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E. A. TROWBRIDGE, *Director*

The Feeding of Livestock

A. G. HOGAN

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The Feeding of Livestock

A. G. HOGAN

In feeding livestock every producer tries to provide a ration that is both satisfactory and inexpensive. There is no simple rule which will assure success in either attempt. It is possible, however, to apply to the needs of animals the knowledge of feeds now available and so provide the ration that is most suitable, and most economical, under a given set of circumstances.

THE COMPOSITION OF FEEDS

The composition of a ration is of primary importance. All common feeds, grains, hays, and commercial by-products such as bran, shorts, or tankage have been analyzed frequently and average analyses are readily available. The more important of these are given in Table 4 and a few examples are given below in Table 1.

TABLE 1.—SAMPLE ANALYSES

	Water	Protein	Nitrogen-free extract	Fiber	Ash	Fat
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Corn	12.0	9.9	69.7	2.0	1.5	4.9
Alfalfa Hay	8.6	14.9	37.3	28.3	8.6	2.3
Tankage	7.9	60.4	3.7	5.3	15.3	7.4

Many feeds, especially the roughages and protein concentrates, are highly variable in composition. The average analysis is a fairly satisfactory approximation, but it may diverge widely from the analysis of any one individual feed. The analysis of a feed is of no value unless its meaning is clear, so a brief explanation will be given.

Moisture.—All feeds contain some moisture, and the amount depends on the length of time the feed has been stored, and on the amount of moisture in the air. If stored in a dry place for a sufficiently long time most feeds in Missouri contain about 10 per cent of water. New corn usually contains considerably more, which explains why it is worth less than old corn, if the quality in other respects is the same.

Nitrogen-Free Extract.—The term nitrogen-free extract includes a variety of substances, but ordinarily the only important one is starch. Sugars are included also, and though many foods contain small quantities of these compounds, only an exceptional few contain enough to be of any consequence. Tables of analyses show that the vast majority of feeds contain more nitrogen-free extract, or starch, than anything else. The more important grains, such as corn, contain more starch than they do of all other constituents combined. This means that, with a few exceptions, the greater part of all the digestible nutrients consumed is starch. For all practical purposes this starch is the same as the corn starch we buy, and it has the same feeding value.

Crude Fiber.—Crude fiber is the least digestible part of a feed, and it is found in largest proportion in hay and straw. The stems of plants, as a corn stalk, contain the largest percentage of crude fiber, the leaves contain less, and the seeds contain the least. Purified crude fiber has many important commercial uses and it is more easily recognized in those forms. Cotton, linen, hemp, paper, are all modifications of crude fiber. Since it is only partly digestible its chief value in a feed is to supply bulk. Cattle, sheep, and horses, all require a certain amount of bulk in their rations. Most concentrates contain less than 10 per cent of crude fiber and most roughages contain over 20 per cent. Since there is no definite dividing line between them intermediate percentages are often classified according to their source.

Fat.—The fat of feeds is very similar to fats from other sources. The fats of corn, cottonseed, flaxseed, and soybeans, are commercial products, and are liquids at ordinary temperatures. The fat of tankage is not markedly different from lard.

Ash.—The ash of feeds is familiar to all. When wood, corn, hay or any other feed, is burned ash or mineral matter is left. A chemist can analyze this ash and find what it contains. He could then go to a drug store, buy mineral preparations such as table salt, lime phosphate, potassium salt, salts of iodine, and others, put them together, and have about the same mineral mixture as remained after the feed has been burned. These minerals are necessary for an animal. They give hardness and strength to the bones. They are an essential part of the blood, the muscles, and all other organs of the entire body. No animal can live without mineral, and none can be healthy if it doesn't have enough.

Protein.—The constituent that should be most emphasized is protein, because it is the most expensive and most likely to be supplied in insufficient amount. This substance is variable in appearance, is seldom seen in pure form, and is the least familiar of all the nutrients. Egg white and the curd that separates out from sour milk are both chiefly protein and water. The fat-free soft organs of the animal body are also good examples.

These proteins may be quite different in color and in texture, but they have one characteristic in common, they all contain nitrogen. For that reason the proteins are sometimes called the nitrogenous nutrients to distinguish them from the fats and carbohydrates which are called carbonaceous nutrients.

The composition of corn is shown graphically in Fig. 1.

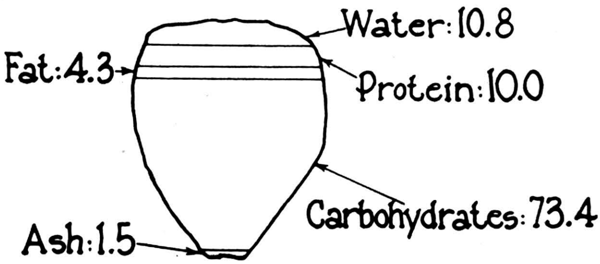

Fig. 1.—Percentage Composition of Corn.

COMPOSITION OF THE ANIMAL BODY

The basis of every organ in the body is protein, or protein and water, for these two are always bound together in a living animal. On the average we find 3 pounds of water to 1 pound of protein. Protein is the chief constituent of dried lean meat, or a clean hide, or of a clean piece of cartilage, or of any of the internal organs. It is the basis of even the bones. If a well cleaned bone is soaked for some days in fairly strong acid, such as vinegar, the minerals will

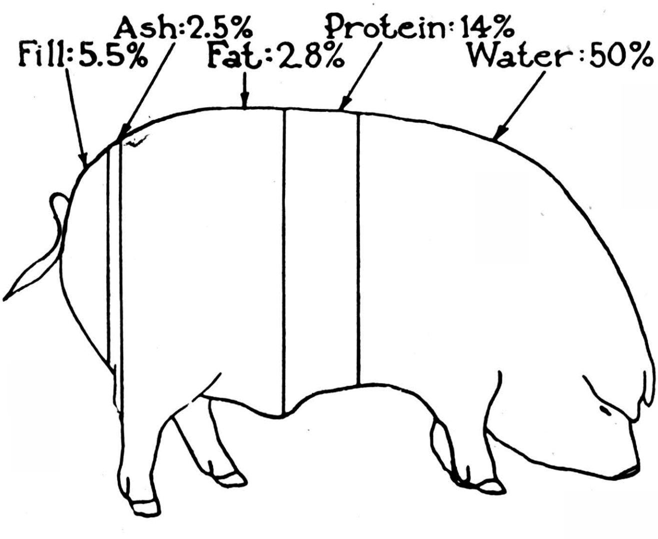

Fig. 2.—Composition of a Barrow.

be dissolved out, leaving a matrix of protein, a tough rubbery material in which the lime phosphate had been imbedded.

Every animal body also contains fat. In the newly born animal, or in one that has been starved, the amount is small. In the excessively fat animal, a fat steer, there may be 40 per cent of fat, and in an over fat hog there may be as much as 50 per cent.

A certain amount of ash is also present in animal tissues. Lean meat contains a little over 1 per cent, a clean bone contains about 25 per cent.

The diagram in Fig. 2 indicates the constituents found in the animal body.

THE FUNCTION OF FEEDS

Maintenance.—An animal differs from an engine in this respect: an engine requires no fuel while at rest, but an animal requires fuel every second of the day, whether it is idle or not. No difference how quietly a horse may be lying in its stall it still requires a certain amount of fuel, and the least amount on which it can exist is called its basal maintenance requirement. An additional amount of fuel is required for the ordinary activity of an animal. Thus an animal requires about 15 per cent more fuel when standing than when lying, and still more for any movement it may make. The total amount of fuel required for an animal that is not used for production of some sort is called its economic maintenance requirement, or simply its maintenance requirement.

In practice the fuel for maintenance is a combination of protein, fat, and nitrogen-free extract, but nitrogen-free extract constitutes by far the greater part because it is the cheapest. Few feeds contain much fat, and the nitrogenous feeds are seldom used for maintenance because of the cost. All animals have a maintenance requirement and this makes up a considerable part, probably one-half, of all the feed they consume. It is seldom, however, that animals are kept on a maintenance ration because usually they are fed at the same time to some productive purpose.

Repair.—In addition to the feed required for fuel, an animal also requires a small amount for repair. The basis of the animal body is protein. As long as the animal is alive this protein is being slowly worn away, and finally the nitrogen of this discarded part is carried away in the excreta. This waste must be repaired, and the only source of repair is the protein of the food. Even for maintenance then, the feed must contain a small amount of protein. Ordinarily this is no problem, for almost any ration will supply all the protein that is required for maintenance. A small amount of minerals is required for maintenance, but this is not a serious problem for only the exceptional ration is deficient in this respect.

Growth.—Since protein is the basis of all parts of the body considerable amounts are necessary during growth. These nitrogenous feeds are the most expensive, so there is a temptation to feed too little. In practice the best amount to feed is governed largely by the market price, and the estimation of this amount is undoubtedly the most important problem in livestock production. A ration that contains a large percentage of protein is described as having a narrow nutritive ratio.

Milk Production.—Since the chief food in the early stages of growth is milk, it may be taken for granted that feeding for milk production requires about the same precautions as feeding for growth. A brood sow must manufacture a large quantity of milk if she is to suckle a large litter successfully, so in the first place she must consume a large quantity of feed. If she does not there will be excessive losses in weight, and the milk flow will fall off too soon. The composition of milk is a good indication of the kind of feed a milking animal should receive. Cow's milk has approximately the following composition:

Water	87.0 per cent
Protein	4.0 per cent
Milk sugar	4.3 per cent
Fat	4.0 per cent
Ash	0.7 per cent

Nearly a third of the dry matter of milk is protein, and all this protein must come from the feed. The ration of a brood sow then must contain a high percentage of protein. Milk also contains a large percentage of calcium and phosphorus so the ration of a milking animal should contain a liberal quantity of these elements. If they are not supplied in the feed they will be abstracted from the bones and in severe cases this results in soreness, stiffness, and in fracture.

Wool Production.—Though a special ration for wool production is seldom employed, the quality of wool is lowered if the animals that produce it are subjected to conditions unfavorable to health and thrift. Sickness of any consequence is usually accompanied by weak spots in the fiber produced at that time. If sheep are underfed wool growth is somewhat reduced. Wool itself is nearly all protein, so a shortage of protein in the ration will slow down the rate of wool production, even though there is no restriction on the amount of feed consumed.

Fattening.—The composition of a ration for fattening alone may be the same as for maintenance, but it must be supplied in larger quantity. Any feed that can be used for animal fuel may also be used for fat production. Body fat, therefore, may be formed from protein, from carbohydrate, or from fat originally present in the feed. Usually carbohydrate is the cheapest source, so except in unusual circumstances rations for fattening contain relatively little protein. Such a ration is described as having a wide nutritive ratio, which means it contains relatively little digestible protein in proportion to the other digestible nutrients.

Evidently the more feed a growing or fattening animal consumes, the more econmical will be its gains. As an illustration it may be assumed that a calf requires 6 pounds of feed daily to maintain it, when making no gain. If the calf receives 3 pounds of additional feed or 9 pounds in all, it gains 1 pound in weight. If it receives 6 pounds of additional feed, or 12 pounds in all, it gains 2 pounds in weight. This means that in both cases every 3 pounds of feed available for gains produced a gain of 1 pound in live weight. On the basis of total feed consumed, however, a gain of one pound in weight required 9 pounds of feed in one case and required only 6 pounds in the other. The calculations are summarized in Table 2.

TABLE 2.—ECONOMY OF GAINS

Feed consumed daily, pounds	6	9	12
Feed used for maintenance, pounds	6	6	6
Feed available for gains, pounds	0	3	6
Increasse in live weight, pounds	0	1	2
Feed consumed per lb. gain, pounds		9	6

For the most economical feeding it is necessary to have animals with a low maintenance requirement. Animals that are wild, or excitable, waste feed by taking unnecessary exercise. It is also necessary to have animals that can consume large quantities of feed. The chief difference between a good feeder and a poor one is in the amount of feed above the maintenance requirement they are able to consume.

Work.—The chief requirement in the ration of a working animal is for fuel, so in many respects the ration for work is identical with that for fattening. A large amount of protein is not required, so the nutritive ratio is usually fairly wide. The ration of a hard working horse should not be too bulky, or he will not have time to consume it and also secure all the rest he needs.

