Head

Live weight, pounds	Digestible protein, pounds	Energy value, therms	Live weight, pounds	Digestible protein, pounds	Energy value, therms
20	.23	.30	100	.10	1.00
40	.05	.54	120	.11	1.13
60	.07	.71	140	.13	1.25
80	.09	.87			

Growing Sheep, Estimated Requirements (Including Maintenance Requirements) per Head Daily

Age, months	Weight, pounds	Digestible protein, pounds	Energy value, therms
6	70	0.30	1.30
9	90	.25	1.40
12	110	.23	1.40
15	130	.23	1.50
18	145	.22	1.60

Types of Sheep.—Sheep are kept for two more or less distinct purposes: For production of wool and for meat production. According to the particular breed kept, emphasis is laid on one or the other of these purposes. We have representatives of both kinds of sheep in this country (Figs. 87, 88, and 89): The range sheep, which are primarily wool producers, and the general farm sheep, "which should be considered, first of all, a producer of mutton and handled so that it will yield the chief source of income through its mutton lambs."

The range areas devoted to sheep raising, like those used for cattle raising, are gradually diminishing with the settlement of western lands by the farmer, but they still furnish our main supply of sheep. The numbers of sheep on farms or ranges in this country have diminished with each decade from 1880 to 1910, while our population increased over 80 per cent during the same period, from 50,000,000 people in 1880 to 92,000,000 in 1910. There has also been a gradual decrease in sheep kept on farms in the eastern and northern States. Sheep raising in these States and on western farms, on land adapted to the production of early lambs and fattening of mature sheep, seems likely, however, to be of increasing importance in the future, as the demand for good mutton increases and prices advance, as they are bound to do, with our rapidly-increasing population and the decreasing ratio of farm animals to population. The primary conditions for success with sheep, as with other farm animals, lie, first, in keeping animals that are adapted for the purpose in view, preferably pure-breds, or sired by a pure-bred ram; and, second, the feeding and caring for these so as to obtain the best results possible under the special conditions surrounding each flock.

Sheep are primarily grazing animals; they serve a special purpose on the farm by being able to utilize feed that is not adapted to, or cannot be used by, other classes of farm animals; stubble fields, volunteer growth, pasturage and, especially, aftermath that is too

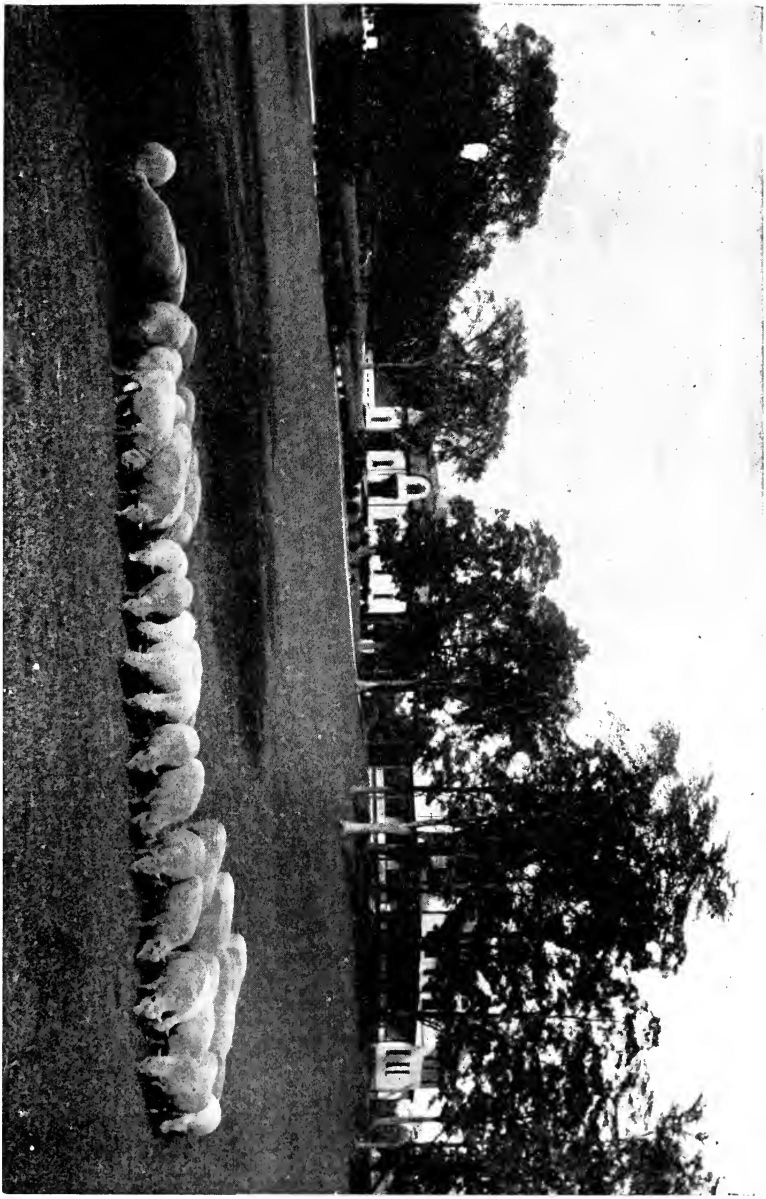

FIG. 87.—Pure-bred flock of mutton sheep at the Morgan Horse Farm, Middlebury, Vermont. (U. S. Department of Agriculture.)

scant to make it worth while to pasture cattle or horses thereon, will often furnish abundant feed for sheep. Their ability to keep weeds in check on farm lands is also important. According to Craig,[1] cattle and horses eat about 50 per cent of the numerous plants regarded as weeds, while the proportion eaten by sheep is over 90 per cent. A single sheep does not destroy a whole plant at one time,

FIG. 88.—A fine bunch of yearling rams. (*Breeders' Gazette.*)

FIG. 89.—A good type of mutton sheep. (*Pacific Rural Press.*)

but, moving as they graze, each sheep nibbles a few leaves in passing, and when the flock has passed the plant is defoliated. Sheep are, therefore, economical feeders if need be, but they also respond better than the larger farm animals to intensive feeding, and will give quicker returns for the investment for stock and equipment than the larger ones. A daily gain in weight of a quarter of a pound to one-half pound is not excessive for sheep weighing 100 pounds, while a 1000 pound steer will not be likely to gain more than

[1] "Sheep Farming," p. 7.

two pounds daily on approximately the same feed as eaten by ten sheep. Sheep are ruminants and consume considerable quantities of rough feed; they, therefore, need smaller proportions of expensive grain feed than do swine. For these and other reasons the further development of the American sheep industry is a matter of great economic importance, especially in view of the decreasing ratio of meat-producing animals to our population, which is likely to continue with the rapid extension of the manufacturing industries in this country.

Wool Production.—In feeding sheep, whether of the wool or mutton type, a growth of both wool and body tissue takes place. If only sufficient feed is given to maintain the sheep at an even body weight, the growth of wool is diminished, but does not stop entirely. When liberal fattening rations are fed, on the other hand, a normal growth of wool results; this cannot be further increased by feeding heavier rations, so far as the wool fiber is concerned, but the weight of fleece obtained may be increased on account of the larger percentage of wool grease found therein. Wool is composed chiefly of the protein substance keratin, containing 4 to 5 per cent sulfur, in addition to the usual components of protein, carbon, hydrogen, oxygen, and nitrogen (p. 22). Since the production of wool is a necessary accompaniment of sheep feeding, whether it is the main object sought or not, it follows that rations fed to sheep should contain considerable protein and have relatively narrow nutritive ratios, especially in the case of growing animals. We find, therefore, that the feeding standards call for a large amount of protein for growing sheep and breeding ewes.

Fattening Sheep.—Mature fattening sheep do not, however, require more protein in their feed than the same class of steers, since there is very little new formation of tissue in the case of these animals, the increase during the fattening period being made up largely of fat. This is shown by the analyses of sheep at different stages of fattening which were made by Lawes and Gilbert, of Rothamsted Experiment Station, about the middle of the last century. The composition of the increase from store to fattened condition, and from fat to very fat condition, is given below:

Composition of Increase of Fattening Sheep, in Per Cent

	Dry substance	Ash	Protein	Fat
Increase from store to fat condition.	78.0	2.12	7.16	68.8
Increase from fat to very fat condition	81.8	3.12	7.75	70.9

By comparing the figures given in the table with the corresponding data for fattening mature steers, it will be seen that sheep build up more fat and less protein (lean meat) during the fattening process than do steers, and the increase in weight consists of more dry substance than in case of these animals (p. 257).

Results obtained by Henneberg and Kern with three mature wethers slaughtered at different stages of the fattening period illustrate the changes that occur in the composition of the carcass of sheep during fattening.[2] One wether was slaughtered and the carcass analyzed at the beginning of the trial, when in a lean condition; another after 70 days of fattening, when half fat, and the third one at the end of 203 days of fattening, when extra fat. The table shows the contents of lean meat and fat in the case of three wethers:

Effect of Fattening on the Carcasses of Mature Sheep

	Lean meat, pounds	Fat, pounds
Lean wether	26.2	11.9
Half-fat wether	25.9	33.2
Extra fat wether	26.7	41.9

We note that there was no material change in the content of lean meat in the three animals, but the per cent of fat in the carcass increased from about 12 to 42 per cent during the fattening process, assuming that the three wethers had a similar composition at the beginning of the trials. This increase in the per cent of fat was accompanied by a decrease in the water content of the carcass during the fattening, as has been previously shown.

Weight of Lambs at Birth.—Lambs will weigh from six to ten pounds at birth, according to the size of the ewes and the breed. The average weight of single lambs of several breeds reported by Humphrey and Kleinheinz from records obtained with the Wisconsin station flock[3] was 9.5 pounds; of twins, 8.0 pounds; and of triplets, 6.8 pounds. The figures for the main breeds were, on the average, for Montana range sheep, Shropshire, and Southdowns between 7 and 8 pounds; for Oxford and Cheviots between 8 and 9 pounds, and for Hampshire and Downs between 9 and 10 pounds. Ram lambs average about one-half pound heavier at birth than ewe lambs.

[2] J. f. Landw., 26, p. 549.
[3] Report 1907.

Feeding Ewes.—Where individual attention can be given to the breeding ewes, as in the case of mutton breeds, it is desirable to secure as many twin lambs as possible, while under western range conditions one lamb to each ewe has been found to give the best results. If the ewes are in a vigorous, well-nourished condition when mated, they are more sure to breed and will give birth to more twins and triplets than when in a thin, run-down condition; hence the practice of "flushing" ewes has become common among breeders of mutton sheep; *i.e.,* these are fed heavily for two or three weeks prior to breeding time by supplying plenty of easily digestible feed, like rape, cabbage, or grain, in addition to pasturage or dry roughage. Breeding ewes in good condition do not need much grain during the winter; one-half pound of a mixture of oats and wheat bran (3 to 1 by weight) per head daily for ewes weighing about 150 pounds is sufficient, with a couple of pounds of good dry roughage, like legume hay, oat hay, nice fodder corn, etc., and two to three pounds of succulent feeds, either silage or roots. Silage from nearly-matured corn, containing not too many ears, may be fed to advantage to pregnant ewes, but moldy, spoiled, or very acid silage must not be fed, nor frozen roots or silage. More silage may be fed after lambing, when feeds favoring the milk secretion are especially valuable. To avoid milk fever, but little grain is fed for a few days after lambing. After this period, when the danger of milk fever is passed, the ewes may be gradually brought over to a full grain allowance. Dry roughage and succulent feeds may be fed safely both before and after lambing.

Ewes' milk contains, on the average, about 7 per cent of fat, but great variations occur in the composition of milk, both in case of ewes of different breeds and of ewes of the same breed. König gives 2.16 and 12.78 per cent as the extremes of the per cent of fat in ewes' milk according to European analyses. At the Wisconsin station the milk from 14 ewes of six different breeds contained 12.2 per cent solids and 7.1 per cent fat on the average; the average daily milk yield from these ewes was 2.8 pounds.[4]

Feeding the Ram.—The ram must be kept in a vigorous, thrifty condition in order to give good service. No grain is necessary while on pasture, except a little for about a month prior to the breeding season. Fattening feeds should be avoided; a common grain mixture consisting of oats and bran (2 to 1 by weight) can be fed in connection with a good quality of hay. Clean, pure water and salt must be supplied as in the case of all sheep.

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[4] Report 1904.

Feeding Lambs.—The dam's milk generally forms the sole feed of lambs during the first two or three weeks of their lives; about this time they begin to nibble a little grain or hay, and should have access to both thereafter. A lamb creep should be provided where the ewes cannot eat the feed intended for the lambs; the creep or pen may be built at one side or corner of the barn with two boards, 1 × 6 inches, of the desired length, to which are nailed vertical strips, 1 × 4 inches wide and 3 feet long. The slats are placed far enough apart to let the lambs slip through. A low, flatbottom trough is placed within the space set apart for the lambs on which the grain is fed, like ground oats, bran, cracked corn, a little linseed meal, etc.[5] Pure water should be supplied regularly. A creep should also be provided for the lambs as the ewes and lambs are let on to the pasture in the spring, where they may find their grain feed. This, in addition to the dam's milk and pasture, will enable them to make a rapid and healthy growth. The ewes will not, however, need any grain when on good pasture. In experiments at the Wisconsin station [6] it was found that lambs fed grain up to ten months old reached a given weight four to seven weeks sooner than when no grain was fed before weaning time, and the lambs were ready for the market at any time during this period, so that advantage might be taken of favorable market conditions. In experiments with different grain feeds for unweaned Shropshire lambs for periods averaging ten weeks 0.3 to 0.4 pound of grain was eaten daily, with resulting average gains of about one-half pound per head daily. The following amounts of different grain feeds were required per 100 pounds of gain in body weight: Wheat bran, 71 pounds; corn meal (4 trials), 74 pounds; whole oats, 78 pounds; and cracked peas, 81 pounds. Unweaned lambs that go into the breeding flock should receive feeds like oats and peas, wheat or bran, while corn is preferable for lambs intended for the butcher, as it tends to produce a fat carcass.

Stomach worms are a common sheep disease east of the Mississippi, especially in lambs, and are a serious drawback to American sheep raising. The eggs of the worms are distributed over the pasture in the droppings of the sheep, where they soon hatch and are taken into the system of the sheep while grazing. Old infested pastures, especially blue-grass, are to be avoided in feeding sheep, and these are changed to clean, fresh pasture every two or three weeks, if possible, during the summer months. Rape pasture and other annual crops will prove of great value where the permanent pastures have become infested with worms. Where sheep are suffering from stomach worms, either of the following remedies may be resorted to: Gasoline,

[5] Kleinheinz, "Sheep Management," p. 65.
[6] Reports 1896 and 1903.

turpentine, or benzine. The dose for lambs is 5 ounces of cows' milk, 1 tablespoonful each of gasoline and raw linseed oil, well mixed and given in a drenching bottle; for older sheep, 1½ tablespoonfuls gasoline are given in the mixture.

The general rules in regard to feeding sheep are similar to those for feeding other classes of farm animals. Regularity of feeding is all-important, as are cleanliness, gentle treatment, patience, and exercise of good judgment on the part of the feeder.

Feeding Fattening Sheep.—The production of fat mutton sheep is of increasing importance in this country, and the industry is capable of still further development, as the quality of the mutton is improved by the feeding of special mutton sheep, and more people learn to appreciate tender, juicy mutton. As with other farm animals, the largest and quickest returns are made by fattening young lambs. The influence of age and the results obtained in fattening sheep are illustrated by feeding trials with range sheep conducted at the Montana station.[7] Four lots of lambs, one- and two-year-old wethers and aged ewes, about 55 in each lot, were fed on rations consisting of clover hay and whole barley for a period of 88 days. The main results obtained are shown in the following table:

Fattening Range Sheep of Different Ages

	Lambs	Yearling wethers	Two-year-old wethers	Aged ewes
Average weight at beginning, pounds	63	95	116	92
Average daily gain, pounds	.27	.27	.28	.18
Average ration: Clover hay, pounds	2.1	3.8	4.1	2.3
Barley, pounds	.68	.68	.68	.68
Feed for 100 pounds gain: Clover hay	763	1413	1469	1320
Barley	253	256	248	387
Digestible feed per pound increase	10.2	16.6	17.1	17.5
Per cent dressed weight	54.2	52.9	53.6	50.6

The lambs made the most rapid and economical gains of the four lots. The amount of feed required for maintenance and increase in weight was smaller and the average percentage dressed weight was higher for this lot than for the older sheep.

Clean, fresh drinking water should always be provided. The amount which sheep will take will vary with the character of the rations fed and the weather, from less than one quart per head when on succulent feed to five quarts or more when on dry feed only. Sheep fed dry roughage and concentrates crave salt, and even when on pasture it should be supplied regularly in order that they may

[7] Bulletin 35; also Bulletins 47 and 59.

do well. Salt furnishes the chlorin required for the hydrochloric acid of the gastric juice, and has also other important functions in the digestion of food (p. 24).

Hot-house Lambs.—The most extreme method of fattening sheep is that of producing so-called hot-house lambs (Fig. 90). The term " hot-house " applies to lambs born in the late fall or early winter, which are fattened during the winter months and marketed in the early spring. The quarters in which the lambs are fed are not artificially heated, the name having reference to the fact that the lambs are produced under artificial conditions for a market willing to pay a very high price for a fancy article, in a similar way

Fig. 90.—Grade Dorset lambs from Merino ewes make excellent hot-house lambs. (Peterson.)

as in the case of ordinary hot-house products. The lambs must be in fat condition to sell as hot-house lambs. Dorsets or Dorset grades are best suited for lamb production, as the ewes will breed earlier than the usual time, viz., during the early summer, and the lambs will be dropped during October and November. The mother's milk is the best feed available, and ewes must be fed liberally on milk-producing feeds so as to give a maximum flow of milk. The ewes' milk is supplemented by grain feeds as the lambs grow older. The following grain mixtures were found to give good results in trials with hot-house lambs at Cornell station: [8]

[8] Bulletin 309, which see for description of the method of management of a hot-house lamb producing flock throughout the year.

(1) 50 pounds corn meal, 50 pounds wheat middlings, and 5 pounds oil meal,

(2) 25 pounds wheat bran, 25 pounds wheat middlings, 25 pounds hominy meal, 8 pounds linseed meal.

The lambs are fed grain in a separate pen (creep), as previously explained. Rightly handled, hot-house lambs will make a sufficiently rapid growth to be ready for the market in ten to twelve weeks from birth. They will gain at least one-half pound each daily during this period, and will reach a weight of about 50 pounds at slaughtering time. These lambs are generally marketed before March, as the prices in the East, where they are mostly produced, as a rule go down after this time.

Early Spring Lambs.—Fattening early spring lambs has become an important industry in the South. By the use of Bermuda grass, bur clover, and Japan clover, permanent pasture may be available in this section ten months of the year, and temporary winter pasture may be resorted to the remaining two months, thus giving both ewes and lambs the advantage of pasturage during practically the entire year; the lambs may be fed grain separately and marketed during April to June, when good prices prevail.[9] In many cases the ewes are fed nothing but cotton-seed meal and cotton-seed hulls, the daily feed being .5 pound meal and 1.3 pounds hulls; another cheap southern feed is soybean hay.

Fall Lambs.—Fattening lambs are often carried until fall on pasturage, with a slight feed of grain, say one-half pound per head daily, and are sold at about eight months old, when they will weigh in the neighborhood of 100 pounds. Rape sown in the corn or on ground set apart especially for this crop will furnish excellent supplemental feed for such lambs, as well as for fattening sheep in general. If rape is grown by itself, it is either sown broadcast or in drills 30 inches apart, the advantage of the latter method being that a larger yield of green forage will be secured, and that the field can be kept free from weeds (p. 138). Movable hurdles are generally used where rape is pastured off by sheep or swine.

Winter Lambs.—Another method is to fatten the lambs during the winter season. This is the common method practised in regions where lambs are fattened for market. In the East the lambs are generally kept in rectangular feeding pens with hay racks and grain troughs provided with vertical slats, making an opening for each lamb. They are put on full feed in about three weeks and

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[9] Alabama Bulletin 148; Missouri Circular 25; Tennessee Bulletin 84.

fed grain until in the right condition for market. Water and salt are supplied in each pen.

In the corn belt the common method is to feed the lambs an abundance of good hay and to bring them slowly on to full grain ration, beginning with one-fourth pound per head daily and gradu-

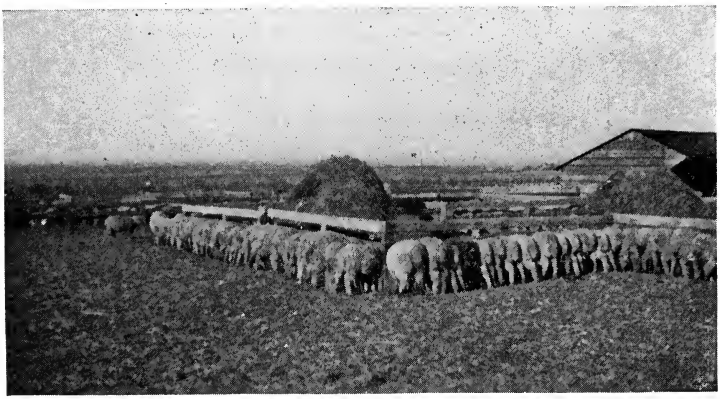

FIG. 91.—Range sheep in feed yards at Caldwell, Nevada. (Iddings.)

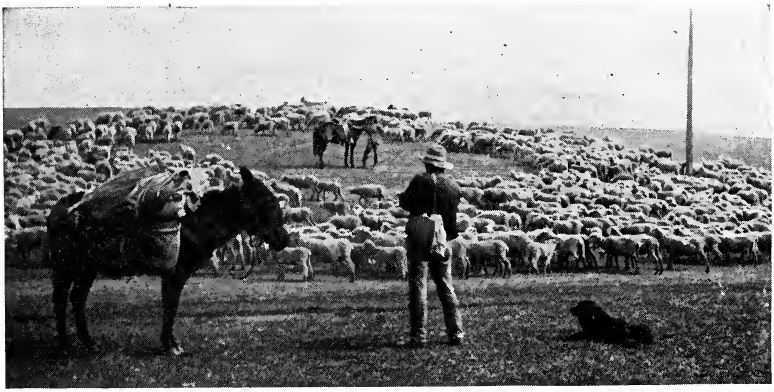

FIG. 92.—A flock of sheep on a western range. (*Pacific Rural Press.*)

ally increasing this to one pound per head daily in about three weeks, after which time they get all the grain they will clean up at each feeding; less hay is eaten as the lambs get on full grain feed. Lambs thus fed should make a gain of 25 to 30 pounds in 100 days, when they will be ready for market. There is considerable variation in the choice of grain mixtures and other feeds. Corn with wheat bran, oats, or linseed meal fed in varying proportions, according to the character of the available roughage and the market prices of the feeds, makes up the majority of the rations fed; other feeds are cotton-seed meal, soybeans, peas, and, of rough feeds, roots or silage, alfalfa or clover hay, corn fodder, etc. The lambs are often fattened in two droves in the corn belt, the first one being purchased in November and fed until the end of January, when the second lot is purchased and fattened by the first of May.

In the western States extensive lamb and sheep feeding operations are carried on each year (Figs. 91, 92, 93, 94). The sheep are usually separated into flocks of about 500 each and fed in lots

Fig. 93.—Lamb-feeding corrals in Idaho. (Iddings.)

arranged in rows with feeding lanes between. No shelter is provided except what may be furnished by a hay or straw stack. The sheep are brought from the high summer ranges to these feeding points where alfalfa hay is available, and are fed all the hay they will eat until they are shipped. If grain is fed, they are given three-fourths to one pound daily per head, generally Indian corn, or barley or wheat in the far western States. Experiments at the New Mexico station[10] show that by an addition of corn to alfalfa hay an improved quality of mutton was obtained and the feeding period was shortened. The general conclusion drawn is that, with

[10] Bulletin 79.

alfalfa alone,[11] it requires about 110 to 120 days to fit the lambs for the local market; with light grain ration (one-fourth pound per head per day), 100 to 110 days; with medium grain ration (one-half pound), 90 to 100 days, and with heavy grain ration (1 pound), 70 to 80 days. The gains were as great (but not as rapid) with one-fourth pound of corn per head daily as with one-half pound. The cost of the gain increased, however, with an increase in the grain ration. Other prominent feeds used for fattening sheep in the West besides alfalfa are beet pulp and field peas (pp. 121 and 194).

Western sheep men calculate that the wool pays the cost of the sheep feeding, and the mutton and lambs represent the profit of the

FIG. 94.—Winter scene of range sheep in the Nevada mountains. (Doten.)

business. Large numbers of wethers are shipped East every year from these States, especially to Chicago, and either go directly on the market, if sufficiently fat, or are fed at some feeding station near the market until they are in prime condition or can be disposed of to good advantage. While at these stations they are fed hay, corn, and, generally, grain screenings, at least in past years.

Value of Various Grain Feeds for Fattening Lambs.—The following table shows the results of a large number of trials with various grains for fattening lambs, which will be of interest in this connection. In the last column of the table the number of feed units required per 100 pounds gain are given, assuming 2½ pounds

[11] Farmers' Bulletin 504, p. 9.

hay, 1.1 pounds oats or emmer, and 1 pound corn, wheat, barley, or screenings, to equal one feed unit; 2 pounds hay (alfalfa) in the western trials were assumed to be equal to one feed unit.

Feeding Various Grains to Fattening Lambs *

Concentrate	Number of trials	Average ration		Average daily gain	Feed per 100 pounds gain		Number of feed units
		Grain	Hay		Grain	Hay	
Indian corn †	4	1.4	1.0	.29	506	350	646
Indian corn ‡	4	1.3	1.5	.31	429	478	668
Wheat, whole	5	1.2	1.4	.25	475	583	708
Oats, whole	3	1.0	1.7	.24	423	744	683
Barley, whole	5	1.1	1.9	.30	390	639	646
Emmer, whole	4	1.3	1.8	.25	537	691	764
Wheat screenings, whole	4	1.3	1.4	.26	488	567	715

* Condensed from summary tables in Henry's "Feeds and Feeding."
† Eastern stations. ‡ Western stations.

We note that there was but little difference in the nutritive effect of the corn and barley, the average daily gains made by the lambs on these grains being 0.3 pound; the other grains produced a gain of about one-fourth pound per head daily. Considering the feed requirements for the production of 100 pounds of gain, there were only slight differences between corn, barley, and oats, while whole wheat, screenings, and emmer gave the lowest returns per 100 pounds feed units.

Self-feeders similar to those used in the case of self-fed steers are employed by some sheep farmers in feeding fattening lambs, a supply of grain feeds sufficient for about a week or less being placed in the feeder. The lambs are able to take all the grain they want as it comes out at the bottom of the feed trough. As in the case of steer feeding, the experience of farmers with self-fed sheep has been both favorable and unfavorable, although the evidence seems, on the whole, more unfavorable than with self-fed steers. According to results obtained at the Michigan station,[12] "Fattening lambs by means of a self-feeder 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." J. E. Wing, a noted authority, states[13] that not only is the death-rate much heavier where self-feeders are used, but the cost of gain is also much greater. It is evident, therefore, that the use of self-feeders for sheep cannot be recommended, except under conditions

[12] Bulletin 128.

[13] "Sheep Farming in America"; see also Michigan Bulletin 113, Minnesota Bulletin 144, Colorado Bulletin 151.

where large numbers of sheep are fed, and where labor is scarce and high.

Rations for Fattening Sheep.—The rations given below will show the kinds and amounts of different feeding stuffs that may be fed to fattening lambs weighing 80 to 100 pounds:

1. 2 pounds clover hay, 1 pound wheat bran, 1½ pounds corn.
2. 1½ pounds hay, 1½ pounds roots, 1½ pounds oats and wheat bran, equal weights.
3. 1½ pounds clover hay, 1 pound roots, 1 pound corn, ½ pound wheat bran.
4. 3 pounds alfalfa hay, ⅔ pound corn.

Fig. 95.—A flock of Angora goats in the California foothills. These goats will keep down underbrush; they furnish mohair fiber used in the manufacture of plush and other fabrics.

5. 1 pound each cotton-seed hulls and cotton-seed meal.
6. 1½ pounds clover hay, 1 pound corn, ¼ pound wheat bran, ½ pound gluten feed.
7. 2 pounds alfalfa hay, 2 pounds ground corn and oats.
8. 2 pounds clover hay, 1½ pounds soybeans, ¼ pound wheat bran.

Feeding Goats.—Goat raising is of importance as an industry in only four or five States in the Union, viz., in Texas, New Mexico, Arizona, Oregon, and California (Fig. 95). In 1910 there were nearly three million goats and kids in the United States, of which over a million were in Texas and about one-half million in New Mexico. Nearly three-quarters of the number of goats in the country were found within the borders of the five States mentioned.

The number of goats in other States is very small, and it is safe to say that the goats kept in them do not often receive any special attention as to feed or care; they are, as a rule, kept in very small flocks and are left to browse and find their feed along the roadside, on vacant town lots, and in waste places.

As in the case of sheep, there are two distinct types of goats: One kept on account of their fleece, and the other type for milk production. The former, which are by far the more numerous in this country, are represented by the Angora goat, whose fleece furnishes the mohair fiber; the latter by imported milch breeds, espe-

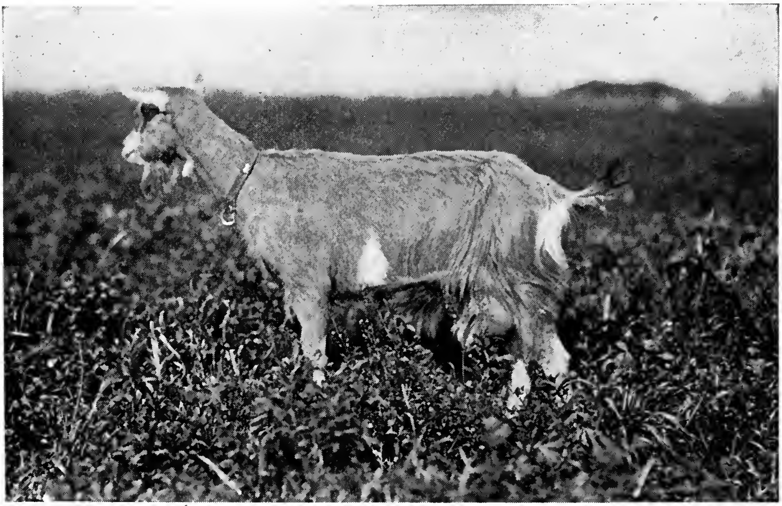

Fig. 96.—An imported Swiss milch goat. (Toggenburg.) These goats will produce over 1000 pounds of milk per year, or about one-fourth as much as an ordinary dairy cow. (Peterson.)

cially Swiss milch goats. Angoras in the far western States and in the north central States serve a useful purpose in keeping down the underbrush; in California and other western States they are used for keeping the fire lines in the forest reserves open and free from underbrush. The goats greatly relish the fresh leaves and buds and tender twigs of bushes and deciduous trees, and keep in good, healthy condition on this feed with what pasturage they may find. Grain is only fed when they are fattened for slaughtering.

Milch Goats.—While the Angora goats will do well on brushwood alone, the milch goats require a more varied feed to give milk of good quality and flavor and to produce milk during a full lactation period (Fig. 96). Goats' milk contains about 4.8 per cent butter fat, on the average (p. 206). A common doe will give a couple of pounds of milk a day for five or six months, while a good milch goat will yield three to four times this amount and continue to produce milk from eight to ten months. Goats are easy keepers, they require but little care and attention, and are economical milk producers. They are often spoken of as "the poor man's cow," on account of their low cost of keep and because they are generally kept by people who cannot afford to buy a cow; three or four milch goats will produce as much milk as a good cow; on the other hand, it is stated on good authority that eight goats can subsist and yield a good flow of milk upon the amount of feed that is required for one cow.[14]

Milch goats should receive a supply of good hay, preferably leguminous, such as clover, alfalfa, cowpeas, etc., throughout the year. Fine, bright corn fodder, straw, or other dry feed may also be given in amounts of two to four pounds per head daily, when they are not on grass. Good vegetable kitchen refuse may often be fed to advantage. Oats, barley, and wheat bran are excellent grain feeds for goats, one-half to one pound per head being the average daily allowance. These may be fed separately or equal weights of each mixture. A little linseed meal, two to three ounces a day per head, makes a valuable addition to the ration; somewhat heavier grain feeding, viz., up to one and one-half or even two pounds per head daily, will pay well during the early part of the lactation, in the case of milch goats of exceptional productive capacity. Pure water and salt should be supplied regularly, as in the case of sheep.

QUESTIONS

1. Name the two types of sheep kept in this country, and give the sections where each type is mainly kept.
2. Give several reasons why it is desirable to keep sheep on most farms.
3. How is the production of wool influenced by the method of feeding practised?
4. Give the average weight of lambs at birth.
5. Discuss briefly the method of feeding (*a*) rams, (*b*) ewes, (*c*) lambs.
6. State the methods followed in fattening (*a*) hot-house lambs, (*b*) early spring lambs, (*c*) fall lambs, (*d*) winter lambs.
7. Give the principal methods adopted in fattening western sheep.
8. State the value of the self-feeder in fattening sheep.
9. Name the two types of goats kept in this country, and state in what section each one is most important.
10. Give the method of feeding goats generally found in your locality.
11. What relation have goats to forestry work in this country?
12. How much milk will an average milch goat produce in a year, and what is the quality of the milk compared with cows' milk?
13. Why is the goat called "the poor man's cow"?

[14] Thompson, "Angora Goat Raising and Milch Goats," p. 200.