TABLE 3.—USE OF FOOD IN THE BODY

Protein.—Builds and repairs May be transformed into fat White of egg Curd of sour milk Lean meat *Fat.*—May be stored as fat Soybean oil Cottonseed oil Corn oil Lard Butter fat *Carbohydrate.*—May be transformed into fat Starch Sugar	All of these may be used as fuel to produce heat, and to do work
Mineral matter, or ash Lime Magnesium Soda Potash Iron Phosphates Chlorides Sulphates Iodine	Give strength to bone. Aid digestion. Help make up red pigment of blood. Essential for every body process.

THE VALUE OF AN ANALYSIS

The analysis of a feed gives the percentage of water, protein, nitrogen-free extract, fat, crude fiber, and ash. It is possible to make a more complete analysis and find the percentage of lime, phosphorus, iron, iodine, and if necessary of other minerals. These analyses are essential and must be made. There are other important factors, however, concerning which the analyses give no information at all. They give no information concerning palatability, vitamin content, or the presence of injurious substances. A feed may have spoiled before it was cured or dried, and actually be detrimental. The ordinary feed analysis does not determine that fact, however, and makes no attempt to do so.

Occasional complaints are heard that a feed has proven injurious to livestock. Even if a feed is injurious the chance of being able to prove it by analysis is very small. The unfavorable results reported are usually due to sickness, or some unsuspected cause.

ESSENTIALS OF AN ADEQUATE RATION

Protein.—Every ration must contain protein, for all animals must have it, and the only way they can get it is by consuming it in their feed. All feeds contain some protein. Straw contains very little, sometimes only 3 or 4 per cent. Tankage may contain 60 per cent, some of the special meat meals may contain 80 per cent.

In the calculation of balanced rations it is customary to assume that all proteins have the same feeding value, though that is not true. The proteins of milk have an unusually high feeding value, and shotes fed skim milk require less protein than if some other protein supplement is used. The proteins of bones have a low feeding value, so if meat meal contains a high percentage of bone its value as a protein supplement is reduced. Fortunately the deficiencies of one protein may be remedied by mixing it with another, hence a mixture of two proteins often has a higher feeding value than either one alone. It is for this reason chiefly that many feeders like to use a considerable variety in their rations.

Total Digestible Nutrients (Energy):—It is common knowledge that a ration must contain protein, fats and carbohydrates. Each of these has specific functions in maintaining a normal body. There are other functions though that can be exercised by any of the nutrients mentioned, and for these purposes they are, within limits, interchangeable. They can all be used to provide energy for maintenance, for work, or for fattening. A satisfactory ration then supplies the various kinds of nutrients that are required, and it supplies them in the amount that is required.

Minerals.—Animals of all ages and condition require considerable amounts of common salt, but the need is so well known that supplying it has become a universal custom.

During the growing stage minerals are as important as protein, but fortunately they can be provided with much less expense. They are chiefly required for growth of the bone, and an adequate amount must be supplied if the bone is to be sound. A sound bone is the foundation of a sound animal. The kind of minerals in the bone is then an indication as to the kinds that should be fed in largest quantity. An analysis shows that the most important minerals of bone are lime and phosphorus, so these two must be supplied in liberal amount to growing animals. One of the effects of a deficiency of lime is illustrated in Fig. 3. With minor exceptions the mineral requirement by animals in milk production is very similar to the requirement during growth.

So far as is known calcium and phosphorus are the only minerals that require any special consideration in Missouri. The ra-

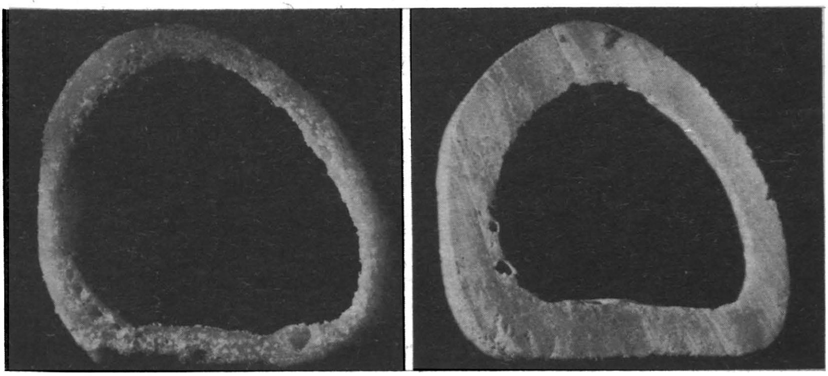

Fig. 3.—The bone on the left was taken from a sow reared on a ration deficient in lime. The wall of the bone is thin, porous, and weak. The bone on the right is from a normal sow.

tions of swine consist chiefly of concentrates, and as a rule this class of feeds is deficient in calcium. Skim milk and tankage are exceptions. The rations of ruminants are more likely to be deficient in phosphorus. Few forages contain large amounts of this element and some do not contain enough. Finely ground limestone is the most economical source of calcium. Steamed bone meal supplies calcium and phosphorus both. Raw rock phosphate is an excellent source of phosphorus, and this material was once used extensively in mineral mixtures. It was discovered later though that rock phosphate contains fluorine, which is a slow poison, and it is no longer regarded favorably as a constituent of feeds. When bone meal is unobtainable defluorinated rock phosphate is recommended as a substitute. Acid phosphate has been used as a source of phosphorus, but it too may contain excessive amounts of fluorine.

Authorities in this field state that a concentration of 0.01 per cent of fluorine in the dry matter consumed approaches the danger level for cattle, sheep, and swine. A concentration of 0.05 per cent may be dangerous for poultry. In order to be safe it was recommended that, on a dry matter basis, the rations of cattle, sheep, and swine should not contain over 0.003 per cent, and the rations of poultry should not contain over 0.015 per cent of fluorine. Defluorinated rock phosphate that contains not over 0.1 per cent of fluorine can be used safely in any reasonable amount. If the animals are to be marketed after a relatively short feeding period it is probably permissible to use treated rock phosphate that contains 1 per cent of fluorine, but this grade should not be supplied to breeding stock. Raw rock prosphate usually contains approximately 3.5 per cent of fluorine, and should not be supplied to livestock at all except for short periods.

It may be well to add that the amounts of phosphorus needed by animals are commonly supplied in most well balanced rations. A ration that contains 0.5 per cent of phosphorus is seldom improved by adding an additional quantity. The requirement for calcium is a little higher, but 0.7 per cent is usually sufficient. Because of the large amount of calcium in the egg shell, the rations of laying hens should contain 2 per cent, or more, of that element. Many poultrymen prefer rations that contain 3 per cent. When mineral supplements are abundant and cheap it may be advisable to feed liberal amounts as a type of insurance. However, when supplies are limited the shortage is aggravated by this practice.

In addition to these minerals which are required in large amounts there are a few which may at times be insufficient, but which are required only in very small quantities. One of these is iodine. Too much is poisonous, and too little is equally disastrous. This element is required for the proper functioning of the thyroid gland, located in the neck. If too little is consumed this gland increases in size, producing a goitre, sometimes referred to as "big neck." Ordinarily Missouri is not supposed to be in the goitre district, and it has never been shown satisfactorily that Missouri livestock need supplements of iodine. It is certain that there can be no great deficiency, but it is possible that in some parts of the State there is a slight deficiency.

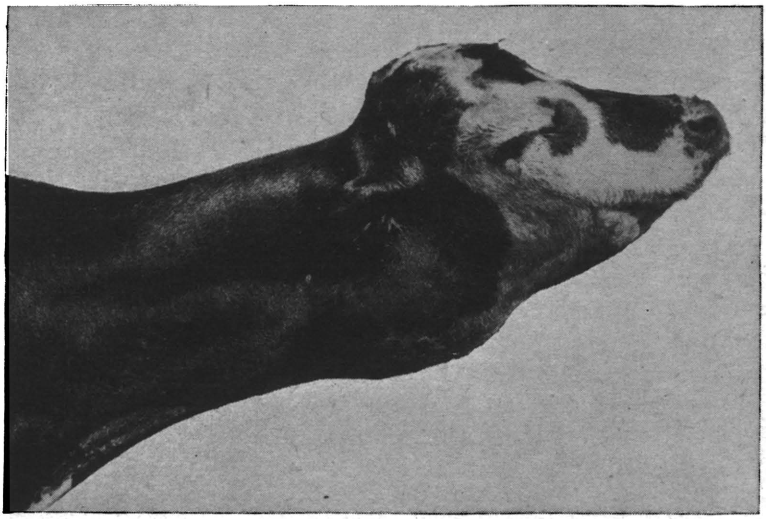

Fig. 4.—Stillborn goitrous calf, one of a pair of twins. Both were affected. (Courtesy of Prof. J. W. Kalkus, Western Washington Experiment Station.)

There are no definite rules as to the amount of iodine to feed, but a large excess should be avoided. It is probable, however, that 15 grains of sodium or potassim iodide per month for every 100 pounds of live weight is sufficient. This may be given in broken doses, or it could be mixed with the feed. A practice that has been used successfully in emergencies is to add 30 grains of sodium iodide to every 100 pounds of feed. Iodized salt is recommended whenever a deficiency of iodine is suspected. A photograph of a goitrous animal is reproduced in Fig. 4.

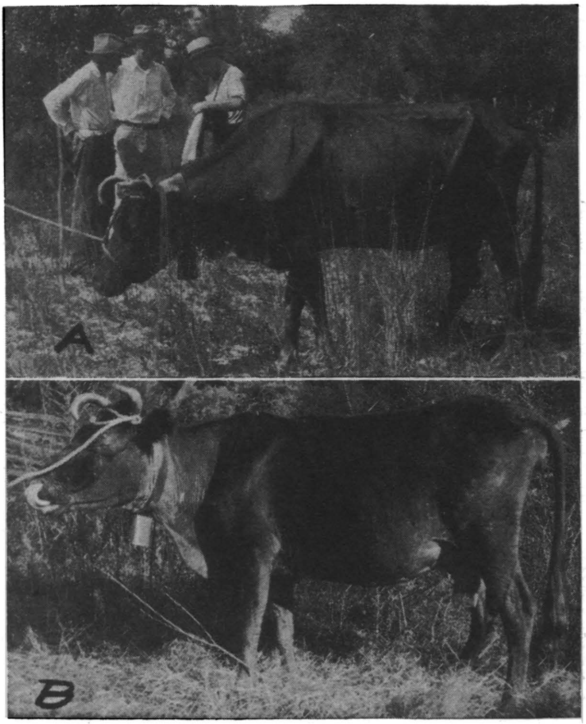

Fig. 5.—A, Anemic cow. Blood contains one-third of normal amount of red pigment. B, Same cow as A, recovered on treatment with iron. (Courtesy of Professors R. B. Becker, W. M. Neal, and A. L. Shealy of the Florida Agricultural Experiment Station.)

Another mineral which is sometimes added to the ration in small amounts is iron, usually in the form of ferrous sulphate, or copperas. There is little reason to believe, however, that this element is likely to be deficient in the Middle West. If pigs are farrowed during bad weather, and kept inside on floors of wood or cement, they frequently become anemic. The blood appears thin and watery, and if the condition is not relieved the pigs become unthrifty in appearance and will finally die. This condition is due to the fact that milk contains practically no iron, and if this element is lacking the red pigment of the blood can not be formed. It has been observed at the Missouri College of Agriculture that if a feed fortified with iron sulphate is kept before the pigs constantly after they are three weeks old, they will consume enough to obtain some iron, and they will recover from the anemia without noticeable injury. This feed should contain one-half pound of iron sulphate for each 100 pounds of feed in order to insure a liberal intake of the mineral. Some investigators recommend that the pigs be dosed with an iron salt, so as to be sure that all get enough. If this is done it is best to begin when they are about a week old. Five grains of iron sulphate, or copperas, per pig each week should be enough.

If pigs have access to the soil of Missouri they will pick up all the iron they require. There are isolated areas in the United States, however, which are deficient in iron, and animals in those regions may develop anemia spontaneously. Such a case is illustrated in Fig. 5.

Isolated instances of deficiencies of copper, cobalt, and manganese have been reported, but apparently these minerals are present in Missouri soils in adequate amount.

It is a common practice to provide a mineral mixture for livestock, swine especially, and several formulae have been recommended. A mixture of two parts of ground limestone and one part of common salt is usually satisfactory. Many feeders prefer a mixture of equal parts of ground limestone, steamed bone meal and common salt, as the phosphorus of the bone meal may provide a wider margin of safety. It is recommended that the minerals be supplied in a self-feeder.