Literature on Sheep and Goats.—Craig, "Sheep Farming," New York, 1913. Kleinheinz, "Sheep Management," Madison, Wis., 1912. Powers, "The American Merino," New York, 1907. Doane, "Sheep Feeding and Farm Management," Boston, 1912. Stewart, "The Domestic Sheep," Chicago, 1900. Wing, "Sheep Farming in America," Chicago. Miller and Wing, "The Winter Lamb," Mechanicsburg, Ohio, 1907. Shaw, "Sheep Husbandry in Minnesota," St. Paul, Minn., 1901. "Shepherd Boy," "Modern Sheep, Breeds and Management," Chicago, 1907. Wrightson, "Sheep, Breeds and Management," London, 1903. Shaw and Heller, "The Management of Sheep on the Farm," Farmers' Bulletin 20, 1894. Craig, "Sheep Feeding," Farmers' Bulletin 49, 1897. Curtiss, "Raising Sheep for Mutton," Farmers' Bulletin 96, 1899. Thompson, "Angora Goat Raising and Milch Goats," Chicago, 1903. Schreiner, "The Angora Goat," New York, 1898. Thompson, "Information Concerning the Milch Goat," Bureau Animal Industry, U. S. Department of Agriculture, Bulletin 68, 1905. Thompson and Shaw, "The Angora Goat," Farmers' Bulletin 137, 1908. Heller, "The Angora Goat," Farmers' Bulletin 573.

Experiment Station Publications.—Colo., b. 32, 52, 75, 76; Ill., b. 129, 166; c. 125; Ind., b. 147, 162; Iowa, b. 17, 18, 33, 35, 48, 63, 110; c. 6; Mich., b. 84, 107, 114, 128, 136, 178, 220; Minn., b. 44, 57, 59, 75, 78; Mo., b. 115; Mont., b. 21, 27, 35, 39, 47, 59; Neb., b. 66, 71; N. H., c. 16; N. Y. (Cornell), b. 309; Ohio, b. 179, 187; Okla., b. 78; S. D., b. 71, 86; Utah, b. 78, 90; Wis., r. '97, '04, '05; b. 32, 41, 58; Wyo., b. 47, 51, 64, 68, 69, 73, 81; Ont. (Guelph), r. 91; Farmers' Bulletins 49, 98, 556; U. S. Bur. An. Ind. b. 77; c. 18.

CHAPTER XXVII

FEEDING POULTRY

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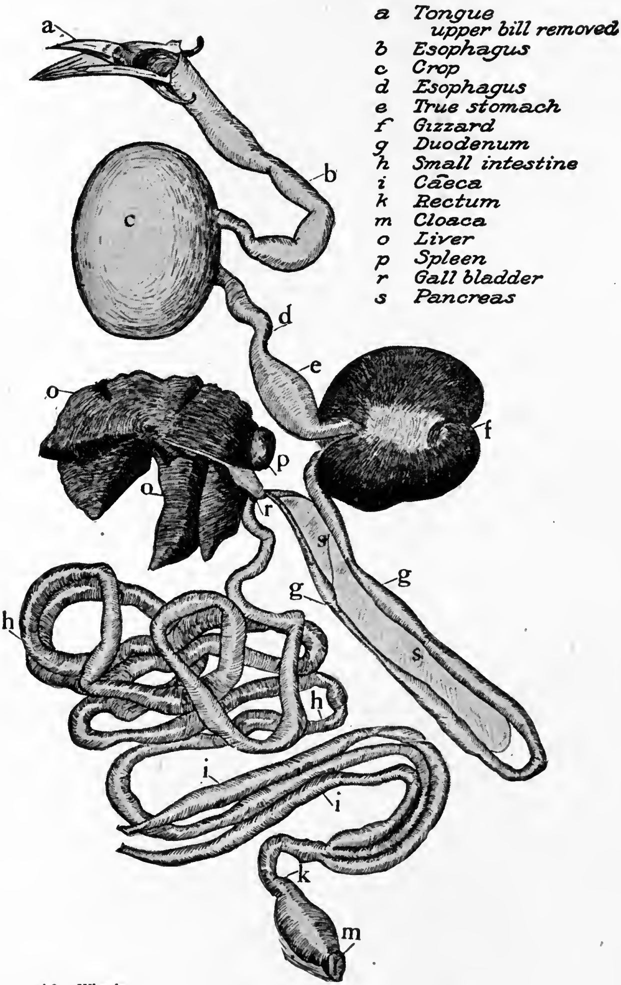
In order to feed poultry intelligently, we must try to analyze and fully understand the combination of causes whose effect will be an abundance of eggs, rapid growth or quick fattening. It is the common practice of some farmers to feed laying hens nothing but shelled corn and then they wonder why they do not get good results. Practically any hen will lay some eggs in the spring, which is the natural laying period. It is the hen that will lay well not only in the spring but throughout the year that returns a net profit to her owner; and it is only by correct feeding, *i.e.,* the feeding of the most suitable feeds in the best proportions to produce eggs, or increase in body weight, that one can expect to obtain the most profitable results from poultry feeding.

Productive feeding requires that one be familiar with (1) the action of the fowl's digestive system in utilizing the feed eaten, (2) the maintenance and productive needs of fowls of different ages and fed for different purposes, such as eggs, market, growth, (3) the nutrient qualities of the feeds fed and their fitness for use in any particular ration.

The Digestive System.—Poultry have no teeth with which to grind or tear feed before letting it pass from the mouth into the crop. Neither can they swallow feed into a storage stomach and later regurgitate and masticate it at leisure ("chew the cud"). Poultry of all kinds must swallow what they eat just as they find it and, for this reason, can only use such grains, pieces of bone, stone, etc., as can be swallowed. Green herbage, vegetables, meat and other soft and easily torn materials can be broken apart into sufficiently small pieces with the strong muscular jaws and horny beak. Young chicks cannot eat as coarse materials as older fowls; so that grains, etc., for chick rations must be ground or cracked more finely than those intended for older fowls.

After being picked up, the feed passes directly from the mouth into the crop, which is a good-sized, bag-like enlargement of the œsophagus serving the purpose of a storage stomach. It is similar in this respect to the rumen or paunch of a cow. In the crop, the feed is mixed with digestive juices which soften and prepare it for the second stomach (proventriculus). This latter



After Wheeler.

FIG. 97.—The digestive tract of a fowl.

organ is much smaller and more muscular than the crop and the feed is passed into it only in small portions (Fig. 97). After being acted upon by the digestive fluids of the second stomach, the partially digested feed is passed on to the gizzard, an extremely powerful grinding organ having a tough and convoluted lining, where it is ground to a very fine state by means of the abrasive action of the stones or grit which the fowl swallows. Pieces of glass have been taken from the gizzard of a chicken that were rounded on the edges and worn as smooth as though ground and polished by hand, and pieces of iron have been removed that had been bent double. Such instances give an idea of the toughness of the gizzard lining and the enormous muscular power of this natural grist mill.

The feed passes from the gizzard into the intestines, where the process of digestion is completed; the digested nutrients are absorbed by the walls and pass into the blood, which distributes them to all parts of the body. The indigestible parts of the feed eaten, together with waste matter which is thrown off by the body and dumped into the lower intestine, are carried on into the *cloaca* and voided in the form of manure. In poultry the urea and all fecal matter are voided together, the whitish part of the normal droppings representing the urea.

Feed Components.—The body of a fowl is composed of approximately 44 per cent dry matter and 56 per cent water. The dry matter consists of 21.6 per cent protein, 17 per cent fat and 3.8 per cent ash.

Protein is needed to furnish materials with which to build new body tissue, as feathers and muscles, and to replace the old, worn-out body tissue and feathers. The albumen of the egg also consists of proteid material so that the laying hen draws quite heavily on the protein in her feed to meet this need.

Carbohydrates furnish muscular energy and heat to keep up the body temperature. The carbohydrate nutrients left after meeting the needs of the fowl's body for heat and muscular energy are stored in the form of body fat or used to make up the yolk of the egg, which is largely fatty material.

Fat performs exactly the same function as do the carbohydrates. It is, however, two and one quarter times more concentrated and efficient.

Ash, including various salts and mineral materials, is essential to a proper functioning of every part of the fowl's body. Among other things it helps build strong bones and rich blood; strengthens the nails and feather quills, and furnishes the material for the shell of the egg. Without mineral matter the bones would be soft and flexible and unable to support any weight.

Crude Fiber.—This is the coarse, woody material in the feed; the seed coats of the different grains, the stems of clover, alfalfa, and hay and straw are high in fiber. It is only slightly digestible and has practically no nutritive value for poultry, but it is a very essential part of a ration because it adds bulk and performs the mechanical function of keeping the feed in the digestive organs loose and spongy so that the digestive fluids can easily penetrate to and act on every part. In the absence of such coarse, fibrous material, the sticky and more concentrated feeds would form a hard, mucilaginous mass in the digestive organs which the digestive juices would not readily penetrate. Digestion would be checked, unhealthy fermentation of the partially digested materials arise and indigestion follow. Fine-cut alfalfa and bran added to a mixture of flour and corn meal make a porous, crumbly, wet mash. Without the alfalfa and bran, the flour and corn meal would form a sticky, lumpy and unpalatable mass when mixed and moistened. A moderate amount of bulky material is always essential to a well-balanced, nourishing ration, but too much of such material is detrimental because it compels the fowl to pass through its body large amounts of useless, indigestible materials.

Feeding standards have not been worked out for poultry to the extent which they have for other kinds of farm livestock. With the larger livestock, standard amounts of feed eaten per day for animals of different ages and used for different purposes have been quite accurately determined but with poultry this has yet to be done. To date the general statement to "feed all the fowls will eat up clean" and nutritive ratios for different purposes represent the extent of our standards for poultry. Undoubtedly curves of feed consumption for different types of poultry, for poultry of different ages, and for poultry used for meat or egg production will eventually be worked out and such curves will prove of inestimable value in more definitely guiding the inexperienced feeder than the above general statement can and in throwing greater light on production and maintenance costs.

Nutritive Ratio Standards for Poultry of Different Ages

Birds	Nutritive Ratio
Growing stock	1:3.7–4.0
Broilers and Fryers (finishing)	1:4.0–4.6
Laying and Breeding Stock (4½–8 lbs.)	1:4.2–4.6
Laying and Breeding Stock (3–4½ lbs.)	1:4.6
Adult stock fattened for market	1:5.5–6.5
Capons	1:5.5–6.5
Crate Fattening	1:4.0–5.0

The foregoing applies to ducks, turkeys, etc., as well as chickens.

Feeding standards are not in any way iron-bound, but they are valuable guides to the feeder in aiding him to mix rations which many years of careful feeding investigations, borne out by practical experience, have found to be most suitable to the needs of poultry.

Growth.—The growing chick requires quite a large amount of protein in its feed to build the new bone, muscle and feathers which develop as growth goes on.

Laying.—The laying hen, on the other hand, has stopped growing, and less protein in the ration is needed to repair the con-

Fig. 98.—Farm poultry colony house, 8x10 feet, capacity 25 to 30 birds.

stantly breaking-down body tissue, but for the production of eggs proteid material is required in considerable amounts for the making of albumen, so that a laying hen requires almost as narrow a ration as growing stock.

Fattening.—The mature fowl that is being fattened for market should be fed a wider ration than laying or growing stock as it is being fed largely for the purpose of developing fatty tissue. Such fowls are fed only enough protein to repair body waste and supply sufficient extra protein material to lay on some new meat tissue mixed in with the fat so that the resulting carcass will be juicy and well marbled. To properly fatten, a fowl must lay on a mixture of lean meat and fatty tissue; if lacking in fat well interspersed with the lean, the meat will be too dry; the overfat fowl will be too greasy to be toothsome. Since broilers and fryers are allowed to get their proper growth first and are then finished off for market, they are fed a narrow growing ration until ready for the finishing process, when they are fed a somewhat wider ration which still contains a sufficient proportion of proteid material to allow for some additional growth.

A ration for poultry may be defined as the grain mixture, mash mixture, greens, grit, oyster shell, etc., that the fowls consume during one day. When the birds are not given free range to wander about the farm at will but are kept in fenced-in yards or runs (Fig. 98), greater attention must be paid to the composition

FIG. 99.—Free range for growing chickens (Wis. Station). The flock requires less feed, grows faster, and is more thrifty when not confined to small yards.

of grain and mash mixtures and other parts of the ration because the fowls cannot then range over the fields for seeds, worms and insects, green herbage and other materials necessary to properly balance their diet. Fowls on free range (Fig. 99) get a great deal of grain from the harvest fields that would otherwise be totally lost; they pick up worms and insects that help supply the animal feed which they need in order to thrive; they secure a great deal of greens that are tender and perfectly fresh because the fowls harvest them themselves. This is why fowls on free range so often do well and produce profitably when fed only a little grain by the owner. In proportion as fowls are restricted in their liberty and forced to depend upon their owner for all of their feed, must the poultryman pay more serious attention to the fowls' diet, in order that they get the materials they need to produce most profitably.

The principal points to be considered in formulating a poultry ration may be set forth as follows:

Variety.—It pays to feed a ration consisting of a well-blended mixture of a number of different feeds but it is not advisable to change the ration from day to day or week to week in order to secure such variety. Continual changing of the ration necessitates a re-adjustment of the fowl's digestive system every time a new kind of feed is eaten. If fed a definite ration regularly, the digestive tract becomes thoroughly adjusted to the handling of that definite ration and a more economic digestion of the feed results. Variety increases palatability. Palatability produces a more efficient use of the feed consumed because it stimulates a more copious secretion of the digestive juices. Variety tends to reduce the cost of the ration. If at a time when wheat, barley and corn are selling for $36, $26 and $32 a ton, respectively, "A" feeds only wheat as a grain, whereas "B" feeds equal parts of the three, then "A" is paying $1.80 per hundred pounds for his poultry grain, whereas "B" is only paying $1.57 per hundred. Variety makes it possible to use in the ration feeds which of themselves might be unpalatable to the fowls, although very desirable from other points of view, but which could be put into a variety ration and disguised by other very palatable materials.

Suitability.—Every ration should be suitable to the purpose for which it is fed if the highest efficiency is to follow, just as in the mechanical world every piece of machinery must be exactly adapted to the work required of it to reach a high efficiency curve. The feed mixtures fed to birds that are being fattened will differ somewhat from rations fed to secure rapid growth of young chicks or a full egg-basket from laying hens. To illustrate, in crate fattening best results are secured by feeding a sloppy mash ration mixed with buttermilk to such a consistency that it will run off a spoon. Setting hens should be fed a mixture of grains only and no mash, because they take so little exercise that an easily digested ground mash would cause them to become overfat. Ducks would suffer if they were not able to take a mouthful of feed and then rush to the water trough to wash it down.

Bulk.—The ration should contain enough bulk to enable the digestive juices to easily penetrate it, but should not contain an excess which must be eliminated with a waste of energy.

Grain to Mash Ratio.—All rations but quick-fattening rations, such as are used for crate fattening, etc., should be made up of both grain and mash mixtures. The grain is needed to provide activity for the muscles of the digestive tract and to keep them in the best working condition. Ground feeds being easily digested do not furnish these muscles with sufficient work. In order to meet the needs of heavy production a part of the ration should consist of soft ground feeds which are easily digested and can rapidly supply the extra needs of heavy egg production, rapid growth and quick fattening.

Digestibility.—The more thoroughly digestible a feed is, the more effective it is. Hay and grains with heavy seed coats are not

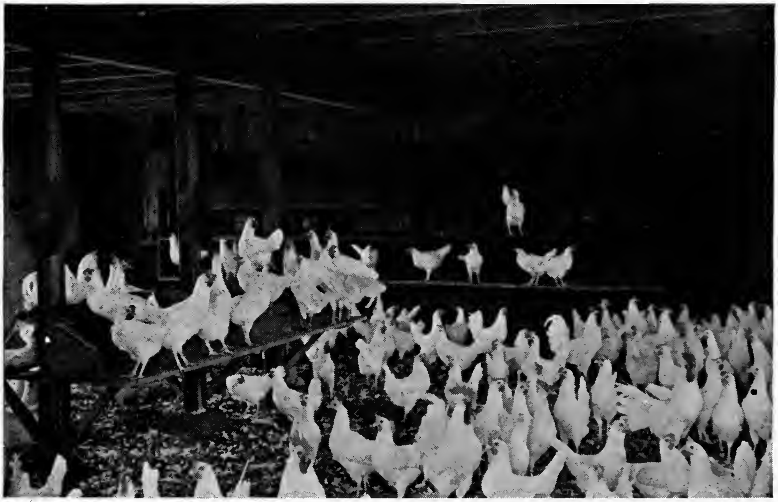


Fig. 100.—Interior of modern poultry house.

as economical feeds for poultry as feeds containing less woody material because the percentage of digestibility is lower. Variety increases the digestibility of a ration.

Cost is an essential item in feeding poultry. The feed cost of producing a dozen eggs when fowls are fed a well-balanced variety ration, is less than when they are fed only one kind of grain, for instance. The most economical ration is one that secures the best results at the lowest cost.

Flavor.—No feeds should be fed which will injure the flavor or keeping quality of the products.

How Much to Feed.—There can be no hard and fast rule laid down for the amounts of feed to be given fowls, except to feed all they will eat up clean. The quantity of feed eaten depends upon age, breed, housing, range and many other factors which the feeder does not always consider as seriously as he should. The heavier breeds will eat more than the lighter breeds. Three-quarter-grown birds may eat more than fully matured ones. Heavy layers will eat more than poor layers.

Perhaps one of the most common troubles to be found among poultry raisers is overfeeding, and such feeding is undoubtedly a major cause for a large number of poultry ills. Feed is allowed to lie on the ground. Fowls do not have to take sufficient exercise for the feed they consume and their crops are continuously crowded to the detriment of their health. The feeder should constantly study his flock. He should occasionally pick up a few and examine them to determine their condition. Under the necessarily intensive conditions which must be practised on the commercial poultry farm, the fowls must be forced to take proper exercise by the methods of feeding used. The mechanics of feeding are represented by the scratching pen, feeders and exercisers.

Fowls must be fed at all ages in such a way that there is always a slight edge upon their appetite, except when they go to bed at night. They should be fed lightly during the day and made to work for all of the grain. Grain mixtures should always be fed in a sufficiently deep litter to force the hens to scratch vigorously for all they get. See the floors in Fig. 101. The mash should be fed in such a way that it cannot be eaten too rapidly nor to eagerly. The amount of wet mash eaten can be regulated by not feeding too often and only as much as the fowls will clean up in twenty or thirty minutes at each meal. The dry mash may be regulated by the length of time the hoppers are left open each day. With the lighter breeds the dry-mash hoppers may as a rule be left open all the time (Fig. 101). The heavier breeds of fowls, however, sometimes overeat of mash and the hoppers must be kept closed during the morning hours. Heavy-laying hens are industrious. The character of industry is so closely related to that of prolificacy that experienced breeders use it as a guide in picking out good layers.

Wet Versus Dry Mash.—Since the introduction of the dry method of mash feeding, there has been much discussion pro and con, and many investigations have been carried on to determine the relative values of the two methods for feeding chickens. In feeding ducks and other waterfowl, the wet mash is used altogether, owing to the shovel-like construction of their bills. Since ducks must shovel the mash into their mouths and cannot pick up small particles of feed like chickens, a slightly sticky, moist mash is most suitable to them. A crumbly, moist mash is more palatable to chickens, but the scooping action of waterfowl in eating would scatter a crumbly mash and make it difficult for them to pick up. Duck raisers generally use a somewhat sticky binding-material, like white middlings or low-grade flour, to bind the particles of mash together.

The dry mash has been more widely adopted with each succeeding year for several reasons:

1. It requires less labor. Sufficient may be mixed at a time to

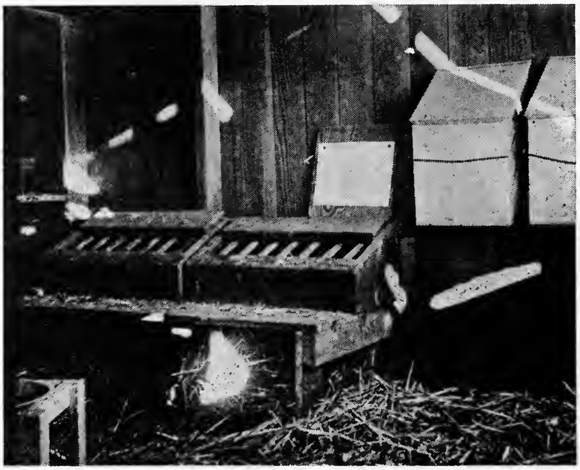


Fig. 101.—Dry mash hoppers in use (California Station). Observe 15-inch high platform to keep hoppers up off ground where they will not be scratched full of dirt and litter.

last for a week or more. The feeds used in the wet mash must not only be mixed dry but the amount needed for each meal must be moistened and mixed just before feeding. By using large hoppers, enough dry mash can be distributed to each pen to last the fowls a week or two.

2. There is less waste. The fowls scatter the wet mash a good deal. They pick out choice portions and carry them off to eat. Some of the feed adheres to mixing utensils, hoppers, etc., and is wasted. Well-constructed dry-mash hoppers are practically non-wasting.

3. The dry mash is more sanitary as there is no wet feed to adhere to mixing box, shovels, pails, and feed hoppers, and become

sour. To keep utensils clean that are used in wet-mash feeding requires extra labor.

4. Fowls that are accustomed to the dry mash will lay just as well as those fed the wet mash. Growing chicks fed a dry mash containing plenty of bran will usually be less subject to digestive diarrhœa than if fed a wet mash, as the dry feed will counteract any tendency to diarrhœa.

Wet mashes are more eagerly eaten than dry feed and should therefore be fed much more carefully to prevent overeating. In cold weather a light noon feed of a wet mash may be advantageously fed as an appetizer and for variety, in addition to the regular dry mash which is kept before the fowls at all times. Fowls are confined a great deal in winter and the days seem long. After working and scratching in the litter all morning they are inclined to sit around in the sun about noon. A scanty feed of wet mash at this time will put new energy into them, set them to exercising vigorously again, and help materially to increase the egg production. At other times of the year when the weather is good and the fowls spend much more time out of doors, the dry mash is all that is needed.

For fattening, the wet mash is better than the dry because the fowls can be induced to eat more feed and will fatten more rapidly. Being more forcing, it should be fed with greater care to prevent over-fatness, indigestion and liver trouble.

Feeding Versus Breeding.—Methods of feeding or the composition of a ration cannot permanently force a fowl to produce more heavily than it is naturally capable of producing. It may be possible to greatly increase production for a short period by overstimulation with condiments and very concentrated ground feeds, but the fowl soon breaks down under such treatment and is ruined for future use. All that feeding should be expected to do is to furnish to the fowls feeds that will be physically suitable, *i.e.*, small enough in size, not too bulky, and not unnaturally stimulating, and so proportioned in the ration as to meet the needs of production and healthful activity to best advantage. "The best ration" is one that promotes the health of the birds and stimulates them to their best productive effort.

Feeding cannot take the place of breeding in building up the productive abilities of fowls from generation to generation. It can only provide the kind of a ration which will most suitably furnish the nutrients needed to develop a fowl productively to the best of her capacity. Increased productive capacity can only be secured *in each succeeding generation* by constantly breeding only from the more vigorous and productive. Although the hen's laying capacity cannot be increased, it can be developed to the fullest degree by providing favorable environmental conditions as feeding, housing, yarding, etc.

Animal Feeds.—Animal feed of one kind or another has been an essential part of the diet of fowls as far back as history extends. A fair proportion of the wild fowl's diet consists of insects, worms and bugs of various kinds. The craving for animal feed of some sort as a part of their diet was natural to the wild ancestors of our present domestic fowls, for nature modeled them so that they should readily catch and utilize such materials as feed and instilled into their being an appetite for animal feed as a part of the daily ration.

This appetite for meat feeds remains with our domestic fowls, even though they have been under domestication for a long period of time. In fact ever since man first began to use poultry for utilitarian purposes, the value of animal products as an essential part of their ration has been recognized. Ten per cent of the total ration or from twenty to twenty-five per cent of the mash is generally recommended as being the proper proportion of such animal feed as dried meat scrap or fish scrap. However, the writer's experience is that where high-protein vegetable feeds are used in the ration as a partial substitute for the more expensive animal protein feed, less than this amount of commercial meat feed can be advantageously fed. Since animal feeds are the most costly materials used in a poultry ration, the cost of the ration and therefore the cost of the product could be reduced if a less expensive vegetable substitute were used for a part of the animal feed.

Buttermilk and skim milk, which are the usual forms of milk used, have proved in a great many tests to be two of the best animal feeds for poultry when properly fed. Since it is difficult to feed skim milk always sweet, and as it is undesirable to feed it sometimes sweet and sometimes sour, a sour condition is the most satisfactory way in which to feed it. With young stock until they are over half-grown, it should not be fed too freely as they are apt to drink too much and contract indigestion or fermentation of the crop.

Meat scrap and fish scrap are the commercial forms of animal feed most widely used for poultry feeding. These are slaughterhouse and fish-cannery by-products that have been cooked, dried and reduced to a finely ground condition. A good grade of commercial fish scrap fed in normal amounts to laying hens will not taint the eggs laid.

Green cut bone from the butcher shop, which consists of waste trimmings with adhering particles of meat, is a very desirable poultry feed, when finely ground and fed perfectly fresh. It is more palatable than dried scraps because it is fresh and succulent. It is usually fed at the rate of about one-half ounce per hen per day. If fed alone, the fowls may be given all they will clean up in fifteen minutes about noon.

Bonemeal or dried commercial ground bone is added to poultry rations to supply calcium phosphate to build strong bone in growing stock, to furnish lime for shell-making in laying stock, and for other purposes. Commercial meat scrap usually contains enough bone for adult stock, but for young stock a small amount of bone meal should be included in the ration. When feeding meat scrap with a very high protein content, ground bone should also be fed with it as the very high grades of scrap do not contain as much bone as the average grades.

Dried blood is used to some extent for poultry but is not as suitable as the feeds mentioned above. It is very concentrated and must be fed with great care. It is also not very palatable.

Linseed meal and soybean meal are very desirable high-protein vegetable feeds to be included in a poultry-laying ration because (1) they are rich in protein and may be used to advantage as substitutes for a part of the animal protein usually fed; (2) these feeds have a gently laxative and natural tonic effect on the digestive system and have been found very beneficial in helping the birds to come strongly through the molt as well as in promoting health and production at all times. The two feeds are quite similar in feeding value but soybean meal is perhaps somewhat more palatable than linseed meal. Such feeds may constitute five to ten per cent of the mash.

Cottonseed meal may be given in the dry mash either in place of or along with the linseed meal; but its use should always be under the watchful eye of the feeder, as it tends to constipate.

Green Feeds.—Some sort of vegetable feed is as essential to the continued health and vigor of poultry as is the grain ration. Its function in the bird's economy is not so much to furnish nutriment, although it does this to some degree, as it is to act as a natural tonic on the fowl's whole system. Green feeds stimulate the liver, induce a copious secretion of digestive fluids and instil into the very cells of the body renewed vigor and force. It is this very beneficial tonic effect that makes green feed such a valuable adjunct to the diet. When plenty of greens are fed there is also a reduction in the amount of grain and mash eaten. The West Virginia Experiment Station found that fowls that were fed no green feed ate more grain and animal feed and produced less eggs than hens that were fed all the green stuff they wanted.

The green feeds that are most valuable in securing results and are relished most by the fowls are the young and tender blades of grass, young alfalfa, kale, chard, rape, etc. Green forage crops,

FIG. 102.—The value of green feed in poultry feeding. Fowls feeding on greens to left; those in bare yard to right eagerly striving to reach greens. (California Station).

grasses and vegetables are more tender and juicy when young than after they have developed strong woody stalks and begun to form seed.

During the growing months fresh, tender, green stuff in the shape of alfalfa, fresh lawn clippings, rape, green alfalfa, or grass-covered range (Fig. 102) can easily be secured. A range covered with a green crop on which the flock can pasture is undoubtedly the most desirable but is not always feasible. The next best way is to run a quantity of fresh green stuff through a feed cutter every day and feed it at noon. A handful for every five fowls is about the proper amount to feed. Give them all they will eat up clean, is always the rule. Since fresh cut greens quickly wilt and become unpalatable, two or three feedings of greens per day are better than one, where it can be done. In winter when fresh, growing greens cannot be had, one has to fall back on sprouted grains, mangels, pumpkins, cabbage, potatoes, and steamed alfalfa or clover hay, for the supply of succulent vegetable feeds. They are named in the order of their preference. Sprouted grains although equal to other fresh tender greens are only used when fresh green stuff from the fields is not to be had because of the labor of sprouting.

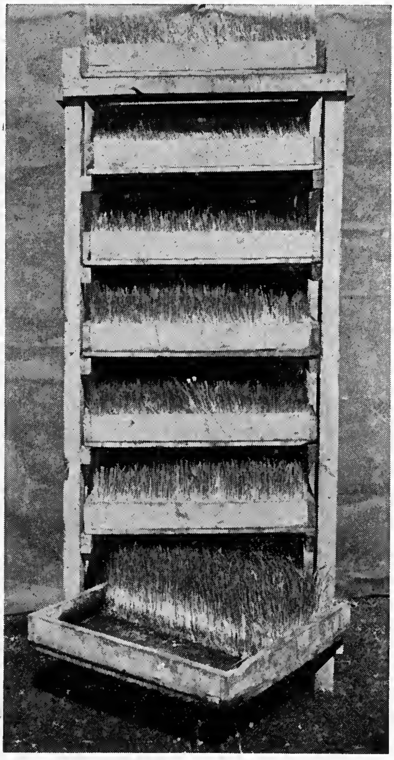


Fig. 103.—Rack for sprouting oats; large enough to provide five hundred laying hens with a continuous supply of succulent food. (Lewis.)

Sprouted oats or barley are among the best winter green feeds. They are fully equal in succulence and tonic value to the tender green stuff of summer. Oats are better to sprout than barley because they do not make such a rank growth. These grains are sprouted by a great many commercial poultrymen for feeding early hatched chicks as well as grown stock.

The grains are usually sprouted in racks about six feet high containing trays two by three feet in size and two inches deep. The trays are spaced about ten inches apart, seven in a tier so that there will be one tray ready to use each day (Fig. 103). In starting, a pail of the right size is nearly filled with oats at night and the oats covered with luke-warm water. The next morning they are dumped in a pile on the top tray and left. At night they are spread out so that the tray is level full of wet oats to a depth of one inch and another pail of oats put to soak. Next morning the top tray of oats is moved down a tray and the other tray put on top to receive the oats from the pail. The trays of oats are thus moved down one step at a time till by the seventh day the first tray is at the bottom and the oats are ready to feed. The oat sprouts should be four to five inches high when fed.

Three things are necessary to sprout grains successfully: (1) A temperature of not less than 70 degrees; (2) moisture; (3) good ventilation. The temperature must usually be secured by artificial heat. Moisture is supplied by wetting the trays every day with warm water from a sprinkling pot. Cracks must be left between the boards in the bottom of the trays so that surplus water will drain away and not rot the oats. Until the sprouts begin to show in a tray, the oats should be raked over each time they are wetted to insure an even distribution of moisture. Raking after the sprouts appear will break them off. Plenty of moisture is of prime importance for good quick growth.

A number of kinds of lamp-heated sprouting cabinets are manufactured, and racks of trays can be made and kept in a warm room or in a cellar with a furnace. To prevent mold, the flats should be thoroughly scrubbed and washed with a 5 per cent solution of formaldehyde each time they are emptied.

Mangels or stock beets are excellent for winter feeding and in some localities, like the South and Southwest, can be left in the ground all winter and harvested as needed. In feeding the mangel it can be split into big pieces and a piece rammed on a nail about a foot from the ground in each pen, for the birds to pick at, or it may be run through a root cutter and fed in a moist mash.

Pumpkins are split up and fed raw, seeds and all.

Cabbage is usually stored in pits or cellars and taken out as needed. It makes a very succulent winter green feed, but is not so easy to grow and keep as mangels, nor is it as economical a feed.

Raw potatoes are not relished by the fowls and are therefore generally boiled and mixed with the mash.

Steamed clover and alfalfa hay do not compare with the other feeds mentioned either in succulence or palatability. As a protein feed containing considerable crude fiber to be used in connection with concentrated fat-forming feeds, like corn or other grain, such feeds are very good. Alfalfa meal mixed in a dry mash has practically no value as a green feed.

Charcoal acts as a blood purifier and as a preventive of indigestion by absorbing poisonous gases. One pound to forty pounds of mash is about the right amount to feed when added to the mash, or it may be fed separately in self-feeding hoppers.

Salt in small quantities seems to increase the palatability of the ration. In large amounts it is poisonous. One pound to 200 pounds of mash is about the right proportion to feed.

Composition of Green Feeds (Without Regard to Digestibility)

	Water	Ash	Fiber	Protein	Carbo-hydrates	Fat
Sprouted oats	75.9	0.8	2.5	3.2	16.3	1.3
Lettuce	95.9	0.8	0.5	1.0	1.6	0.2
Kale	85.2	1.8	1.5	2.6	8.4	.5
Green alfalfa	80.0	1.8	4.7	4.9	7.9	.1
Green barley	76.0	7.3	6.9	2.7	7.0	.1
Lawn clippings	76.4	2.4	4.1	2.3	13.8	1.0
Mangels	90.9	1.1	.9	1.4	5.5	.2
Pumpkins	90.9	.5	1.7	1.3	5.2	.4
Cabbage	90.5	1.4	1.5	2.4	3.8	.4
Potatoes	78.9	1.0	.6	2.1	17.3	.1
Alfalfa hay	11.0	6.4	22.6	17.6	39.3	3.1
Red clover hay	15.3	6.2	24.8	12.3	38.1	3.3

Composition and Digestibility of Animal Feeds

	Water	Ash	Fiber	Digestible protein	Digestible carbohy-drates and fat
Skim milk	90.5	0.9	...	3.3	5.4
Buttermilk	90.4	0.7	...	3.8	5.5
Whey	93.4	0.6	...	0.9	7.7
Meat scrap	10.1	5.8	2.8	57.0	33.3
Fish scrap	Variable and similar to meat scrap				
Dried blood	8.5	4.7	...	60.8	5.6
Fresh-cut green bone	8.9	26.1	...	18.3*	10.5*
Ground dry bone	8.0	64.4	...	19.0*	.....
Pork scrap	11.0	2.2	...	45.0	33.4
Digester tankage	7.0	15.9	5.8	50.1	26.1

* Assumed.