Vitamins.[1]—Originally the evidence that indicated the existence of these substances was only circumstantial. It was shown that life can not be sustained by mixtures of highly purified proteins, fats, carbohydrates, and minerals, and it was concluded that natural foods contain some additional materials which were unknown at the time and which are essential for life. Fourteen vitamins have been definitely discovered, by which we mean they have been prepared and can be examined, in pure form. Each of them is as much a distinct chemical compound as is cane sugar for example.

[1]Mo. Agr. Exp. Sta. Buls. 446 and 453 should be consulted for additional details.

They are present in foods in exceedingly minute amounts, and they are extraordinarily potent. The composition of the first vitamins to be discovered was not worked out for many years, and they were designated at first by letters of the alphabet. It is more customary now to give each vitamin a specific name. Only those vitamins that may be lacking at times, and are therefore of practical importance, will be included in the present discussion.

Vitamin A.—Vitamin A is an animal product, and little or none is present in plants. Commercial vitamin A is all processed

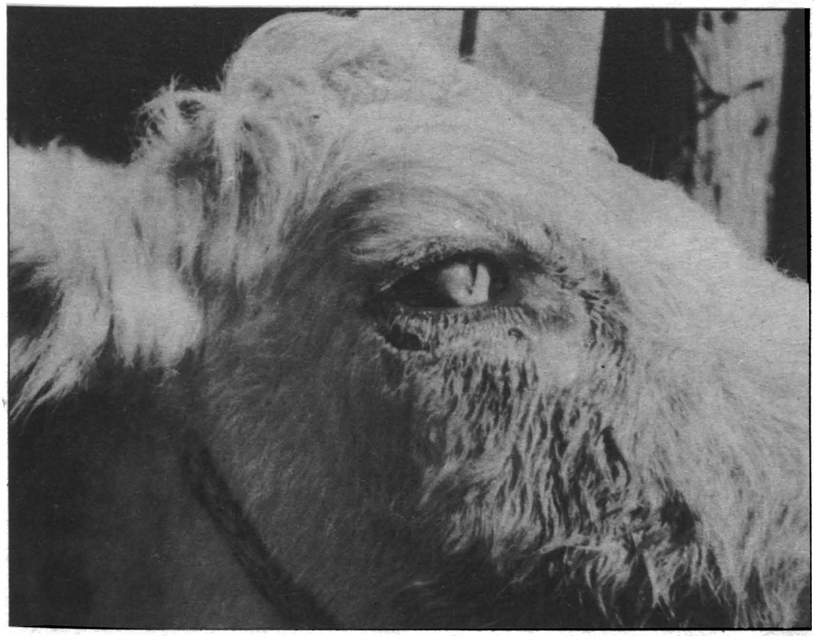

Fig. 6.—This steer developed the inflamed, watery condition of the eyes that is characteristic of a vitamin A deficiency. The animal recovered when alfalfa hay was included in the ration. The photograph was taken on a North Missouri farm.

from certain fish liver oils. Since all animals require vitamin A it is obvious that plants contain one or more provitamins that can be transformed by the animal body into the vitamin. These provitamins are carotene and other carotenoids, all of which are brilliant pigments that vary in color from yellow to red, depending on the physical state and on lighting conditions. For convenience the designation, vitamin A, frequently includes these carotenoids also. Of the concentrates commonly used in livestock feeding, yellow corn is the only one that is a good source of the provitamin.

The best sources for livestock are fresh green forage and the legume hays.

The most characteristic symptom of a deficiency of vitamin A is an eye disease, often called xerophthalmia. The first sign of this is inflammation and sensitivity to light. Later there is a discharge from the eye, the eyelids become swollen, and usually will adhere so the eye can not be opened. In extreme cases the affected animal becomes permanently blind. These, and other symptoms, do not develop unless the supply of vitamin A falls far below the amount necessary to maintain normal health. In practice the mild deficiencies with no specific symptoms probably do more harm than do the severe deficiencies, because they are more common, and since they escape detection they are not corrected. In young animals diarrhoea and slow growth may be due to a lack of vitamin A. In breeding females this deficiency will lower fertility, and result in the birth of young that are weak, or subnormal in vigor. Some of the effects of a deficiency of vitamin A are illustrated in Fig. 6.

Vitamin D.—This is the vitamin that prevents rickets, but it is probably of little practical importance in this state, except in the poultry industry. The symptoms are well known such as softening and bending of the bones, especially in the region of the joints. If the condition persists for any length of time this bending becomes permanent and results in deformities. The vitamin is not present, to any great degree, in any of the naturally occurring feeds, with the possible exception of dried forages that were cured in the sun. This means that under ordinary circumstances our chief defense against rickets is exposure to sunlight. Baby chicks, and poults, are usually hatched during cool weather, before it is warm enough to keep them out in the sun, and they must be supplied with suitable vitamin D preparation. Fish liver oils are the chief commercial sources, but the "D"—activated animal sterols are equally effective. The activated plant sterols are not suitable for poultry. A photograph of a rachitic calf is reproduced in Fig. 7.

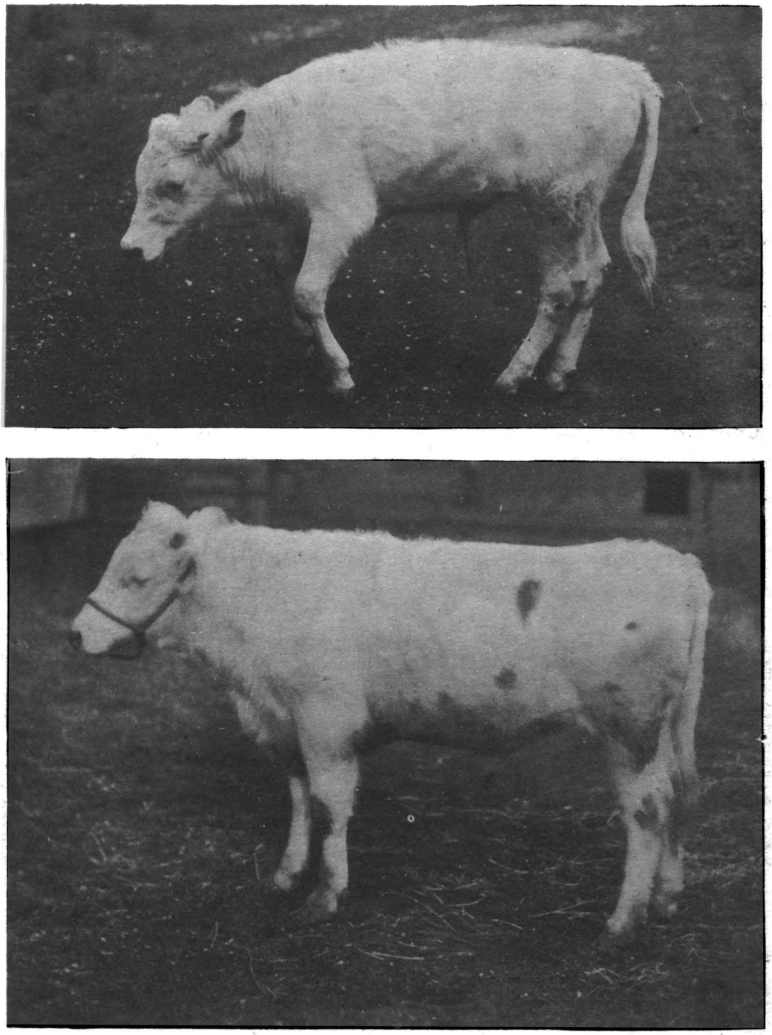

Fig. 7.—Above, a case of rickets under farm conditions. Below, the same calf after treatment with cod-liver oil. (Courtesy of Professors I. W. Rupel, G. Bohstedt, and E. B. Hart, Wisconsin Agricultural Experiment Station.)

Vitamin E.—It was observed 20 years ago that rats of both sexes, on certain diets, become sterile. Later it was shown that the sterility is due to the lack of a certain vitamin, now known as vitamin E. The protective substance came to be commonly known as the anti-sterility vitamin, though as it developed later this term is unfortunate. Vitamin E has other functions than that of preventing sterility. It has been established that poultry require the vitamin, but there is little or no information on the requirement of any other domestic animal for vitamin E. Even if these animals do require the vitamin though it is so widely distributed that a deficiency is very improbable and no special precautions need be taken to provide it.

Riboflavin.—Poultry are probably the only domestic animals likely to receive an insufficient supply of riboflavin. Chickens and turkeys require liberal amounts and many practical rations do not contain enough. It was formerly the custom to rely somewhat on dried skim milk as a source of this vitamin, but there is some doubt now as to whether the supply will be adequate for future needs. Dried whey is an acceptable substitute and some of the by-products in the manufacture of industrial alcohol are recommended for that purpose. The experience of the Missouri Agriculture Experiment Station indicates that the pure vitamin, from commercial sources, can be substituted successfully for the standard riboflavin carriers such as dried skim milk or dried whey.

The effects of supplying the chick with insufficient riboflavin are shown in Fig. 8.

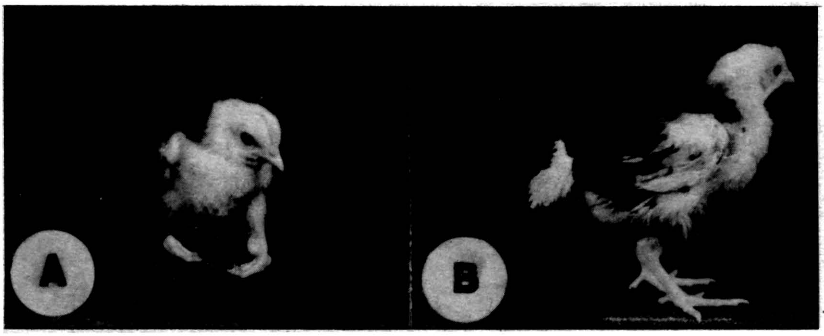

Fig. 8.—This chick was in the condition shown in A when brought to the University from a Missouri farm for diagnosis. It was 16 days old. As shown in B, the chick had recovered four days later after receiving a daily supplement of pure riboflavin. The total amount of supplement was 0.4 milligram, or approximately 1/70,000 ounce. The remainder of the flock recovered quickly after being given skimmilk to drink.

Niacin (Nicotinic Acid).—Cattle and sheep do not require niacin. Nothing is known about the requirement of horses, but it is commonly assumed that they do not require it. Swine do require this vitamin and there are scattered reports on deficiencies observed in the field. Characteristic symptoms are a roughened dirty skin, diarrhoea, loss of appetite, and slow growth. The chick also requires niacin but it is believed practical poultry rations contain an adequate amount. Forages are excellent sources of niacin. Of the cereals, wheat and barley are the best sources. Oats are intermediate and corn is a poor source.

Good feeding practices will supply the vitamins, in adequate amount, that are required by the larger animals. There are times, however, when the feed supply is limited and it is difficult to follow approved practices. The vitamin most likely to be deficient under these circumstances is vitamin A, and this is the only one likely to be deficient in the rations of cattle, sheep, and horses. The rations of swine also may be deficient in this vitamin. There is reason to believe that mild deficiencies of vitamin A, especially in the winter and early spring, are fairly common. Livestock will receive an adequate supply of vitamin A if they are provided with a good quality of winter pasture or legume hay. In addition there is some possibility that swine may receive insufficient riboflavin and nicotinic acid, but according to present knowledge a severe deficiency would not be expected. Poultry then are the only farm animals that regularly require protection from vitamin deficiencies. The prudent feeder will provide vitamins for poultry as carefully as he will provide proteins or minerals. The vitamins most likely to be deficient are vitamins A and D, and riboflavin. Vitamin D must be purchased as a concentrate. The other two can be provided by common feedstuffs if they are selected properly.

Other Vitamins.—In addition to the vitamins just described there are several more, but since their practical importance has not been firmly established they will be merely mentioned.

A list of the vitamins whose existence is undisputed is given below.

Now regarded as of practical importance.—A (carotene may be substituted for vitamin A), D, G or riboflavin.

Not now regarded as of practical importance. B_1 or thiamine, C or ascorbic acid, E, K, Niacin or nicotinic acid, B_6 or pyridoxine, pantothenic acid, choline, biotin, inositol, B_c.

Para-aminobenzoic acid is listed as a vitamin by some, but this classification has not met general approval as yet.