Success with poultry depends upon four factors, *i.e.,* skilful breeding, housing, feeding, management and marketing. The very best ration will not give efficient results unless the fowls are otherwise well taken care of. Feeding is but one part of the problem of successful poultry raising.

There is no one best ration for any particular purpose. The feeds fed and the composition of the ration will depend on the feeds available in any section of the country. Fish scrap is used extensively on the Pacific Coast as a substitute for meat scrap because it can be obtained at a lower price, on account of the many fish canneries located there. Cottonseed meal is used more extensively in the South than in the North and West because the South is a cotton-growing region.

EXAMPLES OF POULTRY RATIONS

The rations that follow are simply given as examples of well-constructed rations. They are given in detail to concretely point out the way in which rations for different purposes should be made up and fed.

Grain	Mash
75 pounds whole wheat,	25 pounds bran,
50 pounds whole or rolled barley,	25 pounds shorts,
25 pounds cracked corn.	25 pounds ground barley,
	15 pounds commercial fish scrap,
	10 pounds linseed meal,
	$2\frac{1}{2}$ pounds fine charcoal,
	.5 pound fine dairy salt.

Oats could be substituted for the barley in the above grain mixture, and whole Egyptian corn, milo or other grain-sorghums for Indian corn. Ground oats could be used in place of ground barley, and soybean meal could substitute for linseed meal in the mash. If skim milk or buttermilk were available, it could be kept before the fowls in drinking vessels and no other animal protein feed need be fed. Fresh, finely-ground, green bone from the butcher shop could be used in place of other animal feed, and fed at the rate of about one-half ounce per hen per day. It could be fed separately at noon if the dry mash were used, or mixed in the wet mash. Milk could be used to mix a wet mash in addition to feeding it alone or, if only a limited amount of milk is available, it could be used to moisten the wet mash, and the amount of other animal feed reduced.

Green feed should be plentifully supplied. Grit and oyster shell should be kept before the fowls in self-feeding hoppers at all times (Fig. 101).

The mixed grain is fed lightly in a deep litter (Fig. 104) in the morning and more freely at night so that the fowls will get all they want before going to roost. The mash, if fed as a dry mash, should be kept constantly in open hoppers before such active fowls as Leghorns. For heavier fowls which have a greater tendency to eat too much mash and to become over-fat, it may be necessary to keep the hoppers closed in the morning and not open them till noon. Approximately one pint of grain to ten hens should be fed in the morning and one and one-half pints at night.

Great care should be taken not to over-feed. Best results are secured in both eggs and health of fowls when they are active and in normal flesh. They should only be fed what they will eat up clean each day and should come hungry to every meal. During the daytime their appetites should be kept keen and never entirely satisfied.

Chick Ration.—The chicks are removed to the brooder after 24 hours, but are not fed for from 60 to 72 hours after the hatch is completed. When the chick leaves the shell its digestive appara-

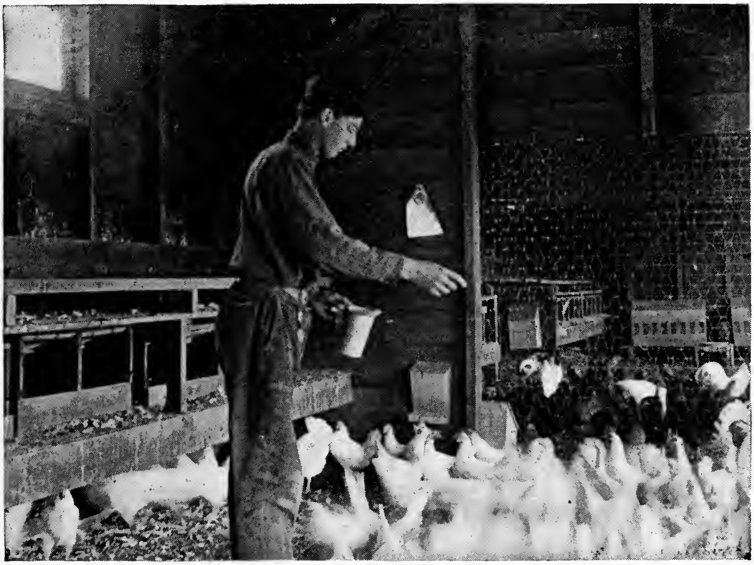


Fig. 104.—Scattering grain in the litter. (California Station.)

tus contains a considerable amount of unabsorbed yolk. Until this is thoroughly digested and absorbed into the blood the chick's delicate stomach is not ready to receive much feed. When they are first taken to the brooder only a fountain of water should be put before them. They will immediately begin picking at the sand on the floor and drinking water. This prepares and hardens the crop for the reception of feed.

In feeding chicks a grain mixture composed of equal parts of fine cracked wheat, fine cracked corn and steel-cut oats is fed in a wooden chick hopper the first two days and left before them all the time so that they can pick at the grains and learn how to eat. They will do a great deal of picking at first but swallow very little. As soon as they have learned how to eat, the grains are scattered on the sand for a day to teach them to scratch, and a light litter of cut alfalfa hay or clover is then put in. From the time the litter is put in, the chicks should be made to scratch for all their grain. Plenty of exercise keeps the system toned up and is the best preventive for the many ills to which little chicks are subject. Later on cut straw can be used instead of the cut clover or alfalfa, but for the first couple of weeks the latter is best as the chicks will eat the finer parts and it will do them good. Pieces of straw would cause inflammation of the crop if eaten at this tender time of the chick's life.

Beginning with the sixth day a dry mash should be fed in the morning at 10 o'clock. This is composed of the following parts by weight:

2 parts bran,
2 parts shorts,
1 part cornmeal or barley meal,
2 parts meat scrap,
1 part powdered bone,
¼ part chick charcoal.

For the next two weeks the litter should be kept very deep and the grain mixture scattered in it early in the morning and about 2 o'clock in the afternoon, with a one-hour feeding of dry mash at 10 o'clock in the morning. As the chicks develop, the dry mash should be gradually left before them for longer intervals until by the time they are from 12 to 14 weeks old they have access to the mash at all times.

The chicks should be gradually changed over from the chick grain to the laying grain-mixture after they are five or six weeks old and big enough to begin to eat somewhat coarser grains.

The steel-cut oats are first slowly eliminated at about five weeks. Just as soon as the chicks can handle larger grains, whole wheat and coarse cracked corn are substituted for the fine cracked corn and wheat. At about ten weeks cracked oats or barley may be added. At five months rolled oats or barley can be given and later whole grains. At six months the pullets should be eating the regular laying grain-mixture. The laying mash may be substituted for the chick mash at four or five months.

Pen-Fattening Broiler Ration.—The regular chick ration should be fed for the first five weeks. The sixth week the dry mash is omitted and a crumbly, moistened mash fed having the following formula:

15 pounds bran,
15 pounds shorts,
15 pounds barley meal or oatmeal,
15 pounds cornmeal,
6 pounds meat scrap,
2 pounds fine charcoal.

The mash is moistened with buttermilk or sour skim milk if possible. If chicks can also be given buttermilk to drink it may be left before them in pans or fountains for about four hours every morning and the meat scrap may then be omitted from the mash.

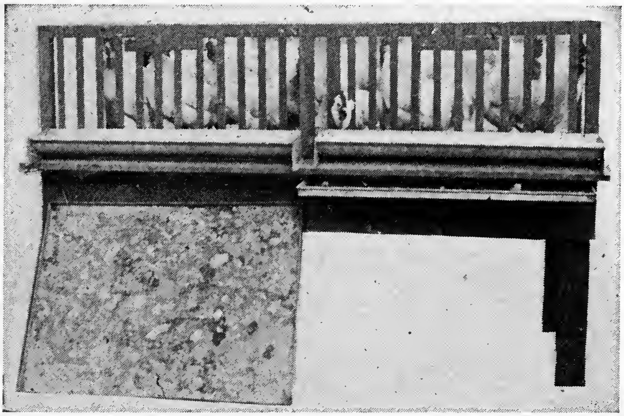


FIG. 105.—Two-compartment fattening crate. Pan to catch droppings pulled out to left. (California Station.)

During the sixth week one feed of this moist mash is given at 11:30 o'clock and the grain mixture fed night and morning in the litter.

The seventh week the moist mash should be fed noon and night, with a feed of scratch grains in the morning; thereafter the moist mash is fed three times a day till the birds are ready for market. Plenty of green and grit are given at all times.

Broilers weighing from one to one and a half pounds should be ready for killing in from nine to twelve weeks when pen-fattened in this way. The above mash should not be fed for more than four or five weeks. Hence, if it is desired to have the birds weigh heavier before marketing, they should be given plenty of exercise and fed on grain and dry mash until it is desired to pen them up to fatten for market.

Crate-Fattening Ration.—Crate-fattening is used where it is desired to produce choice milk-fed fowls that are as tender, juicy and toothsome as possible. Birds under nine weeks of age should be pen-fattened. Fowls three-fourths grown will crate-fatten best (Fig. 105). The following formula is a good example of a suitable crate-fattening ration:

2 pounds barley meal or oatmeal,
1 pound cornmeal,
1 pound shorts,
8 pounds buttermilk.

This ration should be fed two to three times a day, being allowed to sour six to twelve hours before feeding. Charcoal and grit are kept in front of the birds between meals. Birds are fed from ten days to three weeks and starved for twenty-four hours before starting the fattening process.

Crate-fattening should not be carried on longer than from ten to twenty-one days, or the fowls will go off feed and die, since the process is such a forcing one. Large broilers and fryers can be nicely finished off in this way. For roasting carcasses, fowls that are not quite mature make rapid gains when crate-fattened. Cockerels that have matured and become staggy do not make as profitable gains as those that have not yet fully matured. Crate-fattened, milk-fed fowls are always in demand at fancy prices, because the milk ration and close confinement produce such a choice, juicy meat.

Literature on Poultry.—Lewis, "Productive Poultry Husbandry," Phila., 1913; Pearl, Surface and Curtis, "Diseases of Poultry," New York, 1915; Kaup, "Poultry Culture, Sanitation and Hygiene," Phila., 1915; Wortley, "Diseases of Poultry," New York, 1915; "Twenty Lessons in Poultry," Phila., 1916; Woods, "Open Air Poultry Houses," Chicago, 1912; American Poultry Journal Yearbooks 1913, 1914, 1915; Basley "Western Poultry Book," Los Angeles, 1912; Fiske, "Poultry Feeding and Fattening," New York, 1908; Lewis, "Poultry Keeping," Phila., 1915; American Pekin Duck Company, "How We Make Ducks Pay," Boston, 1907.

Experiment Station Circulars and Bulletins.—California c. 99, 142, 145, 150; b. 164; r. 1907, 1908. Colorado, b. 164, 213. Delaware, r. 1901. Indiana, b. 71, 76, 182. Iowa, ext. b. 19, 36, 37. Kansas, b. 164; r. State Bd. of Agr. Sept., 1908, b. 107. Kentucky, b. 197; c. 38. Maine, b. 64, 79, 100, 117, 130, 179, 184. Maryland, b. 157. Massachusetts, b. 106 r. 1897, 1898, 1903, 1905; State Bd. of Agr., b. 1, 1908. Minnesota, b. 119. Mississippi, b. 162. Missouri, c. 76, 79; b. 57. New Jersey, c. 2, 23, 79; b. 57, 265; r. 1905, 1906. New York (Geneva), r. 1888, 1889, 1890, 1892, 1895, 1901, 1908; b. 29, 38, 39, 53, 90, 106, 126, 149, 171, 222, 259, 271. New York

(Cornell), b. 25, 249, 282. North Carolina, b. 211. North Dakota, r. 1897. Ohio, b. 201, 262, 298. Oregon College, b. 108, 157, Extension Series VII. Pennsylvania Dept. of Agr., b. 143. Rhode Island, b. 156; r. 1902; b. 126. Wisconsin, b. 261; c. 56. West Virginia, b. 60, 83, 88, 102, 145. U. S. Farmers' U. C. 22, 84, 97, 222, 244, 259, 412. U. S. Bur. Animal Industry b. 56, 140; r. 1898. Ontario Agr. College, b. 163.

QUESTIONS

1. Describe the digestive system of the fowl.
2. What are the chief functions of protein in the fowl?
3. What are the uses of the carbohydrates and the fat?
4. What special uses has the ash in feeds for poultry?
5. Discuss the advantages of crude fiber for poultry.
6. Define a poultry ration.
7. What are the needs and benefits of a variety?
8. Discuss the advantages of suitability of the feed to the flock.
9. Discuss the question of how much to feed.
10. Enumerate the advantages of the dry-mash.
11. What animal feeds are available for poultry feeding in your section? Which are cheapest?
12. What green feeds are used by poultry keepers in your section in the winter? In summer?
13. Give the composition of a good dry mash for use of laying hens in your section.
14. Outline a good plan for feeding chicks.
15. Describe hen-fattening, and give rations.
16. Give the details of a good plan for crate-fattening.

APPENDIX

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent**

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Digestible Protein	Digestible Carbohydrates and fat
A. ROUGHAGE:								
Green Feeds:								
Alfalfa	71.8	4.8	1.0	7.4	12.3	2.7	3.6	13.0
Alsike clover	74.8	3.9	.9	7.4	11.0	2.0	2.6	12.5
Barley fodder	79.0	2.7	.6	7.9	8.0	.6	1.9	11.1
Bermuda grass	71.7	2.2	.9	5.9	17.2	2.1	1.3	14.3
Burr clover	73.8	5.5	2.0	5.9	10.5	2.3	3.6	13.5
Canada field pea	84.7	2.8	.5	4.4	6.3	1.3	1.8	7.6
Common millet	80.0	1.5	.3	6.5	10.5	1.0	.8	11.5
Cow pea	85.0	2.8	.4	3.5	6.3	2.0	2.1	7.7
Crimson clover	80.9	3.1	.7	5.2	8.4	1.7	2.4	10.2
Horse bean	84.2	2.8	.4	4.9	6.5	1.2	2.3	7.8
Hungarian grass	71.1	3.1	.7	9.2	14.2	1.7	2.0	16.8
Indian corn fodder	79.3	1.8	.5	5.0	12.2	1.2	1.0	12.8
Italian rye grass [1]	73.2	3.1	1.3	6.8	13.3	2.5	1.5	14.2
Japanese millet	75.0	2.1	.5	7.8	13.1	1.5	1.1	14.3
Johnson grass	75.0	1.2	.3	8.9	13.2	1.4	.6	14.2
Kafir corn	76.1	3.2	.8	6.2	12.0	1.7	1.07	13.5
Kentucky blue grass	65.1	4.1	1.3	9.1	17.6	2.8	2.8	21.5
Mammoth red clover	80.0	3.0	.4	5.8	8.9	1.9	2.0	9.6
Meadow fescue, in bloom	69.9	2.4	.8	10.8	14.3	1.8	1.6	19.7
Oat fodder	62.2	3.4	1.4	11.2	19.3	2.5	2.5	20.5
Oats and vetch	80.0	3.0	.5	6.3	8.4	1.8	2.3	10.5
Orchard grass, in bloom	73.0	2.6	.9	8.2	13.2	2.0	1.2	14.5
Pasture grass	80.0	3.5	.8	4.0	9.7	2.0	2.5	11.2
Peas and oats	79.7	2.4	.6	6.1	9.6	1.6	1.8	11.1
Red clover	70.8	4.4	1.1	8.1	13.5	2.1	2.9	16.5
Red top, in bloom	65.3	2.8	.9	11.0	17.7	2.3	1.9	22.4
Rye fodder	76.6	2.6	.6	11.6	6.8	1.8	2.1	15.0
Serradella	79.5	2.7	.7	5.4	8.6	3.2	2.1	9.8
Sorghum fodder	79.4	1.3	.5	6.1	11.6	1.1	.6	13.1
Soybean	75.1	4.0	1.0	6.7	10.6	2.6	3.1	12.1
Sweet clover	80.0	3.8	.6	6.3	7.4	1.9	2.5	9.3

* Compiled from different sources, especially Henry's Feeds and Feeding, Massachusetts Station Report for 1912, and from original data. Figures for Digestible Carbohydrates and Fat, calculated by the author.

[1] Coming into bloom.