It is reasonably certain that there are still other vitamins which have not been identified, and concerning which we have no specific information. It may be added that the requirement of various animals for vitamin B_c has received very little study, and it is not impossible that future investigations may show that this vitamin is deficient in some rations. However that may be, there is reason to believe that at least one vitamin, whether it is vitamin B_c or one not yet recognized, should be added to the list of those that are of practical importance. For example it has been shown that the concentrates commonly used in swine rations are not adequate for brood sows during gestation and lactation, and there is little doubt that they are deficient in an essential vitamin. The pigs have normal birth weights, and for a day or two seem normal in all respects. They gradually take on an unthrifty appearance, however, usually accompanied by diarrhoea, and become listless and apathetic. Following this death comes swiftly. The pigs become cold, go into a coma, and may die in an hour or two. It often happens that a pig may be fairly normal in the morning and be dead before night. There seems to be no doubt that this condition is due to improper feeding of the sows, to supplying them with rations made up of concentrates such as grain and protein supplements, with little or no forage. The concentrates are poor sources of one or more of the essential vitamins, and high quality forage is a good source. A brood sow should have access to a liberal supply of fresh pasture both before and after farrowing. If a sow is to farrow in the spring every effort should be made to supply winter pasture. If that can not be done high grade legume hay should be provided when pasture is not available. One or one and one-half pounds of hay daily per sow is not too much.

The importance of pasture in livestock production can hardly be overemphasized, as it has numerous advantages. It conserves the fertility of the soil. If the pasture is green and tender it supplies a considerable amount of protein. It is a good source of minerals. The liberal use of pasture of high quality will solve many problems in feeding, and it now seems that it will solve the vitamin problem almost completely. If the pasture is overstocked, and eaten down to the roots, it may not be sufficient insurance of an adequate ration. A good pasture, however, is almost perfect insurance. Good feeding practices, and exposure to sunlight will supply all vitamins that are required by the larger domestic animals.

GUIDES IN FEEDING

It is impossible in a short publication to give complete directions for the feeding of any kind of livestock. There are exceptions to most rules, so if a rule is followed literally under all circumstances it will at some time or other lead to unfortunate results. There is no substitute for experience, but the inexperienced feeder may profit from the experience of others and will find it advantageous at first to follow general rules.

One of the first questions to be answered is how much to feed, but in many respects this is the easiest. The live weight of the animal if followed closely is an almost perfect guide. If weight is being lost, a suitable increase in the ration will prevent it. If too much weight is being taken on a suitable decrease in the ration will hold the weight stationary. If growing animals are gaining too slowly, more feed will increase the rate of gain. The question of how much to feed is bound up, however, with the quality of the ration, especially when large gains are desired. If a ration is deficient in any necessary nutrient, the time will come sooner or later when an animal will refuse to consume a large quantity, no matter how much is offered. If a ration contains too little protein, minerals, or vitamins it is useless to expect that it will be consumed in satisfactory quantity. If then an animal is a conspicuously poor feeder, something is wrong. The animal may be injured, it may have defective teeth, or it may be sick. It may also be that the ration lacks something which it ought to contain. It rarely happens that a sound and healthy animal will refuse to eat a good ration in satisfactory quantity.

There should be a word of caution also in regard to over-feeding. Thus cattle or sheep should be put on full feed slowly. Breeding females should be brought back on full feed slowly after they drop their young.

Attention should also be given to the amount of roughage in the ration. The ration of swine, if rapid gains are expected, should contain very little crude fiber—not over 10 per cent. The amount of crude fiber allowable in the ration of horses, cattle, or sheep depends on the rapidity of gain desired. If they are merely being maintained the ration may be all roughage, and contain from 30 to 35 per cent crude fiber. If maximum gains are desired, crude fiber may be reduced to 10 per cent.

The question that is usually most difficult to answer is how much protein should be fed, and the simplest guide in the feeding of livestock is an estimate of the amount of protein that is needed by various animals at various stages of development. This protein requirement is from many standpoints the most important problem of the feeder, and when it is solved the solution of the others becomes relatively simple.

The protein content of feeds cannot be determined except by analysis, and the protein needs of animals cannot be determined except by actual trial. These determinations have been made and averages of the results have been published. These are reproduced in Tables 4, 5, and 6 of this bulletin.

These averages are not perfect guides, but they are useful, and the best available. Feeders are often reluctant to use as much protein as the standards specify, but it should be remembered that too little protein means slow growth. Larger quantities than are necessary are not likely to be injurious, but except in special cases they make the cost unnecessarily high.

TABLE 4.--AVERAGE PERCENTAGE COMPOSITION OF FEEDING STUFFS[1]

Feeding stuff	Water	Ash	Crude Protein	Carbohydrates Fiber	Carbohydrates N-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Concentrates (Grains and other seeds and their by-products; miscellaneous concentrates)						
Barley, common	9.6	2.9	11.8	5.7	68.0	2.0
Beans, field	11.8	4.3	22.9	3.5	56.1	1.4
Beet pulp, dried	8.0	3.5	9.0	18.8	59.9	0.8
Blood meal, or dried blood	8.8	3.8	82.2	1.3	2.7	1.2
Bone meal, steamed	3.6	81.3	7.1	0.8	3.9	3.3
Brewers' grains, dried	7.2	3.7	25.6	14.8	42.0	6.7
Buttermilk, condensed	70.1	3.7	11.3	--	13.3	1.6
Buttermilk, dried	7.8	10.5	33.8	0.4	41.9	5.6
Coconut oil meal, old process	9.3	6.3	20.8	10.4	45.0	8.2
Corn, dent, Grade No. 2	14.8	1.3	9.4	2.2	68.4	3.9
Corn, dent, soft or immature	30.5	1.1	7.4	1.2	56.0	3.8
Corn and cob meal	11.5	1.4	8.2	8.2	67.4	3.3
Corn bran	9.9	2.3	9.8	9.8	61.8	6.4
Corn germ meal	7.0	3.3	19.8	8.9	53.2	7.8
Corn gluten meal	8.5	1.8	42.9	2.5	42.0	2.3
Cottonseed, whole	7.3	3.5	23.0	16.9	26.3	23.0
Cottonseed meal, 43 o/o protein grade	6.5	5.5	43.2	10.6	27.0	7.2
Cowpeas	11.4	3.5	23.6	4.1	55.9	1.5
Emmer grain (spelt)	8.8	3.7	12.0	9.8	63.8	1.9
Fish meal, 58-63 o/o protein	7.8	19.8	60.2	0.8	3.9	7.5
Hominy feed	9.1	2.7	11.0	4.8	65.5	6.9
Kafir grain	11.4	1.7	11.2	2.3	70.3	3.0
Linseed meal, old process	8.7	5.5	35.2	8.0	36.3	6.3
Meat and bone scraps, 50 o/o protein grade	6.2	27.8	50.8	2.1	2.0	11.1
Milk, cow's	87.2	0.7	3.5	--	4.9	3.7
Molasses, cane	25.9	9.4	2.8	--	61.9	--
Oats	8.9	3.6	12.0	10.6	60.2	4.7
Oat kernels, without hulls	8.3	1.9	16.2	1.9	65.3	6.4
Oat meal (rolled oats)	8.5	2.4	16.3	2.8	64.1	5.9
Peanut-oil-meal	6.6	6.3	42.7	8.9	27.0	8.5
Rice bran	8.9	10.8	12.8	13.0	41.1	13.4
Rice polish	9.5	6.1	12.7	3.0	57.2	11.5
Rye grain	10.0	2.0	12.3	2.3	71.7	1.7
Skimmilk, centrifugal	90.4	0.8	3.7	--	5.0	0.1
Skimmilk, dried	6.2	8.0	34.8	--	50.1	0.9
Soybeans	9.8	5.3	36.9	4.5	26.3	17.2
Soybean oil meal	8.3	5.7	44.3	5.6	30.3	5.7
Sunflower seed	6.6	3.1	15.9	28.1	21.2	25.1
Sunflower seed, without hulls	4.5	3.8	27.7	6.3	16.3	41.4
Tankage, 60 o/o protein grade	7.8	19.2	61.3	1.4	1.5	8.8
Wheat, recent analyses	10.2	2.0	13.1	3.0	70.0	1.7
Wheat bran, all analyses	9.4	6.0	15.8	9.5	54.3	5.0
Wheat standard middlings	10.0	4.2	17.4	6.8	56.1	5.5
Whey, dried	5.0	9.7	12.5	--	72.1	0.7
Yeast, dried	8.0	7.0	45.0	1.0	36.0	3.0

[1]Taken by special permission of the Morrison Publishing Company, Ithaca, New York, from Feeds and Feeding, 20th Edition, F. B. Morrison.

TABLE 4 (Cont.)

Feeding stuff	Water	Ash	Crude Protein	Carbohydrates Fiber	Carbohydrates N-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Dry Roughages						
Alfalfa hay	9.6	8.3	14.7	29.0	36.4	2.0
Alfalfa leaves	11.0	10.2	21.9	14.1	39.8	3.0
Alfalfa meal good	8.1	8.5	15.2	28.4	37.9	1.9
Alfalfa stems	11.4	6.6	10.0	36.6	34.2	1.2
Barley hay	8.1	6.8	7.5	26.6	49.0	2.0
Bluegrass hay, Kentucky,	10.6	6.5	8.2	29.8	42.1	2.8
Clover hay, alsike	11.0	7.9	12.0	27.1	39.8	2.2
Clover hay, red	11.8	6.4	11.8	27.3	40.1	2.6
Clover hay, sweet, first year	6.7	8.7	19.5	21.0	41.2	2.9
Clover hay, sweet, second year	8.0	7.5	14.0	29.8	38.7	2.0
Corn fodder, medium in water	17.5	5.1	6.7	21.7	46.9	2.1
Corn stover, medium in water	19.0	5.5	5.7	27.7	40.9	1.2
Cottonseed hulls	9.4	2.5	3.9	46.6	36.7	0.9
Cowpea hay, all analyses	9.6	11.3	18.6	23.3	34.6	2.6
Kafir fodder, dry	8.9	9.4	8.9	26.8	43.2	2.8
Kafir stover, medium in water	16.3	8.3	5.1	27.4	41.2	1.7
Lespedeza hay, annual	10.9	5.4	12.8	26.2	42.4	2.3
Millet hay, common	10.0	6.6	8.7	25.5	46.4	2.8
Oat hay	12.0	6.9	8.3	28.4	41.7	2.7
Oat hulls	6.5	6.7	3.8	30.6	51.2	1.2
Oat straw	10.4	6.0	4.0	36.1	41.2	2.3
Prairie hay, western	9.6	7.6	5.7	30.3	44.4	2.4
Red top hay, all analyses	9.0	6.9	7.2	29.3	45.3	2.3
Sorghum fodder, sweet, dry	10.8	7.2	6.4	25.8	47.3	2.5
Soybean hay, all analyses	9.2	7.3	14.8	28.4	37.0	3.3
Sudan grass hay, all analyses	10.8	8.0	8.8	27.9	42.9	1.6
Timothy hay, all analyses	11.3	5.0	6.2	30.1	45.0	2.4
Vetch hay, hairy	12.1	8.5	19.4	24.8	32.6	2.6
Wheat straw	9.9	8.2	3.8	35.7	40.9	1.5
Green Roughahes, Roots, Etc.						
Alfalfa, green, all analyses	74.6	2.4	4.6	7.0	10.4	1.0
Bluegrass, Kentucky, all analyses	68.2	2.8	4.2	8.7	14.9	1.2
Bluegrass, Kentucky, before heading	75.2	2.8	5.6	5.3	9.8	1.3
Cabbage, entire	90.6	0.9	2.2	1.0	5.0	0.3
Carrots, roots	88.1	1.2	1.2	1.1	8.2	0.2
Clover, alsike	77.8	2.3	3.8	5.8	9.7	0.6
Clover, red, all analyses	75.0	2.1	4.0	6.8	11.2	0.9
Clover, sweet	78.0	1.8	3.9	6.4	9.2	0.7
Kale	88.2	1.8	2.4	1.6	5.5	0.5
Lespedeza, annual	63.4	3.5	6.7	10.7	14.7	1.0
Mangels, roots	90.6	1.0	1.4	0.8	6.1	0.1
Potatoes, tubers	78.8	1.1	2.2	0.4	17.4	0.1
Pumpkins, field	89.6	0.9	1.7	1.6	5.2	1.0
Rape	83.6	2.2	2.9	2.6	8.1	0.6
Rutabagas, roots	88.9	1.0	1.3	1.4	7.2	0.2
Soybeans, all analyses	75.6	2.3	4.2	6.7	10.1	1.1
Sudan grass, all analyses	74.3	1.8	2.0	8.5	12.8	0.6
Timothy, all analyses	68.7	2.4	3.8	8.6	15.5	1.0
Timothy, before bloom	75.8	1.7	2.5	7.3	12.0	0.7
Turnips	90.5	0.9	1.4	1.1	5.9	0.2
Silages						
Apple pomace	79.1	1.0	1.6	4.4	12.6	1.3
Corn, dent, well-matured	71.7	1.7	2.3	6.9	16.5	0.9
Corn, dent, stover silage (ears removed)	77.4	1.5	1.5	7.7	11.3	0.6

TABLE 5.--AVERAGE PERCENTAGE OF DIGESTIBLE NUTRIENTS IN FEEDING STUFFS[1]

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutri-ents	Nutri-tive ratio
	per cent	per cent	per cent	1:
Concentrates (Grains and other seeds and their by-products; miscellaneous concentrates.)				
Barley, common	90.4	9.3	78.7	7.5
Beans, field	88.2	19.9	75.6	2.8
Beet pulp, dried	92.0	4.8	71.8	14.0
Blood meal, or dried blood	91.2	70.7	75.9	0.7
Bone meal, steamed	96.4	---	---	---
Brewer's grains, dried	92.8	20.7	65.3	2.2
Buttermilk, condensed	29.9	10.7	27.3	1.6
Buttermilk, dried	92.2	32.1	85.5	1.7
Coconut oil meal, old process	90.7	18.7	80.8	3.3
Corn, dent, Grade No. 2	85.2	7.1	80.6	10.3
Corn, dent, soft or immature	69.5	5.6	66.7	10.9
Corn and cob meal	88.5	6.0	75.9	11.2
Corn bran	90.1	5.7	74.4	12.1
Corn germ meal	93.0	14.5	79.5	4.5
Corn gluten meal	91.5	36.5	81.8	1.2
Cottonseed, whole	92.7	17.0	91.0	4.4
Cottonseed meal, 43 o/o protein grade	93.5	35.0	75.5	1.2
Cowpeas	88.6	19.4	76.5	2.9
Emmer grain (spelt)	91.2	9.6	74.7	6.8
Fish meal, 58-63 o/o protein	92.2	48.8	67.7	0.4
Hominy feed	90.9	7.8	85.2	9.9
Kafir grain	88.6	9.1	80.1	7.8
Linseed meal, old process	91.3	30.6	78.2	1.6
Meat and bone scraps, 50 o/o protein grade	93.8	46.7	71.2	0.5
Milk, cow's	12.8	3.3	16.2	3.9
Molasses, cane	74.1	0.9	56.6	61.9
Oats	91.1	9.4	71.5	6.6
Oat kernels, without hulls	91.7	14.6	93.9	5.4
Oat meal (rolled oats)	91.5	14.7	92.5	5.3
Peanut oil meal	93.4	38.0	82.1	1.2
Rice bran	91.1	8.8	67.7	6.7
Rice polish	90.5	9.3	85.7	8.2
Rye grain	90.0	10.3	80.1	6.8
Skimmilk, centrifugal	9.6	3.5	8.6	1.5
Skimmilk, dried	93.8	33.1	84.1	1.5
Soybeans	90.2	32.8	86.2	1.6
Soybean oil meal	91.7	37.7	82.2	1.2
Sunflower seed	93.4	14.6	87.8	5.0
Sunflower seed, without hulls	95.5	25.5	122.5	3.8
Tankage, 60 o/o protein grade	92.2	56.4	78.0	0.4
Wheat, recent analyses	89.8	11.3	83.6	6.4
Wheat bran, all analyses	90.6	13.1	70.2	4.4
Wheat standard middlings	90.0	14.4	78.4	4.4
Whey, dried	95.0	11.9	84.1	6.1
Yeast, dried	92.0	35.6	74.6	1.1

[1]Taken by special permission of the Morrison Publishing Company, Ithaca, New York, from Feeds and Feeding, 20th Edition, F. B. Morrison.

TABLE 5.--Continued

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutri-ents	Nutri-tive ratio
	percent	percent	percent	1:
Dry Roughages				
Alfalfa hay	90.4	10.6	50.3	3.7
Alfalfa leaves	89.0	16.9	57.0	2.4
Alfalfa meal, good	91.9	10.8	53.9	4.0
Alfalfa stems	88.6	5.1	40.8	7.0
Barley hay	91.9	4.9	54.1	10.0
Bluegrass hay, Kentucky	89.4	4.7	53.3	10.3
Clover hay, alsike	89.0	7.7	49.0	5.4
Clover hay, red	88.2	7.0	51.9	6.4
Clover hay, sweet, first year	93.3	14.6	53.5	2.7
Clover hay, sweet, second year	92.0	10.5	49.9	3.8
Corn fodder, medium in water	82.5	3.5	54.6	14.6
Corn stover, medium in water	81.0	2.1	46.2	21.0
Cottonseed hulls	90.6	0.8	43.7	53.6
Cowpea hay, all analyses	90.4	12.6	49.4	2.9
Kafir fodder, dry	91.1	4.6	54.1	10.8
Kafir stover, medium in water	83.7	1.7	47.7	27.1
Lespedeza hay, annual	89.1	9.2	52.2	4.7
Millet hay, common	90.0	5.2	51.5	8.9
Oat hay	88.0	4.5	46.3	9.3
Oat hulls	93.5	0.8	38.3	46.9
Oat straw	89.6	0.9	44.1	48.0
Prairie hay, western	90.4	2.6	49.2	17.9
Red top hay, all analyses	91.0	4.5	53.6	10.9
Sorghum fodder, sweet, dry	89.2	3.6	52.7	13.6
Soybean hay, all analyses	90.8	11.1	50.6	3.6
Sudan grass hay, all analyses	89.2	4.3	48.5	10.3
Timothy hay, all analyses	88.7	2.9	46.9	15.2
Vetch hay, hairy	87.9	15.3	57.0	2.7
Wheat straw	90.1	0.8	35.7	43.6
Green Roughages, Roots, Etc.				
Alfalfa, green, all analyses	25.4	3.4	14.7	3.3
Bluegrass, Kentucky, all anal.	31.8	2.4	18.6	6.8
Bluegrass, Ky., before heading	24.8	4.4	17.7	3.0
Cabbage, entire	9.4	1.9	8.1	3.3
Carrots, roots	11.9	0.8	9.6	11.0
Clover, alsike	22.2	2.4	13.2	4.5
Clover, red, all analyses	25.0	2.6	15.4	4.9
Clover, sweet	22.0	3.0	14.0	3.7
Kale	11.8	1.9	7.8	3.1
Lespedeza, annual	36.6	5.0	20.9	3.2
Mangels, roots	9.4	1.0	7.3	6.3
Potatoes, tubers	21.2	1.1	17.3	14.7
Pumpkins, field	10.4	1.3	9.0	5.9
Rape	16.4	2.6	13.0	4.0
Rutabagas, roots	11.1	1.0	9.3	8.3
Soybeans, all analyses	24.4	3.2	15.1	3.7
Sudan grass, all analyses	25.7	1.4	17.7	11.6
Timothy, all analyses	31.3	1.8	18.1	9.1
Timothy, before bloom	24.2	1.6	15.9	8.9
Turnips	9.5	1.3	8.5	5.5
Silages				
Apple pomace	20.9	0.6	15.5	24.8
Corn, dent, well-matured	28.3	1.3	18.7	13.4
Corn, dent, stover silage (ears removed)	22.6	0.8	13.6	16.0

TABLE 6.--MORRISON FEEDING STANDARDS [1]

	Digestible protein		Total digestible nutrients	
	Minimum allowance advised	Recom-mended for good cows under usual conditions	Minimum allowance advised	Recom-mended for good cows under usual conditions
	Lbs.	Lbs.	Lbs.	Lbs.
1. Dairy cows				
A. For main-tenance (Per head daily)				
700-lb. cow	0.440	0.476	5.13	5.81
800-lb. cow	0.494	0.536	5.77	6.53
900-lb. cow	0.547	0.593	6.38	7.23
1000-lb. cow	0.600	0.650	7.00	7.93
1100-lb. cow	0.652	0.706	7.60	8.61
1200-lb. cow	0.703	0.762	8.20	9.29
1300-lb. cow	0.754	0.817	8.80	9.97
1400-lb. cow	0.805	0.872	9.39	10.63
B. For milk pro-duction per pound of milk (To be added to allowance for maintenance)				
For 3 o/o milk	0.036	0.043	.261	.276
For 3.5 o/o milk	0.038	0.046	.284	.300
For 4.0 o/o milk	0.041	0.049	.307	.324
For 4.5 o/o milk	0.044	0.052	.330	.349
For 5.0 o/o milk	0.046	0.056	.353	.373
For 5.5 o/o milk	0.049	0.059	.376	.397
For 6.0 o/o milk	0.052	0.062	.399	.422

[1] Taken by special permission of the Morrison Publishing Company, Ithaca, New York, from Feeds and Feeding, 20th Edition, F. B. Morrison.

TABLE 6.--MORRISON FEEDING STANDARDS--CONTINUED

	Requirements per head daily			
	Dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1:
2. Growing dairy cattle				
Weight 100 lbs.	1.4- 2.4	0.24-0.40	1.2- 2.0	3.9-4.5
Weight 150 lbs.	3.0- 4.0	0.41-0.52	2.3- 3.0	4.4-5.1
Weight 200 lbs.	4.6- 5.6	0.52-0.62	3.3- 4.0	5.0-5.5
Weight 250 lbs.	5.9- 6.9	0.61-0.71	4.1- 4.8	5.7-6.2
Weight 300 lbs.	7.2- 8.0	0.67-0.78	4.9- 5.5	6.3-6.8
Weight 400 lbs.	9.0-10.0	0.80-0.90	6.1- 6.6	6.5-7.0
Weight 500 lbs.	10.6-11.8	0.87-0.98	6.9- 7.7	6.9-7.4
Weight 600 lbs.	12.0-13.6	0.94-1.06	7.7- 8.7	7.2-7.7
Weight 700 lbs.	13.4-15.5	1.00-1.13	8.4- 9.7	7.4-7.9
Weight 800 lbs.	14.8-17.4	1.06-1.20	9.1-10.7	7.6-8.1
Weight 900 lbs.	16.1-19.2	1.11-1.27	9.8-11.7	7.8-8.3
Weight 1000 lbs.	17.5-21.0	1.16-1.33	10.4-12.6	8.0-8.4
3. Growing beef cattle, fed liberally for rapid growth				
Weight 100 lbs.	1.4- 2.4	0.24-0.40	1.2- 2.0	3.9-4.5
Weight 150 lbs.	3.1- 4.1	0.42-0.54	2.4- 3.1	4.4-5.1
Weight 200 lbs.	4.8- 5.8	0.54-0.64	3.4- 4.2	5.0-5.5
Weight 250 lbs.	6.2- 7.2	0.64-0.75	4.3- 5.0	5.7-6.2
Weight 300 lbs.	7.7- 8.6	0.72-0.83	5.2- 5.9	6.3-6.8
Weight 400 lbs.	9.8-10.9	0.87-0.98	6.6- 7.2	6.5-7.0
Weight 500 lbs.	11.7-13.0	0.96-1.08	7.6- 8.5	6.9-7.4
Weight 600 lbs.	13.2-15.0	1.03-1.17	8.5- 9.6	7.2-7.7
Weight 700 lbs.	14.7-17.1	1.10-1.24	9.2-10.7	7.4-7.9
Weight 800 lbs.	16.3-19.1	1.17-1.32	10.0-11.8	7.6-8.1
Weight 900 lbs.	17.7-21.1	1.22-1.40	10.8-12.9	7.8-8.3
Weight 1000 lbs.	19.3-23.1	1.28-1.46	11.4-13.9	8.0-8.9
4. Calves being fattened for beef baby				
Weight 400 lbs.	9.6-12.7	0.98-1.23	7.4- 9.8	6.5-7.0
Weight 500 lbs.	11.4-14.5	1.19-1.43	9.0-11.4	6.6-7.1
Weight 600 lbs.	13.3-16.1	1.39-1.60	10.6-12.9	6.6-7.1
Weight 700 lbs.	14.8-17.5	1.55-1.75	12.0-14.2	6.7-7.2
Weight 800 lbs.	16.1-18.7	1.69-1.89	13.1-15.2	6.7-7.2
Weight 900 lbs.	17.0-19.4	1.75-1.95	13.8-15.8	6.8-7.3
5. Fattening yearling cattle				
Weight 600 lbs.	13.2-16.3	1.20-1.41	10.3-12.7	7.0-8.0
Weight 700 lbs.	15.2-18.3	1.41-1.60	12.0-14.4	7.0-8.0
Weight 800 lbs.	17.0-20.3	1.59-1.79	13.5-16.1	7.0-8.0
Weight 900 lbs.	18.5-21.8	1.74-1.94	14.8-17.4	7.0-8.0
Weight 1000 lbs.	19.7-22.9	1.87-2.06	15.9-18.5	7.0-8.0
Weight 1100 lbs.	20.8-24.0	1.99-2.17	16.9-19.5	7.0-8.0
6. Fattening 2-year-old cattle				
Weight 900 lbs.	18.7-22.3	1.62-1.83	14.6-17.4	7.5-8.5
Weight 1000 lbs.	20.0-23.5	1.78-1.98	16.0-18.8	7.5-8.5
Weight 1100 lbs.	20.9-24.1	1.87-2.07	17.0-19.6	7.5-8.5
Weight 1200 lbs.	21.8-24.7	1.95-2.12	17.7-20.1	7.5-8.5