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent*—Continued

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Digestible Protein	Digestible Carbohydrates and fat
A. ROUGHAGE—Con.								
Green Feeds—Con.								
Timothy, different stages	61.6	3.1	1.2	11.8	20.2	2.1	1.5	21.3
Velvet bean	82.2	3.5	.7	5.1	6.6	1.9	2.7	9.3
Vetch, spring	85.0	2.7	.4	4.5	6.1	1.4	1.9	7.1
Vetch, winter, or sand	85.3	3.6	.4	4.0	4.6	2.1	2.8	7.1
Wheat and vetch	80.0	3.4	.5	6.4	8.1	1.6	2.6	11.0
Wheat fodder	77.3	2.4	.7	5.9	11.9	1.8	1.7	12.9
Hay from Grasses:								
Barley hay	15.0	8.8	2.4	24.7	44.9	4.2	5.7	45.9
Bermuda grass	7.1	10.7	2.9	25.0	51.0	3.5	6.4	48.5
Cornstalks (stover)	40.5	3.8	1.1	19.7	31.5	3.4	1.4	32.8
Fodder corn, field-cured	42.4	4.5	1.6	14.3	34.7	2.7	2.5	37.3
Foxtail	12.0	7.5	1.8	33.5	39.8	5.4	4.3	43.4
Hungarian grass	7.7	7.5	2.1	27.7	49.0	6.0	5.0	49.4
Italian rye grass	8.5	7.5	1.7	30.5	45.0	6.9	4.5	45.4
Johnson grass	10.2	7.2	2.1	28.5	45.9	6.1	2.9	47.4
Kafir forage	52.1	2.5	1.8	21.0	20.1	2.4	1.1	24.8
Kentucky blue grass	21.2	7.8	3.9	23.0	37.8	6.3	4.4	41.3
Marsh grass	10.4	5.5	2.4	30.0	44.1	7.7	3.1	41.7
Meadow fescue	20.0	7.0	2.7	25.9	38.4	6.8	4.2	40.3
Milo forage	40.9	2.9	2.3	19.1	31.8	2.9	1.2	30.3
Mixed grasses	15.3	7.4	2.5	27.2	42.1	5.5	4.2	44.9
Native hay	6.6	8.5	3.8	29.9	44.6	6.6	4.8	53.8
Oat hay	14.0	8.9	2.8	27.4	41.2	5.7	4.7	40.5
Orchard grass	9.9	8.1	2.6	32.4	41.0	6.0	4.9	45.6
Prairie hay	6.5	8.0	2.06	30.5	44.7	7.7	4.0	43.9
Red top	8.9	7.9	1.9	28.6	47.5	5.2	4.8	49.1
Rowen (mixed)	16.6	11.6	3.1	22.5	39.4	6.8	8.0	45.4
Smooth brome grass	14.3	9.7	2.2	22.8	41.6	9.4	6.6	47.9
Sudan grass	26.3	5.1	2.1	20.6	40.6	5.3	1.9	41.4
Sweet sorghum forage	41.7	3.2	2.9	17.0	32 2	3 0	1.3	29.6
Teosinte	18.9	7.6	2.6	24.9	36 0	9 9	4.2	46.6
Timothy	13.2	5.9	2.5	29.0	45.0	4 4	2.8	45.3

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent*—Continued

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Digestible	
							Protein	Carbohydrates and fat
A. ROUGHAGE—Con.								
Hay from Legumes:								
Alfalfa	17.1	14.0	1.9	25.0	34.7	7.3	10.4	38.2
Alsike clover	9.7	12.8	2.9	25.6	40.7	8.3	8.4	42.2
Cowpea	10.5	14.2	2.6	21.2	42.6	8.9	9.2	42.2
Crimson clover	9.6	15.2	2.8	27.2	36.6	8.6	10.5	37.6
Florida beggar weed	9.2	11.8	2.9	29.3	42.1	4.7	6.8	46.4
Japan clover	11.0	13.8	3.7	24.0	39.0	8.5	9.1	40.9
Mammoth red clover	21.2	10.7	3.9	24.5	33.6	6.1	6.2	39.4
Oat and pea	10.0	10.3	2.6	28.3	41.2	7.1	7.6	43.9
Peanut vines	7.6	10.7	4.6	23.6	42.7	10.8	6.7	49.0
Red clover	15.3	12.3	3.3	24.8	38.1	6.2	7.1	41.9
Soybean	11.8	14.9	4.3	24.2	37.8	7.0	10.6	43.6
Sweet clover	9.2	18.0	3.2	28.0	41.8	9.9	11.9	37.8
Velvet bean	10.0	14.0	1.8	37.7	30.6	5.9	9.6	55.7
Winter vetch	11.3	17.0	2.3	25.4	36.1	7.9	11.9	44.3
Straw, Chaff, etc.								
Barley straw	14.2	3.5	1.5	36.0	39.0	5.7	.9	41.5
Buckwheat	9.9	5.2	1.3	43.0	35.1	5.5	1.2	38.5
Flax shives	10.0	5.1	3.1	42.7	35.2	3.9	1.2	36.7
Horse bean	9.2	8.8	1.4	37.6	34.3	8.7	4.3	41.3
Lima bean	10.0	10.7	1.9	21.1	46.7	9.6	5.4	41.5
Millet	15.0	4.1	1.8	34.2	39.7	5.2	.9	35.9
Oat chaff	14.3	4.0	1.5	34.0	36.2	10.0	1.5	34.6
Oat straw	9.2	4.0	2.3	37.0	42.4	5.1	1.3	41.3
Rice straw	7.5	3.9	1.4	33.5	39.2	14.5	.9	38.5
Rye straw	7.1	3.0	1.2	38.9	46.6	3.2	.7	40.5
Soybean	10.1	4.6	1.7	40.4	37.4	5.8	2.3	42.4
Wheat chaff	14.3	4.5	1.4	36.0	34.6	9.2	1.2	26.8
Wheat straw	9.6	3.4	1.3	38.1	43.4	4.2	.8	36.1
Roots, Tubers, etc.								
Cabbage	90.0	2.6	.2	.9	5.5	.8	2.3	6.1
Carrot	88.6	1.1	.4	1.3	7.6	1.0	.8	8.4
Cassava	66.0	1.1	.2	1.8	30.2	.7	.8	29.4
Chufa	79.5	.7	6.6	2.2	10.5	.4	.6	21.7
Jerusalem artichoke	79.5	2.6	.2	.8	15.9	1.0	1.3	15.2

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent*—Continued

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Digestible Protein	Digestible Carbohydrates and fat
A. ROUGHAGE—Con.								
Roots, Tubers, etc.—								
Con. Kale	88.7	2.4	.5	1.5	5.0	1.9	1.9	5.4
Kohlrabi	88.5	1.3	.2	1.2	8.1	.7	.9	8.1
Mangel	90.9	1.4	.2	.9	5.5	1.1	1.0	6.0
Parsnip	88.3	1.6	.2	1.0	10.2	.7	1.1	10.6
Pie melon	94.5	.8	.2	1.2	2.9	.4	.7	3.8
Potato	79.1	2.1	.1	.4	17.4	.9	1.1	15.9
Pumpkin	90.9	1.3	.4	1.7	5.2	.5	1.0	6.3
Rape	85.7	2.2	.5	2.1	7.0	2.5	2.0	8.7
Rutabaga	88.6	1.2	.2	1.3	7.5	1.2	1.0	8.6
Sugar beet	86.5	1.8	.1	.9	9.8	.9	1.3	10.0
Sweet potato	68.3	1.9	.7	1.1	26.8	1.1	.8	23.6
Turnip	90.1	1.3	.2	1.2	6.3	.9	.9	6.6
Miscellaneous Coarse Feeds:								
Acorns	55.3	2.5	1.9	4.4	34.8	1.0	2.1	38.2
Apples	80.8	.7	.4	1.2	16.6	.4	.8	17.0
Apple pomace	83.0	1.0	.9	2.9	11.6	.6	.5[1]	10.7
Brush feed	5.0	5.4	2.4	46.6	37.9	2.7	3.0	28.9
Cane cacti	78.5	1.4	.6	3.6	12.3	3.6	.9	12.0
Icelandic moss	64.4	1.0	.9	15.1	18.0	.6	.5[1]	21.5
Oak leaves	4.9	9.5	4.5	25.8	45.1	9.7	3.2	38.2
Prickly pear	84.2	.7	.3	2.4	9.0	3.1	.4	6.7
Salt bush	75.8	3.5	.5	3.9	10.5	5.8	2.2	9.2
Sugar beet leaves	88.0	2.6	.4	2.2	4.4	2.4	1.9	5.5
Silage:								
Alfalfa	74.4	4.8	1.1	3.8	8.9	5.1	2.3	12.8
Apple pomace	85.0	1.2	1.1	3.3	8.8	.6	.7	10.7
Barley	74.0	2.6	1.2	9.0	10.7	2.5	1.8	14.7
Barnyard millet and soybean	79.0	2.8	1.0	7.2	7.2	2.8	1.6	10.8
Corn and soybeans	76.0	2.5	.8	7.2	11.1	2.4	1.6	14.8
Corn cannery refuse	83.8	1.4	1.1	5.2	7.9	.6	.8	10.4
Corn stover	73.7	2.2	.9	6.5	15.1	1.6	1.1	16.5
Cowpea	79.3	2.7	1.5	6.0	7.6	2.9	1.5	10.6
Canada field pea	50.1	5.9	1.6	13.0	26.0	3.5	3.4	27.8
Durra	79.7	1.2	.7	7.0	9.5	1.8	.3	10.8

[1] Assumed.

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent*—Continued

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Digestible	
							Protein	Carbohydrates and fat
A. ROUGHAGE—Con.								
Silage—Con.								
Indian corn	73.6	2.7	.9	7.8	12.9	2.1	1.4	15.8
Kafir corn	67.2	2.1	1.4	11.2	15.2	2.9	.6	16.7
Millet	74.0	1.7	.8	7.5	13.6	2.4	.2	14.5
Milo maize	74.6	2.2	.7	7.9	12.7	1.8	.6	12.9
Oats	72.0	2.2	1.2	9.4	13.1	2.1	1.5	16.8
Orchard grass	77.0	1.9	1.4	9.1	8.6	2.0	1.1	12.9
Pea cannery refuse	76.8	2.8	1.3	6.5	11.3	1.3	2.1	14.9
Red clover	72.0	4.2	1.2	8.4	11.6	2.6	2.0	15.7
Rye	80.8	2.4	.3	5.8	9.2	1.6	.7	9.5
Sorghum	76.1	.8	.3	6.4	15.3	1.1	.6	15.4
Soybean	74.2	4.1	2.2	9.7	7.0	2.8	2.7	11.7
Sugar beet leaves and tops	76.0	2.0	1.0	3.0	14.3	3.7	1.3	9.1
Sugar beet pulp	90.0	1.5	.4	3.1	4.7	.3	1.1	5.2
Wet brewers' grains	70.3	6.3	2.1	4.5	15.6	1.2	4.6	15.6
B. CONCENTRATES:								
Grains and Seeds:								
Barley	10.8	12.0	1.8	4.2	68.7	2.5	9.4	75.9
Broom corn	12.8	9.9	3.2	7.0	64.3	2.8	4.6	45.6
Buckwheat	13.4	10.8	2.4	11.7	59.7	2.0	8.1	53.2
Canada field pea	15.0	23.7	.8	7.9	50.2	2.4	19.7	50.2
Corn-and-cob meal	15.1	8.5	3.5	6.6	64.8	1.5	4.4	66.5
Corn meal	15.0	9.2	3.8	1.9	68.7	1.4	6.7	72.2
Cotton seed	9.9	19.4	19.5	22.6	23.9	4.7	12.5	68.9
Cowpea	14.6	20.5	1.5	3.9	56.3	3.2	16.8	57.4
Egyptian corn	12.6	10.0	3.9	1.9	69.7	1.9	4.6	45.8
Emmer	8.0	11.5	2.2	11.1	62.9	3.9	10.0	60.2
Flaxseed	9.2	22.6	33.7	7.1	23.2	4.3	20.6	82.4
Grain screenings (wheat)	11.6	12.5	3.0	4.9	65.1	2.9	9.6	52.5
Horse bean	11.3	26.6	1.0	7.2	50.1	3.8	23.1	51.6
Indian corn, dent	10.6	10.3	5.0	2.2	70.4	1.5	7.8	76.5
Indian corn, flint	11.3	10.5	5.0	1.7	70.1	1.4	8.0	75.9
Indian corn, sweet	8.8	11.6	8.1	2.8	66.8	1.9	8.8	79.5
Kafir corn	9.9	11.2	3.1	2.7	71.5	1.6	5.2	47.5
Millet	12.1	10.9	3.5	8.1	62.6	2.8	7.1	54.1
Milo maize	9.0	10.7	2.8	3.0	72.2	2.3	4.9	47.7
Oats	10.4	11.4	4.8	10.8	59.4	3.2	10.7	62.3

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent*—Continued

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen-free extract	Ash	Digestible	
							Protein	Carbohydrates and fat
B. CONCENTRATES—Con.								
Grains and Seeds—Con.								
Rice, hulled	12.4	7.4	.4	.2	79.2	.4	6.4	80.1
Rice, paddy	9.6	7.6	1.9	9.3	66.7	4.9	4.7	68.4
Rye	8.7	11.3	1.9	1.5	74.5	2.1	9.5	72.1
Sorghum	12.8	9.1	3.6	2.6	69.8	2.1	4.5	67.4
Soybean	11.7	33.5	17.2	4.5	28.3	4.8	29.1	56.2
Wheat, all analyses	10.5	11.9	2.1	1.8	71.9	1.8	8.8	70.9
Wheat, spring	10.4	12.5	2.2	1.8	71.2	1.9	9.3	69.8
Wheat, winter	10.5	11.8	2.1	1.8	72.0	1.8	8.7	70.4
Factory By-products:								
Barley feed	8.9	13.8	3.9	9.1	59.9	4.4	11.5	66.8
Beet molasses	20.8	9.1	...	...	59.5	10.6	4.7	54.1
Beet pulp, dried	8.4	8.1	.7	17.5	60.8	4.5	4.1	64.9
Beet pulp, wet	89.8	.9	...	2.4	6.3	.6	.5	7.7
Brewers' grains, dried	8.7	25.0	6.7	13.6	42.3	3.7	20.0	45.7
Brewers' grains, wet	75.7	5.4	1.6	3.8	12.5	1.0	4.9	11.4
Buckwheat bran	8.2	12.6	3.5	32.9	37.9	4.9	5.9	38.5
Buckwheat feed	11.6	18.3	4.9	19.2	42.1	3.9	15.6	48.1
Buckwheat hulls	13.2	4.6	1.1	43.5	35.3	2.2	1.2	29.7
Buckwheat middlings	12.8	26.7	6.8	4.4	44.3	5.0	22.7	51.2
Cane molasses	25.9	2.7	...	...	65.1	6.3	1.4	59.2
Coconut meal	14.1	19.5	10.4	9.5	42.1	4.4	16.4	64.2
Cold-pressed cotton-seed cake	7.6	24.2	9.7	21.1	32.5	4.9	17.9	47.6
Corn bran	9.4	11.2	6.2	11.9	60.1	1.2	6.0	63.4
Corn cobs	10.7	2.4	.5	30.1	54.9	1.4	.5	44.8
Cotton-seed hulls	11.3	4.2	2.2	45.3	34.1	2.7	.4	34.8
Cotton-seed meal	7.0	45.3	10.2	6.3	24.6	6.6	37.6	43.0
Dried distillers' grains	7.6	31.2	12.2	11.6	35.4	2.0	22.8	65.8
Germ oil meal	8.6	21.7	11.2	3.8	47.3	2.4	15.8	63.1
Gluten feed	9.2	25.0	3.5	6.8	53.5	2.0	21.3	59.3
Gluten meal	9.5	33.8	6.6	2.0	46.6	1.5	29.7	56.2
Hominy meal	9.6	10.5	8.0	4.9	64.3	2.7	6.8	77.2
Linseed meal, new-process	9.0	37.5	2.9	8.9	36.4	5.5	31.5	41.1
Linseed meal, old-process	9.8	33.9	7.8	7.3	35.9	5.5	30.2	47.5
Malt sprouts	9.5	26.3	1.6	11.6	44.9	6.1	20.3	49.2

TABLE I.—*Average Composition and Digestibility of American Feeding Stuffs, in Per Cent*—Continued

Feeding stuffs	Moisture	Protein	Fat	Fiber	Nitrogen free extract	Ash	Digestible	
							Protein	Carbohydrates and fat
B. CONCENTRATES—Con.								
Factory By-products—Con.								
Molasses beet pulp	7.0	9.6	.5	16.1	61.3	5.5	6.1	68.7
Oat dust	6.5	13.5	4.8	18.2	50.2	6.9	5.1	38.0
Oat feed	7.0	8.0	2.9	21.5	55.3	5.3	5.2	36.0
Oat shorts	8.8	16.2	6.9	7.1	56.5	4.5	13.1	72.3
Peanut meal	10.7	47.6	8.0	5.1	23.7	4.9	42.9	38.3
Red-dog flour	9.9	18.4	4.0	3.0	63.5	2.6	16.2	64.7
Rice bran	9.7	11.9	10.1	12.0	46.6	9.7	7.6	55.2
Rice hulls	8.8	3.2	1.0	36.2	35.2	15.6	.3	20.1
Rice meal	10.2	12.0	13.1	5.4	51.2	8.1	7.4	75.1
Rice polish	10.8	11.9	7.2	3.3	62.3	4.8	7.9	70.5
Rye bran	11.6	14.6	2.8	3.5	63.9	3.4	11.2	52.9
Rye feed	12.4	15.7	3.1	4.1	61.5	3.2	12.6	62.9
Rye middlings	11.8	14.3	2.9	2.4	66.9	1.7	11.0	58.8
Soybean meal	12.6	41.4	7.2	5.3	28.2	5.3	36.0	34.3
Wheat bran	11.9	15.4	4.0	9.0	53.9	5.8	11.9	47.6
Wheat middlings, flour	10.0	19.2	4.8	3.2	59.6	3.2	16.9	62.8
Wheat middlings, standard (shorts)	11.2	16.9	5.1	6.2	56.2	4.4	13.0	55.8
Animal Feeds:								
Bone meal (raw)	8.0	23.9	.3	...	3.4	64.4	19.1[1]	...
Buttermilk	90.4	4.0	.5	...	4.4	.7	3.8	5.5
Cows' milk, colostrum	74.6	17.6	3.6	...	2.7	1.6	16.7	10.8
Cows' milk, normal	87.3	3.4	3.7	...	4.9	.7	3.2	13.2
Dried blood	8.5	84.4	2.5	...	...	4.7	60.8	5.6
Fish meal	10.8	48.4	11.6	...	...	29.2	45.0	25.7
Meat meal	10.7	71.2	13.7	...	.3	4.1	66.2	30.2
Skim milk	90.5	3.5	.2	...	4.9	.9	3.3	5.4
Tankage	7.0	53.9	11.8	5.8	5.6	15.9	50.1	26.1
Whey	93.4	.9	.3	...	4.8	.6	.8	5.5

[1] Assumed.