TABLE 6.--MORRISON FEEDING STANDARDS--CONTINUED

	Requirements per head daily			
	Dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1:
7. Wintering pregnant beef cows				
Weight 1000 lbs.	14.2-20.0	0.60-0.70	7.5-10.5	10.0-15.0
8. Horses, idle				
Weight 1000 lbs.	13.0-18.0	0.6-0.8	7.0- 9.0	10.0-12.0
Weight 1200 lbs.	14.8-20.6	0.7-0.9	8.0-10.3	10.0-12.0
Weight 1400 lbs.	16.6-23.0	0.8-1.0	8.9-11.5	10.0-12.0
Weight 1600 lbs.	18.3-25.4	0.8-1.1	9.9-12.7	10.0-12.0
9. Horses at light work				
Weight 1000 lbs.	15.0-20.0	0.8-1.0	9.0-11.0	9.0-11.0
Weight 1200 lbs.	17.4-23.1	0.9-1.2	10.4-12.7	9.0-11.0
Weight 1400 lbs.	19.6-26.2	1.0-1.3	11.8-14.4	9.0-11.0
Weight 1600 lbs.	21.9-29.2	1.2-1.5	13.1-16.0	9.0-11.0
10. Horses at medium work				
Weight 1000 lbs.	16.0-21.0	1.0-1.2	11.0-13.0	9.0-11.0
Weight 1200 lbs.	18.8-24.6	1.2-1.4	12.9-15.2	9.0-11.0
Weight 1400 lbs.	21.5-28.2	1.3-1.6	14.8-17.4	9.0-11.0
Weight 1600 lbs.	24.1-31.6	1.5-1.8	16.6-19.6	9.0-11.0
11. Horses at hard work				
Weight 1000 lbs.	18.0-22.0	1.2-1.4	13.0-16.0	9.0-11.0
Weight 1200 lbs.	21.3-26.1	1.4-1.7	15.4-19.0	9.0-11.0
Weight 1400 lbs.	24.7-30.2	1.6-1.9	17.8-21.9	9.0-11.0
Weight 1600 lbs.	28.0-34.2	1.9-2.2	20.2-24.8	9.0-11.0
12. Brood mares nursing foals, but not at work				
Weight 1000 lbs.	15.0-22.0	1.2-1.5	9.0-12.0	6.5- 7.5
Weight 1100 lbs.	16.2-23.8	1.3-1.6	9.7-13.0	6.5- 7.5
Weight 1200 lbs.	17.4-25.5	1.4-1.7	10.4-13.9	6.5- 7.5
Weight 1300 lbs.	18.5-27.1	1.5-1.9	11.1-14.8	6.5- 7.5
Weight 1400 lbs.	19.6-28.8	1.6-2.0	11.8-15.7	6.5- 7.5
Weight 1500 lbs.	20.8-30.4	1.7-2.1	12.5-16.6	6.5- 7.5
Weight 1600 lbs.	21.9-32.1	1.7-2.2	13.1-17.5	6.5- 7.5
13. Growing draft colts, after weaning				
Weight 400 lbs.	9.2-11.3	0.8-0.9	5.6- 7.2	6.5- 7.0
Weight 500 lbs.	10.9-13.3	0.9-1.0	6.6- 8.4	6.6- 7.1
Weight 600 lbs.	12.4-15.2	1.0-1.2	7.6- 9.6	6.7- 7.2
Weight 700 lbs.	13.9-17.0	1.1-1.3	8.5-10.8	6.8- 7.3
Weight 800 lbs.	15.3-18.7	1.2-1.4	9.4-11.9	6.9- 7.4
Weight 900 lbs.	16.7-20.4	1.3-1.5	10.2-13.0	7.0- 8.0
Weight 1000 lbs.	18.0-22.0	1.4-1.6	11.0-14.0	7.0- 8.0
Weight 1100 lbs.	19.3-23.6	1.5-1.6	11.8-15.0	7.2- 8.2
Weight 1200 lbs.	20.6-25.1	1.5-1.7	12.6-16.0	7.5- 8.5

TABLE 6.--MORRISON FEEDING STANDARDS--CONTINUED

	Requirements per head daily			
	Dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1:
14. Pregnant ewes, up to 4 to 6 weeks before lambing.				
Weight 100 lbs.	2.0-2.3	0.16-0.18	1.5-1.8	7.5-8.5
Weight 120 lbs.	2.3-2.6	0.18-0.21	1.7-2.0	7.5-8.5
Weight 140 lbs.	2.6-2.9	0.20-0.23	1.9-2.2	7.5-8.5
15. Pregnant ewes, last 4 to 6 weeks before lambing.				
Weight 100 lbs.	2.5-2.8	0.21-0.23	1.9-2.2	7.2-8.2
Weight 120 lbs.	2.8-3.1	0.23-0.26	2.1-2.4	7.2-8.2
Weight 140 lbs.	3.1-3.4	0.25-0.28	2.3-2.6	7.2-8.2
16. Ewes nursing lambs				
Weight 100 lbs.	2.9-3.2	0.27-0.29	2.3-2.6	6.7-7.7
Weight 120 lbs.	3.2-3.5	0.29-0.32	2.5-2.8	6.7-7.7
Weight 140 lbs.	3.5-3.8	0.31-0.34	2.7-3.0	6.7-7.7
17. Fattening lambs				
Weight 50 lbs.	1.9-2.3	0.16-0.19	1.2-1.5	6.5-7.0
Weight 60 lbs.	2.0-2.5	0.20-0.23	1.5-1.8	6.7-7.2
Weight 70 lbs.	2.2-2.7	0.21-0.24	1.7-2.0	6.9-7.4
Weight 80 lbs.	2.3-2.8	0.22-0.25	1.8-2.1	7.1-7.6
Weight 90 lbs.	2.4-2.9	0.23-0.26	1.9-2.2	7.3-7.8
Weight 100 lbs.	2.5-3.0	0.25-0.27	2.0-2.3	7.5-8.0
18. Growing and fattening pigs				
Weight 30 lbs.	1.3-1.9	0.25-0.32	1.2-1.7	4.0-4.5
Weight 50 lbs.	2.1-2.8	0.35-0.43	1.9-2.5	4.5-5.0
Weight 75 lbs.	2.9-3.9	0.43-0.52	2.6-3.5	5.3-5.8
Weight 100 lbs.	3.6-4.8	0.50-0.60	3.2-4.3	5.8-6.2
Weight 150 lbs.	4.8-6.2	0.65-0.75	4.3-5.6	6.2-6.5
Weight 200 lbs.	5.8-7.1	0.73-0.83	5.2-6.4	6.4-6.7
Weight 250 lbs.	6.5-7.8	0.80-0.90	5.9-7.0	6.5-6.8
Weight 300 lbs.	7.1-8.4	0.85-0.95	6.4-7.6	6.6-7.0
19. Wintering pregnant gilts				
Weight 200 lbs.	3.3-4.0	0.43-0.47	3.0-3.6	6.0-7.0
Weight 250 lbs.	3.9-4.7	0.50-0.55	3.5-4.2	6.0-7.0
Weight 300 lbs.	4.4-5.4	0.57-0.63	4.0-4.8	6.0-7.0
20. Wintering pregnant older sows				
Weight 300 lbs.	3.7-4.5	0.43-0.49	3.2-4.1	6.5-7.5
Weight 400 lbs.	4.6-5.6	0.53-0.60	4.0-5.0	6.5-7.5
Weight 500 lbs.	5.4-6.6	0.63-0.71	4.7-5.9	6.5-7.5
Weight 600 lbs.	6.2-7.6	0.72-0.81	5.4-6.8	6.5-7.5
21. Brood sows nursing litters				
Weight 300 lbs.	8.9-10.9	1.16-1.23	8.1- 9.5	6.0-7.0
Weight 400 lbs.	9.4-11.5	1.22-1.29	8.5-10.0	6.0-7.0
Weight 500 lbs.	9.8-12.7	1.28-1.35	8.9-10.5	6.0-7.0
Weight 600 lbs.	11.2-13.8	1.34-1.42	9.4-11.0	6.0-7.0

The simplest method of assessing the value of a ration is merely to estimate the amount of protein that is to be supplied daily. Reference to column 3 of Table 6 shows how much protein should be supplied daily, at various weights, for any class of animal. Suppose a feeder has a herd of shotes, with an average weight of 75 pounds, and he is feeding corn alone. If additional protein is required it will be supplied in tankage. The amount of digestible protein in these feeds as shown in Table 5 is as follows:

	Digestible protein per cent
Corn	7.1
Tankage	56.4

Experience shows that shotes do poorly on corn alone and we will assume that each pig consumes 2.25 pounds daily. Corn contains 7.1 per cent digestible protein, therefore 2.25 pounds would contain 0.16 pounds of digestible protein. Table 6 shows that one pig should receive 0.43-0.52 pounds. Suppose the feeder now adds 0.4 pounds of tankage. Tankage contains 56.4 per cent of digestible protein, therefore 0.4 pounds of tankage contains 0.23 pounds. The corn contains 0.16 pounds of protein and if these amounts are added the sum is 0.39 pounds, which is slightly below the minimum.

Corn,	2.25 lbs.	x .071	= 0.16
Tankage,	0.4 "	x .564	= 0.23
Total			= 0.39

This ration will permit the pigs to grow faster and they will eat more. We may assume the pigs will now consume 3.5 pounds of corn daily, which contains 0.25 lbs. of protein. The total amount of protein in the corn and tankage together is 0.48 pounds, which is well within the recommended range of the standard.

Corn,	3.5 lbs.	x .071	= 0.25
Tankage,	0.4 "	x .564	= 0.23
Total			= 0.48

The protein requirement for steers may be calculated in the same way. We will assume that a feeder has a bunch of fattening yearling cattle with an average weight of 600 pounds, and that he has enough clover hay, corn fodder, and corn to finish them out. If additional protein is needed he can purchase cottonseed meal. The analyses of the feeds for digestible protein as shown in Table 5 are as follows:

	Digestible Protein per cent
Clover hay	7.0
Corn fodder	3.5
Corn	7.1
Cottonseed meal	35.0

Table 6 shows each steer should receive from 1.20 to 1.41 pounds of digestible protein daily. It will be assumed that the daily allowance is 3 pounds of clover hay, 3 pounds of corn fodder, and 10 pounds of corn. The amount of protein this supplies is as follows.

Clover hay, 3 lbs.	x .070	= 0.21
Corn fodder, 3 lbs.	x .035	= 0.11
Corn, 10 lbs.	x .071	= 0.71
Total		= 1.03

Since the standard called for a minimum of 1.20 pounds of digestible protein there is a deficit of at least 0.17 pounds daily. If one pound of corn is replaced by one pound of cottonseed meal the quantity of protein supplied is 1.31 pounds which comes well within the range recommended.