TABLE II.—*Ready Reference Tables of Composition of Feeds.*

(Hills.)

The following tables save calculations of percentages; since the weights and contents are given in pounds, it is only necessary to find the kind and desired amount of a certain feed, and the tables give the exact feed contents in pounds; *e.g.*, 15 pounds of green fodder corn contain 3.1 pounds of dry matter, 0.17 pound of digestible protein, and 1.9 pounds digestible carbohydrates and fat.

Pounds of feed	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat
Green fodders	Pasture grass 1 : 4.8			Timothy grass 1 : 14.3			Ky. blue grass, 1 : 9.2		
2½	0.5	0.06	0.3	1.0	0.04	0.5	0.9	0.05	0.5
5	1.0	0.12	0.6	1.9	0.08	1.1	1.8	0.10	0.9
10	2.0	0.23	1.1	3.8	0.15	2.1	3.5	0.20	1.8
15	3.0	0.35	1.7	5.8	0.23	3.2	5.2	0.30	2.7
20	4.0	0.46	2.2	7.7	0.30	4.3	7.0	0.40	3.7
25	5.0	0.58	2.8	9.6	0.38	5.4	8.7	0.50	4.7
30	6.0	0.69	3.3	11.5	0.45	6.4	10.5	0.60	5.5
35	7.0	0.81	3.9	13.4	0.53	7.5	12.2	0.70	6.4
40	8.0	0.92	4.4	15.4	0.60	8.6	14.0	0.80	7.3
	Green fodder corn, 1 : 11.7			Green oat fodder, 1 : 8.7			Green rye fodder, 1 : 7.2		
2½	0.5	0.03	0.3	0.9	0.06	0.5	0.6	0.05	0.4
5	1.0	0.06	0.6	1.9	0.12	1.0	1.2	0.11	0.7
10	2.1	0.11	1.3	3.8	0.24	2.1	2.3	0.21	1.5
15	3.1	0.17	1.9	5.7	0.36	3.1	3.5	0.32	2.3
20	4.1	0.22	2.6	7.6	0.48	4.2	4.7	0.42	3.0
25	5.2	0.28	3.2	9.5	0.60	5.2	5.9	0.52	3.8
30	6.2	0.33	3.9	11.3	0.72	6.2	7.0	0.63	4.5
35	7.2	0.39	4.5	13.2	0.84	7.3	8.2	0.74	5.3
40	8.3	0.44	5.2	15.1	0.96	8.3	9.4	0.84	6.0
	Oats and peas, 1 : 4.2			Green alfalfa, 1 : 3.6			Red clover (green), 1 : 5.7		
2½	0.5	0.07	0.3	0.7	0.09	0.3	0.7	0.07	0.4
5	1.1	0.14	0.5	1.4	0.18	0.7	1.5	0.15	0.8
10	2.1	0.27	1.1	2.8	0.36	1.3	2.9	0.29	1.6
15	3.2	0.41	1.7	4.2	0.54	2.0	4.4	0.44	2.5
20	4.3	0.54	2.3	5.6	0.72	2.6	5.9	0.58	3.3
25	5.3	0.68	2.9	7.1	0.90	3.3	7.3	0.73	4.1
30	6.4	0.81	3.4	8.5	1.08	3.9	8.8	0.87	4.9
35	7.5	0.95	4.0	9.9	1.26	4.6	10.2	1.02	5.7
40	8.5	1.08	4.6	11.3	1.44	5.2	11.7	1.16	6.6

Composition of Feeds—Continued

Pounds of feed	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrate and fat	Total dry matter	Protein	Carbohydrates and fat
Green fodders	Corn silage, 1 : 11.9			Corn stover silage, 1 : 15.0			Clover silage, 1 : 4.7		
2½	0.7	0.03	0.4	0.7	0.03	0.4	0.7	0.07	0.3
5	1.3	0.06	0.8	1.3	0.06	0.8	1.4	0.14	0.6
10	2.6	0.14	1.6	2.6	0.11	1.7	2.8	0.27	1.3
15	4.0	0.20	2.3	3.9	0.17	2.5	4.2	0.41	1.9
20	5.3	0.26	3.1	5.3	0.22	3.3	5.6	0.54	2.6
25	6.6	0.33	3.9	6.6	0.28	4.1	7.0	0.68	3.2
30	7.9	0.39	4.7	7.9	0.33	5.0	8.4	0.81	3.9
35	9.2	0.46	5.5	9.2	0.39	5.8	9.8	0.95	4.5
40	10.6	0.52	6.2	10.5	0.44	6.6	11.2	1.08	5.1
Roots	Potatoes, 1 : 17.3			Sugar beets, 1 : 6.8			Carrots, 1 : 9.6		
2½	0.5	0.02	0.4	0.3	0.04	0.3	0.3	0.03	0.2
5	1.1	0.05	0.8	0.7	0.08	0.5	0.5	0.05	0.5
10	2.1	0.09	1.6	1.4	0.16	1.1	1.1	0.10	1.0
15	3.2	0.14	2.3	2.0	0.24	1.7	1.6	0.15	1.4
20	4.2	0.18	3.1	2.7	0.32	2.2	2.3	0.20	1.9
25	5.3	0.23	3.9	3.4	0.40	2.7	2.9	0.25	2.4
30	6.3	0.27	4.7	4.1	0.48	3.3	3.4	0.30	2.9
35	7.4	0.32	5.4	4.7	0.56	3.8	4.0	0.35	3.4
40	8.4	0.36	6.2	5.4	0.64	4.4	4.6	0.40	3.8
	Mangels, 1 : 4.9			Rutabagas, 1 : 8.6			Turnips, 1 : 7.7		
2½	0.2	0.03	0.1	0.3	0.03	0.2	0.2	0.03	0.2
5	0.4	0.06	0.3	0.5	0.05	0.4	0.5	0.05	0.4
10	0.9	0.11	0.5	1.1	0.10	0.9	1.0	0.10	0.8
15	1.4	0.17	0.8	1.6	0.15	1.3	1.4	0.15	1.2
20	1.8	0.22	1.1	2.3	0.20	1.7	1.9	0.20	1.5
25	2.3	0.28	1.4	2.9	0.25	2.2	2.4	0.25	1.9
30	2.7	0.33	1.6	3.4	0.30	2.6	2.9	0.30	2.3
35	3.2	0.39	1.9	4.0	0.35	3.0	3.3	0.35	2.7
40	3.6	0.44	2.2	4.6	0.40	3.4	3.8	0.40	3.1
Milk	Skim milk, 1 : 2.0			Buttermilk, 1 : 1.7			Whey, 1 : 8.7		
2½	0.2	0.07	0.1	0.2	0.10	0.2	0.2	0.02	0.1
5	0.5	0.15	0.3	0.5	0.19	0.3	0.3	0.03	0.3
10	0.9	0.29	0.6	1.0	0.38	0.6	0.6	0.06	0.5
15	1.4	0.44	0.9	1.5	0.57	1.0	0.9	0.09	0.8
20	1.9	0.58	1.2	2.0	0.76	1.3	1.2	0.12	1.0
25	2.4	0.73	1.6	2.5	0.95	1.6	1.5	0.15	1.3
30	2.8	0.87	1.8	3.0	1.14	1.9	1.9	0.18	1.6
35	3.2	1.02	2.1	3.5	1.33	2.2	2.2	0.21	1.8
40	3.7	1.16	2.4	4.0	1.52	2.6	2.5	0.24	2.1

Composition of Feeds—Continued

Pounds of feed	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat
Hays	Mixed hay, 1 : 10.0			Timothy hay, 1 : 16.5			Ky. blue grass hay, 1 : 10.6		
2½	2.1	0.11	1.1	2.2	0.07	1.2	1.9	0.09	1.0
5	4.2	0.22	2.2	4.3	0.14	2.3	3.7	0.19	2.0
7½	6.4	0.33	3.3	6.5	0.21	3.5	5.6	0.28	3.0
10	8.5	0.44	4.4	8.7	0.28	4.6	7.4	0.37	3.9
12½	10.6	0.55	5.5	10.9	0.35	5.8	9.2	0.46	4.9
15	12.7	0.66	6.6	13.0	0.42	6.9	11.1	0.56	5.9
17½	14.8	0.77	7.7	15.2	0.49	8.1	13.0	0.65	6.9
20	16.9	0.88	8.8	17.4	0.56	9.2	14.8	0.74	7.9
25	21.2	1.10	11.0	21.7	0.70	11.6	18.5	0.93	9.9
	Oat hay, 1 : 9.9			Oat and pea hay, 1 : 4.1			Hungarian, 1 : 10.0		
2½	2.3	0.10	1.0	2.2	0.28	1.2	2.1	0.12	1.2
5	4.6	0.21	2.0	4.4	0.56	2.3	4.2	0.25	2.4
7½	6.8	0.31	3.0	6.6	0.84	3.5	6.3	0.37	3.6
10	9.1	0.41	4.0	8.9	1.12	4.6	8.4	0.49	4.9
12½	11.4	0.51	5.1	11.1	1.40	5.8	10.4	0.62	6.2
15	13.7	0.62	6.1	13.3	1.68	6.9	12.5	0.74	7.4
17½	16.0	0.72	7.1	15.5	1.96	8.1	14.6	0.86	8.6
20	18.2	0.82	8.1	17.7	2.24	9.2	16.7	0.98	9.8
25	2.28	1.03	10.2	22.1	2.80	11.6	20.9	1.23	12.3
	Red clover hay, 1 : 5.9			Alfalfa hay, 1 : 3.7			Oat straw, 1 : 38.3		
2½	2.1	0.18	1.0	2.1	0.26	1.0	2.3	0.03	1.2
5	4.2	0.36	2.1	4.1	0.52	1.9	4.6	0.06	2.3
7½	6.4	0.53	3.2	6.2	0.78	2.9	6.8	0.09	3.5
10	8.5	0.71	4.2	8.3	1.04	3.8	9.1	0.12	4.6
12½	10.6	0.89	5.2	10.4	1.30	4.8	11.4	0.15	5.8
15	12.7	1.07	6.3	12.4	1.56	5.7	13.9	0.18	6.9
17½	14.8	1.24	7.3	14.5	1.82	6.7	16.0	0.21	8.1
20	16.9	1.42	8.3	16.6	2.08	7.6	18.2	0.24	9.2
25	21.2	1.78	10.5	20.7	2.60	9.6	22.7	0.30	11.5
Dry fodders	Corn fodder, 1 : 14.3			Corn stover, 1 : 23.6			Wheat straw, 1 : 93.0		
2½	1.4	0.06	0.9	1.5	0.04	0.8	2.3	0.01	0.9
5	2.9	0.13	1.8	3.0	0.07	1.7	4.5	0.02	1.9
7½	4.3	0.19	2.7	4.5	0.11	2.5	6.8	0.03	2.8
10	5.8	0.25	3.6	6.0	0.14	3.3	9.0	0.04	3.7
12½	7.2	0.32	4.5	7.5	0.18	4.1	11.3	0.05	4.6
15	8.7	0.38	5.4	9.0	0.21	5.0	13.5	0.06	5.6
17½	10.1	0.44	6.2	10.5	0.25	5.8	15.8	0.07	6.5
20	11.6	0.50	7.1	12.0	0.28	6.6	18.1	0.08	7.4
25	14.5	0.63	8.9	15.0	0.35	8.3	22.6	0.10	9.3

Composition of Feeds—Continued

Pounds of feed	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat
Grains	Corn meal, 1 : 9.9			Corn and cob meal, 1 : 13.9			Oats, 1 : 6.2		
¼	0.2	0.02	0.2	0.2	0.01	0.2	0.2	0.02	0.1
½	0.4	0.04	0.4	0.4	0.02	0.3	0.4	0.05	0.3
1	0.9	0.08	0.8	0.9	0.05	0.7	0.9	0.09	0.6
2	1.8	0.16	1.5	1.7	0.10	1.3	1.8	0.18	1.1
3	2.7	0.23	2.3	2.6	0.14	2.0	2.7	0.28	1.7
4	3.6	0.31	3.1	3.4	0.19	2.7	3.6	0.37	2.3
5	4.5	0.39	3.8	4.3	0.24	3.4	4.5	0.46	2.8
7½	6.7	0.59	5.7	6.4	0.36	5.1	6.7	0.69	4.3
10	8.9	0.78	7.7	8.5	0.48	6.7	8.9	0.92	5.7
	Barley, 1 : 8.0			Barley screenings, 1 : 7.7			Wheat bran, 1 : 3.8		
¼	0.2	0.02	0.2	0.2	0.02	0.2	0.2	0.03	0.1
½	0.4	0.04	0.3	0.4	0.04	0.3	0.4	0.06	0.2
1	0.9	0.09	0.7	0.9	0.09	0.7	0.9	0.12	0.5
2	1.8	0.17	1.4	1.8	0.17	1.3	1.8	0.24	1.0
3	2.7	0.26	2.1	2.6	0.26	2.0	2.6	0.36	1.4
4	3.6	0.35	2.8	3.5	0.34	2.7	3.5	0.48	1.8
5	4.5	0.44	3.5	4.4	0.43	3.3	4.4	0.60	2.3
7½	6.7	0.65	5.2	6.6	0.65	5.0	6.6	0.90	3.4
10	8.9	0.87	6.9	8.8	0.86	6.6	8.8	1.20	4.6
By-products	Wheat middlings, 1 : 4.6			Wheat screenings, 1 : 5.2			Red-dog flour, 1 : 3.3		
¼	0.2	0.03	0.1	0.2	0.02	0.1	0.2	0.04	0.1
½	0.4	0.06	0.3	0.4	0.05	0.2	0.5	0.09	0.3
1	0.9	0.13	0.6	0.9	0.10	0.5	0.9	0.18	0.6
2	1.8	0.25	1.2	1.8	0.20	1.0	1.8	0.36	1.2
3	2.6	0.38	1.7	2.7	0.29	1.5	2.7	0.53	1.7
4	3.5	0.50	2.3	3.5	0.39	2.0	3.6	0.71	2.3
5	4.4	0.63	2.9	4.4	0.49	2.5	4.6	0.89	2.9
7½	6.6	0.94	4.4	6.6	0.74	3.8	6.8	1.34	4.4
10	8.8	1.25	5.8	8.8	0.98	5.1	9.1	1.78	5.8
	Rye, 1 : 7.8			Rye bran, 1 : 5.1			Cotton-seed meal, 1 : 1.0		
¼	0.2	0.02	0.2	0.2	0.03	0.2	0.2	0.10	0.1
½	0.4	0.04	0.3	0.4	0.06	0.3	0.5	0.20	0.2
1	0.9	0.09	0.7	0.9	0.12	0.6	0.9	0.40	0.4
2	1.8	0.18	1.4	1.8	0.25	1.3	1.8	0.80	0.8
3	2.7	0.27	2.1	2.7	0.37	1.9	2.8	1.20	1.2
4	3.5	0.36	2.8	3.5	0.49	2.5	3.7	1.60	1.6
5	4.4	0.46	3.5	4.4	0.62	3.1	4.6	2.00	2.0
7½	6.6	0.67	5.2	6.6	0.92	4.7	6.9	3.00	3.0
10	8.8	0.89	6.9	8.8	1.23	6.3	9.2	4.00	4.0