Clover hay,	3 lbs. x .070	= 0.21
Corn fodder,	3 lbs. x .035	= 0.11
Corn,	9 lbs. x .071	= 0.64
Cottonseed meal,	1 lb. x .350	= 0.35
Total		= 1.31

If the method just described of calculating rations is used the total amount of feed to supply is estimated by the performance of the animals. If they are not gaining rapidly enough, or are losing too much weight, the total quantity of feed may be increased. If they are putting on too much fat, as is possible for idle horses, the total amount of feed may be reduced.

Calculating a Balanced Ration.—The method just described is helpful in estimating the amount of protein to feed, but it does not specify the total amount of feed or of total digestible nutrients that should be supplied. Therefore when greater exactness is desired it is the custom to calculate what is called a balanced ration. A balanced ration is one that contains the proper amount of digestible protein on one hand, and the proper amount of digestible carbohydrate and fat on the other. These are two of the most important things about a feed, but it must be understood they are not the only important considerations. It disregards the quality of the protein, and the kind and amount of both minerals and vitamins. These must be given separate consideration.

When calculating a balanced ration it is necessary to have a standard, and the standards most commonly used in the United

States are the Morrison Feeding Standards. These standards must be accompanied by tables which show the percentage of digestible nutrients in the feeds to be used. These feeding standards and the table showing the percentage of digestible nutrients in the more common feeds, are given on pages 25 to 30.

Some explanation may be desirable in order that the tables may be used more easily. On examining the table showing the quantity of digestible nutrients in the feeds, it is seen that the first column gives the percentage of dry matter. This makes it easy to calculate the total weight of the ration, and so to decide whether it contains a suitable amount of roughage. If this were disregarded it would be possible to calculate a ration that was theoretically well balanced but which was either too bulky or not bulky enough. The second column gives the percentage of digestible protein. The third gives the percentage of total digestible nutrients. This table then shows two of the important things about a feed, its content of protein, and its total fuel value. The last column in the table gives the nutritive ratio, and it is important to understand this. The nutritive ratio is the ratio of digestible protein to the digestible carbohydrate and fat, often called the carbohydrate equivalent. The sum of digestible protein and of carbohydrate equivalent makes up the total digestible nutrients commonly abbreviated to TDN. The method of calculating the nutritive ratio is simple. The percentage of digestible protein is subtracted from the percentage of total digestible nutrients, and then divided into the difference. The quotient gives the nutritive ratio. As an example we will take the analysis of corn.

	Crude protein	Total Digestible Nutrients	Nutritive Ratio
	per cent	per sent	
Corn	7.1	80.6	10.3
		7.1	
Carbohydrate equivalent		73.5	

$$73.5 \div 7.1 = 10.3$$

This means that for every pound of digestible protein, there are 10.3 pounds of digestible carbohydrate and fat, or carbohydrate equivalent. When there is relatively little protein, as in corn, or timothy hay, that feed has a wide nutritive ratio. If there is a high percentage of digestible protein, as in soybeans, that feed has a narrow nutritive ratio.

If we turn to the tables of feeding standards on pages 27 to 30 we see that the first column tells what kind of animal is to be fed, and gives the more important specifications. It will be observed that the ration of 50-pound pigs should differ from that of 200-

pound pigs, and the ration of a horse at hard work should differ from that of an idle horse.

The second column gives the approximate amount of dry matter that should be consumed by animals at the weights specified. The third column tells how much protein should be consumed, and the fourth tells what quantity of total nutrients should be consumed. The fifth column tells what the nutritive ratio should be.

Feeding standards are guides, not fixed rules. In the first place the feeder never knows the exact percentage of digestible nutrients in his rations. The values given in the tables are averages of a large number of analyses, and are not exactly correct for any one feed. Furthermore all animals do not respond alike to a given ration, and a ration that is satisfactory in one trial may not be so satisfactory in another. Finally, the kind of ration that is most profitable depends on market prices of the feeds, and of the livestock. If protein supplements are cheap as compared to grain it may be profitable to feed a narrower nutritive ratio than is specified in the feeding standard. Or it may happen that if a feeder has a large quantity of legume hay, or soybeans, he wishes to use up it might be impossible for him to keep the quantity of protein down within the range specified. In such cases there is no objection to departing from the standards. If, however, protein feeds are excessively high in price, it may be economical to feed a wider nutritive ratio than is specified in the table. The answer to these questions depends on the judgment and experience of the feeder.

It is impossible in a bulletin to describe the various short cuts by which the calculation of rations may be simplified, but a few examples will demonstrate the more important principles.

As a simple case a ration is to be calculated for pigs, weighing 30 pounds, from corn and tankage. The standard specifies how much of the ration and of the various constituents should be supplied to each animal. There is considerable variability in feeds, and in animals, therefore the standard provides some leeway in each specification. As an example, the standard daily requirement for a 30 pound fattening pig is given below:

	Requirement per head daily			
	Dry matter	Digestible protein	Total digestible nutrients	Nutritive ratio
30 lb. pig	1.3-1.9	0.25-0.32	1.2-1.7	1: 4.0-4.5

The allowance of dry matter per day is approximately 1.6 pounds daily and, since most feeds contain moisture, it is evident that the total weight of the ration will probably be between 1.5 and 2.0 pounds. As a first estimate we will try a 22:1 ratio of corn and tankage, 2.2 pounds of corn and 0.10 pounds of tankage, and calculate the nutrients and nutritive ratio it will supply.

FIRST TRIAL RATION FOR A PIG WEIGHING 30 POUNDS

Feeds	Dry matter lbs.	Digestible crude protein lbs.	Total digestible nutrients lbs.	Nutritive ratio 1:
Corn, 2.2	1.87	0.16	1.77	10.3
Tankage, 0.1	0.09	0.06	0.08	0.4
Total	1.96	0.22	1.85	7.4
Standard	1.3-1.9	0.25-0.32	1.2-1.7	4.0-4.5

A comparison of the ration with the standard shows that the dry matter in the ration is above the maximum, the protein is below the minimum, and the total digestible nutrients are over the maximum. The nutritive ratio is much too wide. The quantity of protein can be increased by increasing the amount of tankage, and the total digestible nutrients can be decreased by decreasing the amount of corn. In the final calculation the tankage is increased by 0.2 pound and the corn is reduced by 0.6 pound.

FINAL TRIAL RATION FOR A PIG WEIGHING 30 POUNDS

Feeds	Dry matter lbs.	Digestible crude protein lbs.	Total digestible nutrients lbs.	Nutritive ratio 1:
Corn, 1.6 lbs.	1.36	0.11	1.29	
Tankage, 0.3 lbs.	0.28	0.17	0.23	
Total, 1.9 lbs.	1.64	0.28	1.52	4.4
Standard	1.3-1.9	0.25-0.32	1.2-1.7	4.0-4.5

Inspection shows that this ration is in satisfactory agreement with the standard.

We will next assume that a ration is to be calculated for steers weighing 800 pounds, and that corn silage, red clover hay, and corn are on hand. Usually there are limitations on the amounts available of some feeds, and the ration has to be planned with that in mind. In this case it is assumed that there is available 3 pounds of clover hay and 12 pounds of silage daily per steer. Corn is available in whatever amount is necessary. As a first trial 16 pounds of corn are added to the hay and silage.

FIRST TRIAL RATION FOR A FATTENING YEARLING STEER, WEIGHING 800 POUNDS

Feeds	Dry matter lbs.	Digestible crude protein lbs.	Total digestible nutrients lbs.	Nutritive ratio 1:
Red clover hay, 3 lbs.	2.65	0.21	1.51	
Corn silage, 12 lbs.	3.40	0.16	2.24	
Corn, 16 lbs.	13.63	1.14	12.90	
Total	19.68	1.51	16.65	10
Standard	17.3-20.3	1.59-1.79	13.5-16.1	7-8

Inspection shows that the total amount of dry matter meets the standard, but the ration is slightly deficient in protein and contains a slight excess of total digestible nutrients. The nutritive ratio is much too wide. This can be remedied by reducing the amount of corn and replacing part of it with cottonseed meal. The final amounts are 12.5 pounds of corn and 1.25 pounds of cottonseed meal daily.

FINAL TRIAL RATION FOR A FATTENING YEARLING STEER, WEIGHING 800 POUNDS

Feeds	Dry matter lbs.	Digestible crude protein lbs.	Total digestible nutrients lbs.	Nutritive ratio 1:
Red clover hay, 3 lbs.	2.65	0.21	1.51	
Corn silage, 12 lbs.	3.40	0.16	2.24	
Corn, 12.5 lbs.	10.65	0.89	10.08	
Cottonseed meal, 1.25 lbs.	1.17	0.44	0.94	
Total	17.87	1.70	14.77	7.7
Standard	17.0-20.3	1.59-1.79	13.5-16.1	7-8

This ration conforms to the standard and may be regarded as satisfactory.

The inexperienced feeder is often uncertain as to the amounts of concentrates and roughage that are required by various classes of animals, therefore useful general rules have been formulated on these points.

"*Dairy cows in milk* will eat about 2 lbs. of good quality dry roughage daily per 100 lbs. live weight. Silage may be substituted for dry roughage at the rate of 3 lbs. of silage for 1 lb. of dry roughage. A common rule is to feed 1 lb. of hay and 3 lbs. of silage daily per 100 lbs. live weight. Sufficient concentrates should be fed in addition to bring the nutrients up to the standard."

"*Fattening cattle* should receive 2.1 lbs. or more of concentrates and dry roughage (or equivalent in silage) daily per 100 lbs. live weight, the allowance of concentrates ranging from less than 1 lb. to 1.7 lbs. or more daily per 100 lbs. live weight, depending on the rate of gain desired and the character of the roughage."

"*Work horses and mules* should be fed approximately the following amounts daily per 100 lbs. live weight of concentrates (including grain and other concentrates) and of hay:

At hard work, 1.0 to 1.40 lbs. of concentrates and about 1.0 lb. hay.
At medium work, 0.75 to 1.00 lb. of concentrates and about 1.00 to 1.25 lbs. of hay.
At light work, 0.40 to 0.75 lb. of concentrates and 1.25 to 1.50 lbs. of hay.
Idle, chiefly or entirely on roughage, unless it is of poor quality, when some grain must be used."

"*Fattening lambs* averaging 70 to 75 lbs. in weight will consume about 1.4 lbs. per head daily of hay or other dry roughage when fed all the grain they will eat. They will eat 2.3 lbs. or more of hay per head daily when the grain allowance is restricted."

"*Swine* can make but very limited use of dry roughage, except in the case of brood sows not nursing litters."[1]

[1]Taken by special permission of the Morrison Publishing Company, Ithaca, New York, from *Feeds and Feeding*, 20th Edition, by F. B. Morrison.

ESTIMATING THE VALUE OF A FEED

Estimating the value of a feed from its guaranteed analysis will be considered next. The state feed law requires that all prepared feeds shall be sold on a guarantee of the analysis. Corn, wheat, oats, hay, do not require an analysis, but bran, shorts, linseed oil meal, cottonseed meal, tankage and of course all ready mixed feeds must be sold on guarantee. This law is administered by the State Commissioner of Agriculture and bulletins are published giving the results of the inspection of Missouri feeds. Examination of these publications shows that the guaranteed analyses are usually correct, and it is very seldom that the actual analysis is much below guarantee.

To get the most out of this inspection, however, the buyer should be able to look at the tag and decide at once whether it is the feed that suits his purpose.

Starch makes up the greatest part of the feed consumed, and it may be used for maintenance or for fattening. Corn is usually the cheapest source of starch, and it should be used in largest quantity. Starch and similar substances are all included together by the feed chemist in one group, known as nitrogen-free extract, and this is the cheapest material that can be fed.

A balanced ration contains a considerable quantity of protein, and this is the most expensive nutrient, at least in first cost. It is absolutely necessary, however, at least in some quantity. If it is not supplied, the animals will die. If they are fed an insufficient amount they will grow, or fatten, very slowly. It will be necessary to keep them too long, and the extra feed for maintenance will make the cost of production excessive. The lowest cost of production is obtained only by feeding just enough protein. If too much protein is fed it is wasted, and that also makes the cost of production excessive. One of the essentials of good feeding is to provide enough protein, and in Missouri that is the greatest problem. Feeders have frequently asked if it is economical to buy feeding molasses instead of protein concentrates such as cottonseed meal. Molasses may be very useful if properly used, but it should be remembered that it is high in sugar, a carbohydrate, and contains practically no protein. Molasses may be combined with a protein concentrate, but it is in no way a substitute for protein.

Let us now return to the use of feed tags. If he has plenty of corn, the only thing the buyer should be interested in is the amount of protein in the feed. Inspection of the Missouri Feed Bulletin shows that feeds range in protein content all the way from 10 to 60 per cent. There is no use in considering feeds that contain only 10 per cent, for corn contains that much. Suppose, however, two feeds are being considered, one of which contains 20, the other 40 per cent of protein. The first sells for $2.00 a hundred pounds, the other at $2.50. Which is the cheapest? In the first case the buyer gets 10 pounds of protein for $1.00, or 1 pound for 10 cents. In the second he gets 16 pounds for $1.00, or 1 pound for 6.25 cents.

Price per cwt. $	Protein per cent	Cost per lb. protein cents
2.00	20	10.00
2.50	40	6.25

Suppose, however, it becomes necessary to buy all the feed used. It is possible of course to buy corn and a protein separately, such as linseed oil meal, cottonseed meal, or tankage. On the other hand it may be possible to buy a mill feed, bran, shorts, or mixed feed, that contains not only nitrogen-free extract, but also a considerable quantity of protein. How can one decide whether to take it, or whether it would be cheaper to buy corn and the protein supplement separately. There is a simple rule to follow which is very helpful. Let us suppose a mixed feed which contains 15 per cent or protein is offered at $1.90 per cwt. Corn which contains 10 per cent of protein may be purchased at $1.50 per cwt., and soybean oil meal which contains 45 per cent of protein, at $2.50 per cwt.

The problem is to mix corn and soybean oil meal in such proportions that the mixture will contain 15 per cent of protein. It will then be possible to calculate which is the cheapest, corn and soybean oil meal, or the 15 per cent mixed feed. The method of calculation is as follows: The percentage of protein in corn, which is 10, is subtracted from the desired percentage which is 15. The difference is 5, therefore 5 pounds of soybean oil meal are set aside. The percentage of protein in the mixture, which is 15, is subtracted from the percentage of protein in soybean oil meal which is 45. The difference is 30, therefore 30 pounds of corn are set aside. If the 30 pounds of corn and the 5 pounds of soybean meal are mixed the mixture will weigh 35 pounds and will contain 15 per cent of protein. At the prices given the corn would cost 45 cents and the soybean meal would cost 11.25.cents. The 35 pound mixture would cost 56.25 cents or $1.60 per cwt. With this information the purchaser is in a better position to decide which combination he prefers. The actual calculation is illustrated below.

Corn	10		30
		15	
Soybean oil meal	45		5

30	pounds corn at 1.5 cents	= 45.00	cents
5	pounds soybean oil meal at 2.25 cents	= 11.25	"
35		= 56.25	"
100	pounds mixture at 1.6 cents	= $1.60	

There is one other constituent that should be noticed, especially when buying feeds low in protein, and that is crude fiber. Suppose a feed runs 12 or 13 per cent protein, and 15 per cent crude fiber. It should be remembered that crude fiber in feeds has practically no market value, and that other things being equal, a feed with a high fiber content should sell lower than one that contains 5 per cent or less. If a feed is to be used as a concentrate it should not contain much over 10 per cent crude fiber as a maximum.

THE PREPARATION OF FEEDS

This topic deserves separate consideration, and will not be discussed in detail at present. The various methods of preparing feeds have found favor in special cases, but it should be pointed out that under average conditions they offer no marked advantages. Grinding feed usually increases the digestibility, but this is seldom enough to pay for the cost of grinding. The smaller grains, such as wheat, rye, or kafir, are exceptions, as they have hard coats that are not easily broken in the digestive tract. If grinding is not practicable these grains may be made more digestible by soaking. Feeders are often urged to grind roughages also, such as alfalfa, but actual trials indicate that this process is usually unprofitable.

Attempts have also been made to increase digestibility by subjecting feeds to chemical action. It is possible to use strong chemicals that will digest crude fiber in the laboratory, and make most of it as digestible as corn starch. A number of attempts have been made to find a mild treatment for roughage, such as corn stover, that will convert it into highly digestible material comparable to corn. A device that has been advertised for this purpose is often called a predigester. This process requires expensive equipment, and furthermore does not work. It has been tried by various agricultural experiment stations, and all agree that the process is worthless.

SPECIAL PROPERTIES OF FEEDS

Soft Pork—In addition to the chemical composition of a feed there are occasionally certain characteristics that require some mention. One of these is the presence in some feeds of fat that is soft at ordinary temperatures. The fat of our domestic animals is ordinarily solid, and when chilled it is firm enough that the meat can be evenly and neatly sliced. If fattening animals, as hogs, are fed a considerable quantity of certain liquid fats these will be laid down in the body without undergoing much change, and so produce soft pork. Such pork is flabby and oily even in a refrigerator, and is very objectionable both to the butcher and to his customer. The soybean contains nearly 20 per cent of a soft oil, and pigs fed largely on soybeans make soft pork. Strangely enough cottonseed oil is said to produce a firm body fat. A photograph of hard and soft bacon is reproduced in Fig. 9.

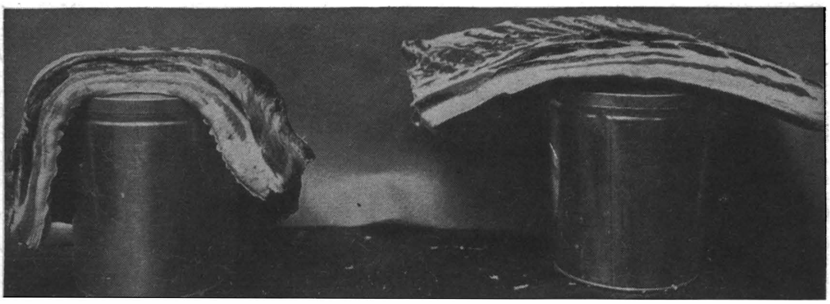

Fig. 9.—The bacon on the left is oily, which makes it unpopular with dealers and consumers. The specimen on the right is preferable because of its firmness. (Courtesy of Professor Sleeter Bull, University of Illinois.)

Prussic Acid.—Some feeds are occasionally poisonous. For example sorghum, Sudan, and Johnson grass have all been reported as killing livestock at times. A careful examination of any of these plants will nearly always show that they contain a trace of prussic acid, one of the most deadly poisons known. The amount is usually so small that it is of no consequence but occasionally it will accumulate and suddenly become dangerous. There is no known way to eliminate this hazard. If poisonous sorghum is cut and either cured or put in a silo the poison will rapidly leave and in a few days the feed can be used safely. Prussic acid is also found in the leaves of the wild cherry.

Fluorine.—It sometimes happens that rock phosphate is used as a source of calcium and phosphorus in preparing mineral feeds, and that the results are unsatisfactory. As was mentioned previously rock phosphate contains fluorine, and is now regarded unfavorably as a constituent of mineral feeds unless a low percentage of fluorine is assumed.

Cottonseed Meal.—It is generally believed that cottonseed meal is slightly poisonous to swine, and there seems to be little doubt that a small quantity of poison may be present in this feed. It is probable, though, that the danger has been exaggerated. Very large quantities of cottonseed meal may be fed to cattle without danger, and many feeders have been using it in swine rations with no unfavorable effects.

Sweet Clover.—It is also stated on good authority that hay made from sweet clover is occasionally poisonous. It is believed the poison is to be found only in moldy hay, but the conditions that govern its development are uncertain. Cattle are most subject to this disease, though it may occur in sheep also. Horses are not affected by this toxin. Rabbits react as readily as cattle, and they are sometimes used to test suspected hay.

The toxic substance acts on the blood so as to prevent it from clotting, and if affected cattle are dehorned or wounded in any way they may bleed to death. Internal hemorrhages may also occur, especially in the muscles of the rump, thigh, neck, or shoulders. The blood tends to collect in pockets, and the swelling that results is sometimes diagnosed as blackleg. An animal may recover from a mild attack, but in severe cases it will literally bleed to death. There are not many instances of this sort on record, and the danger of sweet clover poisoning seems remote.

Forage Poisoning.—A number of cases of forage poisoning have been reported, but the cause of the disease is obscure, and there is no known method of preventing it. Some investigators believe the disease is caused by bacteria and that it is similar to ptomaine poisoning in man. Horses and cattle are sometimes killed by the corn stalk disease but the origin of the trouble is uncertain. One explanation is that the stalks do not become thoroughly dry, and the agent of the disease forms as they slowly decompose.

There are a number of plants that are always poisonous, but fortunately they are either rare in Missouri, or else animals will not eat them unless forced to do so.

Tonics and Condiments.—The stock foods in common use are mixtures of mineral and organic compounds, and it was formerly supposed that they had some special value in maintaining livestock in a thrifty condition, in warding off disease, and in increasing the rate of gain per pound of feed consumed. Such mixtures have only two legitimate uses. First they may be used as medicine in the treatment of sick animals, but in such cases the disease should be diagnosed and the treatment prescribed by a competent veterinarian. Second, as mentioned before, they may be used as mineral supplements. If, however, animals are well, and fed properly it is not believed that their performance will be improved by supplying them with tonics or condiments.

FERTILIZER CONSTITUENTS OF FEEDS

There is another aspect of feeds that requires more attention than it ordinarily receives, and that is their content of substances that contribute to soil fertility. Few soils are inexhaustible, and they are slowly but surely depleted if the plant growth is continuously removed, and no precautions are taken to return plant food to the soil. It is recognized that the feeding of livestock is essential for a permanent system of agriculture. There is no better way to maintain soil fertility than to feed livestock, if the manure is returned to the soil.

The fertilizing constituents in which we are interested are nitrogen, phosphorus, and potassium. Of course the value of the manure excreted depends on the degree of success in having it returned to the soil. It is worth while to examine the various crops for their fertilizing constituents, and make some estimate of the amount they contain. It is possible then to compare the price of the feed with the expense of buying high grade fertilizers to replace the fertilizer constituents contained in the crop. A few of the more common commercial feeds have also been included in these comparisons. In addition one may also calculate the value of the fertilizer constituents voided in the manure, both liquid and solid. Such calculations can only be approximate because the prices, especially of feed, are quite variable. Furthermore it is difficult to estimate what proportion of the fertilizer constituents will be stored in the bodies of the animals that consume the feed, and what proportion will be voided in the manure. For example a mature horse voids as much as it consumes. A growing pig, however, stores considerable quantities of nitrogen and phosphorus, and small quantities of potassium. For these calculations it is assumed that at least 70 per cent of the nitrogen consumed is excreted. Some of this will be lost by fermentation, so it is assumed that 65 per cent of the nitrogen consumed may be returned to the soil. The value of this nitrogen is assumed to be 13⅓ cents per pound. It is also assumed that at least 80 per cent of the phosphorus and potassium consumed will be returned to the soil. Phosphoric acid is assumed to be worth 6 cents per pound, potash 5 cents a pound. With these assumptions then, it is possible to calculate the value of the fertilizer contituents that may be recovered in the manure, as shown in Table 7.

TABLE 7.—LIVESTOCK FEEDING AIDS IN MAINTAINING SOIL FERTILITY

	Fertilizer Constituents in Feed*			Cost of feed per ton $	Value of fertilizer constituents	
	Nitrogen (N) per cent	Phosphorus (P_2O_5) per cent	Potassium (K_2O) per cent		Consumed $	Excreted $
Wheat	1.65	0.85	0.62	32.00	6.04	4.18
Wheat bran	2.52	2.54	1.58	16.50	11.34	8.06
Wheat middlings	3.01	2.01	1.23	20.00	11.66	8.12
Corn	1.39	0.60	0.41	20.00	4.84	3.32
Oats	1.74	0.90	0.50	20.00	6.22	4.28
Clover hay	2.08	0.39	2.04	9.00	8.06	5.62
Alfalfa hay	2.31	0.51	0.92	10.00	7.69	5.23
Timothy hay	0.85	0.26	0.68	8.00	3.26	2.27
Soybeans	6.31	1.36	2.30	33.00	20.75	14.07
Linseed oil meal	5.68	1.61	1.32	45.00	18.39	12.44
Cottonseed meal	5.74	3.10	1.99	35.00	21.01	14.52
Skim milk	0.51	0.22	0.15	5.00	1.81	1.24
Tankage	9.37	3.73	0.66	45.00	30.02	20.27

*Recalculated from Ohio Agr. Exp. Sta. Bul. 255, by E. B. Forbes, F. M. Beegle, and J. E. Meusching.