Composition of Feeds—Continued

Pounds of feed.	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat	Total dry matter	Protein	Carbohydrates and fat
By-products	Cotton-seed hulls			Linseed meal, o.-p., 1 : 1.5			Linseed meal, n.-p., 1 : 1.3		
¼	0.2	....	0.1	0.2	0.08	0.1	0.2	0.08	0.1
½	0.4	....	0.2	0.5	0.15	0.2	0.4	0.16	0.2
1	0.9	....	0.4	0.9	0.31	0.5	0.9	0.32	0.4
2	1.8	....	0.7	1.8	0.62	1.0	1.8	0.65	0.8
3	2.7	....	1.1	2.7	0.92	1.4	2.7	0.97	1.3
4	3.6	....	1.5	3.6	1.23	1.8	3.6	1.30	1.7
5	4.5	....	1.8	4.9	1.54	2.3	4.5	1.62	2.1
7½	6.7	....	2.7	6.8	2.31	3.4	6.7	2.43	3.2
10	8.9	....	3.7	9.0	3.08	4.6	8.9	3.24	4.2
	Flaxseed meal, 1 : 1.4			Gluten meal (Chicago), 1 : 1.5			Gluten meal, cream, 1 : 1.7		
¼	0.2	0.08	0.1	0.2	0.08	0.1	0.2	0.07	0.1
½	0.4	0.16	0.2	0.4	0.16	0.2	0.4	0.15	0.2
1	0.9	0.32	0.4	0.9	0.32	0.5	0.9	0.30	0.5
2	1.8	0.64	0.9	1.8	0.64	0.9	1.8	0.59	1.0
3	2.7	0.96	1.3	2.6	0.96	1.4	2.7	0.89	1.5
4	3.6	1.28	1.7	3.5	1.28	1.9	3.6	1.19	2.1
5	4.5	1.60	2.2	4.4	1.60	2.3	4.5	1.49	2.6
7½	6.7	2.40	3.3	6.6	2.40	3.5	6.7	2.23	3.9
10	8.9	3.21	4.3	8.8	3.21	4.7	9.0	2.97	5.1
	Gluten feed, Buffalo, 1 : 2.4			Hominy chop, 1 : 9.2			Dried brewers' grains, 1 : 3.0		
¼	0.2	0.06	0.1	0.2	0.02	0.2	0.2	0.04	0.1
½	0.4	0.12	0.3	0.5	0.04	0.4	0.5	0.08	0.3
1	0.9	0.23	0.6	0.9	0.09	0.8	0.9	0.16	0.5
2	1.8	0.47	1.1	1.8	0.17	1.6	1.8	0.31	0.9
3	2.7	0.70	1.7	2.8	0.26	2.4	2.8	0.47	1.4
4	3.6	0.93	2.3	3.7	0.35	3.2	3.7	0.63	1.9
5	4.5	1.17	2.8	4.6	0.44	4.0	4.6	0.79	2.4
7½	6.8	1.75	4.3	6.9	0.65	6.0	6.9	1.18	3.5
10	9.0	2.33	5.7	9.2	0.87	8.0	9.2	1.57	4.7
	Atlas gluten meal, 1 : 2.6			Malt sprouts, 1 : 2.2			Pea meal, 1 : 3.2		
¼	0.2	0.06	0.2	0.2	0.05	0.1	0.2	0.04	0.1
½	0.5	0.12	0.3	0.4	0.09	0.2	0.4	0.08	0.3
1	0.9	0.25	0.6	0.9	0.19	0.4	0.9	0.17	0.5
2	1.8	0.49	1.3	1.8	0.37	0.8	1.8	0.33	1.1
3	2.8	0.74	1.9	2.7	0.56	1.2	2.7	0.50	1.6
4	3.7	0.98	2.6	3.6	0.74	1.6	3.6	0.67	2.1
5	4.6	1.23	3.2	4.5	0.93	2.0	4.5	0.84	2.7
7½	6.9	1.85	4.9	6.7	1.40	3.0	6.7	1.26	4.0
10	9.2	2.46	6.5	9.0	1.86	4.0	9.0	1.68	5.3

Table III.—*Dry Matter, Digestible Protein, and Energy Values in Common Feeding Stuffs, per 100 Pounds.*

(Armsby.)

Feeding stuff	Total dry matter, pounds	Digestible true protein, pounds	Energy value, therms
Green fodder and silage:			
Alfalfa	28.2	2.50	12.45
Clover, crimson	19.1	2.19	11.30
Clover, red	29.2	2.21	16.17
Corn fodder, green	20.7	.41	12.44
Corn silage	25.6	1.21	16.56
Hungarian grass	28.9	1.33	14.76
Rape	14.3	2.16	11.43
Rye	23.4	1.44	11.63
Timothy	38.4	1.04	19.08
Hay and dry coarse fodders:			
Alfalfa hay	91.6	6.93	34.41
Clover hay, red	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	40.76
Hungarian hay	92.3	3.00	44.03
Oat hay	84.0	2.59	26.97
Soybean hay	88.7	7.68	38.65
Timothy hay	86.8	2.05	33.56
Straws:			
Oat straw	90.8	1.09	21.21
Rye straw	92.9	.63	20.87
Wheat straw	90.4	.37	16.56
Roots and tubers:			
Carrots	11.4	.37	7.82
Mangels	9.1	.14	4.62
Potatoes	21.1	.45	18.05
Rutabagas	11.4	.38	8.00
Turnips	9.4	.22	5.74
Grains:			
Barley	89.1	8.37	80.75
Corn	89.1	6.79	88.84
Corn-and-cob meal	84.9	4.53	72.05
Oats	89.0	8.36	66.27
Pea meal	89.5	16.77	71.75
Rye	88.4	8.12	81.72
Wheat	89.5	8.90	82.63
By-products:			
Brewers' grains, dried	92.0	19.04	60.01
Brewers' grains, wet	24.3	3.81	14.82
Buckwheat middlings	88.2	22.34	75 92
Cotton-seed meal	91.8	35.15	84.20
Distillers' grains, dried			
Principally corn	93.0	21.93	79.23
Principally rye	93.2	10.38	60.93
Gluten feed, dry	91.9	19.95	79.32
Gluten meal, Buffalo	91.8	21.56	88.80
Gluten meal, Chicago	90.5	33.09	78.49
Linseed meal, old-process	90.8	27.54	78.92
Linseed meal, new-process	90.1	29.26	74.67
Malt sprouts	89.8	12.36	46.33
Rye bran	88.2	11.35	56.65
Sugar-beet pulp, fresh	10.1	.63	7.77
Sugar-beet pulp, dried	93.6	6.80	60.10
Wheat bran	88.1	10.21	48.23
Wheat middlings, flour	84.0	12.79	77.65

TABLE IV.—*The Feed-unit System*

AMOUNTS OF DIFFERENT FEEDS REQUIRED TO EQUAL ONE FEED UNIT

Feeding stuff	Feed required to equal 1 unit	
	Average, pounds	Range, pounds
Concentrates:		
Corn, wheat, rye, barley, hominy feed, dried brewers' grains, wheat middlings, oat shorts, peas, Unicorn Dairy Ration, molasses beet pulp, coconut meal . . .	1.0	
Cotton-seed meal, dried blood	0.8	
Linseed meal, Ajax Flakes (dried distillers' grains), gluten feed, soybeans.	0.9	
Wheat bran, oats, dried beet pulp, barley feed, malt sprouts, International Sugar feed, Badger Dairy feed, Schumacher stock feed, molasses grains.	1.1	
Alfalfa meal, Victor feed, June pasture, alfalfa molasses feeds.	1.2	1.5
Hay and Straw:		
Alfalfa hay, clover hay.	2.0	1.5– 3.0
Mixed hay, oat hay, oat and pea hay, barley and pea hay, red-top hay	2.5	2.0– 3.0
Timothy hay, prairie hay, sorghum hay. . .	3.0	2.5– 4.0
Corn stover, stalks or fodder, marsh hay, cut straw.	4.0	3.5– 6.0
Soiling Crops, Silage and Other Succulent Feeds:		
Green alfalfa.	7.0	6.0– 8.0
Green corn, sorghum, clover, peas and oats, cannery refuse.	8.0	7.0–10.0
Alfalfa silage.	5.0	
Corn silage, pea-vine silage.	6.0	5.0– 7.0
Wet brewers' grains.	4.0	
Potatoes, skim milk, buttermilk.	6.0	
Sugar beets.	7.0	
Carrots.	8.0	
Rutabagas.	9.0	8.0–10.0
Field beets, green rape.	10.0	
Sugar beet leaves and tops, whey.	12.0	
Turnips, mangels, pumpkins, fresh beet pulp	12.5	10.0–15.0

The value of pasture is generally placed at 8 to 12 units per day, on the average, varying with kind and condition.

Table V.—*Manurial Value of Feeding Stuffs and Farm Products*

(U. S. Department of Agriculture)

Material	Water, per cent	Ash, per cent	Nitrogen, per cent	Phosphoric acid, per cent	Potash, per cent
Green Fodders:					
Alfalfa (lucern)	75.3	2.25	.72	.13	.56
Alsike clover	81.8	1.47	.44	.11	.20
Corn silage	78.0	.....	.28	.11	.37
Cowpea	78.8	1.47	.27	.10	.31
Green fodder corn	78.6	4.84	.41	.15	.33
Oat fodder	83.4	1.31	.49	.13	.38
Pasture grass	63.1	3.27	.91	.23	.75
Prickly comfrey	84.4	2.45	.42	.11	.75
Red clover	80.0	.....	.53	.13	.46
Rye fodder	62.1	.....	.33	.15	.73
Scarlet clover	82.5	.....	.43	.13	.49
Soybean	73.2	.....	.29	.15	.53
Sorghum fodder	82.2	.....	.23	.09	.23
Timothy grass	66.9	2.15	.48	.26	.76
White clover	81.0	.....	.50	.20	.24
Hay and Dry Coarse Fodders:					
Alfalfa	6.55	7.07	2.19	.51	1.68
Alsike clover	9.94	11.11	2.34	.67	2.23
Barley chaff	13.08	.....	1.01	.27	.99
Barley straw	11.44	5.30	1.31	.30	2.09
Buckwheat hulls	11.90	.....	.49	.07	.52
Common millet	9.75	.....	1.28	.49	1.69
Corn stover (without ears)	9.12	3.74	1.04	.29	1.40
Fodder corn (with ears)	7.85	4.91	1.76	.54	.89
Hay of mixed grasses	11.99	6.34	1.41	.27	1.55
Hungarian grass	7.69	6.18	1.20	.35	1.30
Mammoth red clover	11.41	8.72	2.23	.55	1.22
Oat straw	9.09	4.76	.62	.20	1.24
Red clover	11.33	6.93	2.07	.38	2.20
Red-top	7.71	4.59	1.15	.36	1.02
Rye straw	7.61	3.25	.46	.28	.79
Scarlet clover	18.30	7.70	2.05	.40	1.31
Timothy	7.52	4.93	1.26	.53	.90
Wheat chaff	8.05	7.18	.79	.70	.42
Wheat straw	12.56	3.81	.59	.12	.51
White clover	.....	.....	2.75	.52	1.81
Roots, Bulbs, Tubers, etc.:					
Carrots	89.79	1.22	.15	.09	.51
Mangels	87.29	1.22	.19	.09	.38
Potatoes	79.24	.89	.32	.12	.46
Red beets	87.73	1.13	.24	.09	.44
Rutabagas	89.13	1.06	.19	.12	.49
Sugar beets	86.95	1.04	.22	.10	.48
Sweet potatoes	71.26	1.00	.24	.08	.37
Turnips	89.49	1.01	.18	.10	.39
Yellow fodder beets	90.60	.95	.19	.09	.46

TABLE V.—*Manurial Value of Feeding Stuffs and Farm Products*—Continued.

Material	Water, per cent	Ash, per cent	Nitrogen, per cent	Phosphoric acid, per cent	Potash, per cent
Grains and Other Seeds:					
Barley	14.30	2.48	1.51	.79	.48
Buckwheat	14.10	.....	1.44	.44	.21
Corn	10.88	1.53	1.82	.70	.40
Japanese millet	13.68	.....	1.73	.69	.38
Millet, common	12.68	.....	2.04	.85	.36
Oats	18.17	2.98	2.06	.82	.62
Rice	12.60	.82	1.08	.18	.09
Rye	14.90	.....	1.76	.82	.54
Soybeans	18.33	4.99	5.30	1.87	1.99
Sorghum seed	14.00	.....	1.48	.81	.42
Wheat, spring	14.35	1.57	2.36	.70	.39
Wheat, winter	14.75	.....	2.36	.89	.61
Other Concentrated Feeds:					
Apple pomace	80.50	.27	.23	.02	.13
Apples, fruit	85.30	.39	.13	.01	.19
Brewers' grains, dry	9.14	3.92	3.62	1.03	.09
Brewers' grains, wet	75.01	.....	.89	.31	.05
Buckwheat middlings	12.00	4.80	4.53	2.34	1.18
Corn-and-cob meal	8.96	.....	1.41	.57	.47
Corn cobs	12.09	.82	.50	.06	.60
Corn meal	12.95	1.41	1.58	.63	.40
Cotton-seed hulls	10.17	2.40	.69	.25	1.02
Cotton-seed meal	7.81	6.95	6.79	2.88	.87
Gluten meal	8.59	.73	5.03	.33	.05
Ground barley	13.43	2.06	1.55	.66	.34
Ground oats	11.17	3.37	1.86	.77	.59
Hominy feed	8.93	2.21	1.63	.98	.49
Linseed meal (new-process)	7.77	5.37	5.78	1.83	1.39
Linseed meal (old-process)	8.88	6.08	5.43	1.66	1.37
Malt sprouts	18.38	12.48	3.55	1.43	1.63
Pea meal	8.85	2.68	3.08	.82	.99
Rice bran	10.20	12.94	.71	.29	.24
Rice polish	10.30	9.00	1.97	2.67	.71
Rye bran	12.50	4.60	2.32	2.28	1.40
Rye middlings	12.54	3.52	1.84	1.26	.81
Starch feed (glucose refuse)	8.10	.....	2.62	.29	.15
Wheat bran	11.74	6.25	2.67	2.89	1.61
Wheat flour	9.83	1.22	2.21	.57	.54
Wheat middlings	9.18	2.30	2.63	.95	.63
Dairy Products, etc.:					
Butter	79.10	.15	.12	.04	.04
Buttermilk	90.50	.70	.48	.17	.16
Cheese	33.25	2.10	3.93	.60	.12
Cream	74.05	.50	.40	.15	.13
Skim milk	90.25	.80	.56	.20	.19
Whey	92.97	.60	.15	.14	.18
Whole milk	87.00	.75	.53	.19	.18
Animals:					
Live cattle	50.2	4.40	2.48	1.76	.16
Sheep	44.8	2.90	1.95	1.13	.14
Swine	42.0	1.80	1.76	.73	.10

Table VI.—*Average Weights of Concentrated Feeding Stuffs*

Feeding stuff	One quart weighs, pounds	One pound measures, quarts
Alfalfa meal	.6	1.7
Barley meal	1.1	.9
Barley, whole	1.5	.7
Beet pulp, dried	.6	1.8
Brewers' grains, dried	.6	1.7
Buckwheat bran	.6	1.7
Buckwheat middlings	.9	1.1
Coconut meal	1.5	.7
Corn-and-cob meal	1.4	.7
Corn and oat feed	.7	1.4
Corn bran	.5	2.0
Corn meal	1.5	.7
Corn, whole	1.7	.6
Cotton seed	1.0	1.0
Cotton-seed hulls	.3	3.3
Cotton-seed meal	1.5	.7
Distillers' grains, dried	.6	1.7
Germ oil meal	1.4	.7
Gluten feed	1.3	.8
Gluten meal	1.7	.6
Hominy meal	1.1	.9
Kafir meal	1.6	.6
Linseed meal (new-process)	.9	1.1
Linseed meal (old-process)	1.1	.9
Malt sprouts	.6	1.7
Mixed mill feed (bran and middlings)	.6	1.7
Molasses	3.0	.3
Molasses beet pulp	.8	1.3
Oat feed	.8	1.3
Oat middlings	1.5	.7
Oats, whole	1.0	1.0
Rice bran	.8	1.3
Rice polish	1.2	.8
Rye bran	.6	1.7
Rye feed (rye bran and rye middlings)	1.3	.8
Rye meal	1.5	.7
Rye, whole	1.7	.6
Wheat bran	.5	2.0
Wheat feed, mixed	.6	1.7
Wheat, ground	1.7	.6
Wheat middlings (flour)	1.2	.8
Wheat middlings (standard)	.8	1.3
Wheat, whole	1.9	.5
Wheat screenings	1.0	1.0

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