AUGUST, 1942 BULLETIN 453

UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
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Vitamins for Livestock

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Practically all of our fundamental knowledge of vitamins was gained by studies on small laboratory animals, such as the rat, guinea pig, and chick. The requirements of the larger domestic animals for vitamins have been investigated much less extensively but certain nutritional deficiencies have been observed at times under practical feeding conditions. These deficiencies have been investigated by the methods acquired through small animal experimentation and we now have considerable information as to which vitamins are required by livestock and as to the symptoms by which a deficiency may be recognized. Of the vitamins that are described in the following pages, a few are of considerable practical importance because they may be deficient at times unless special care is exercised. A few are of little practical importance because they are deficient only under unusual circumstances. The others are probably never of practical importance but for various reasons they have aroused considerable public interest. Some of the recognized vitamins are merely mentioned, because they are neither of practical importance, nor as yet of general interest.

Vitamin A

Vitamin A itself is a light yellow oil and is found only in animal tissues, or products, such as milk and eggs. The liver oils of certain fish are the most potent sources. Plants do not contain vitamin A but they do contain a pigment, carotene, which is transformed by the animal body into vitamin A. Since either can be substituted for the other, carotene is often referred to in popular language as vitamin A.

Symptoms of a deficiency.—The first symptom of a deficiency in cattle, sheep, or horses is night-blindness, or inability to see well in a dim light. As the deficiency becomes more pronounced the eyelids become inflamed and swollen, and a watery exudate flows from the eyes continually. In later stages the eyelids of cattle and sheep swell shut but this has apparently not been observed in horses. If the deficiency is sufficiently prolonged and severe, permanent blindness would be expected. The affected animals are unthrifty and the feed intake is greatly reduced. Watery, swollen joints have been reported in cattle, pneumonia and scours in calves.

When a deficiency in vitamin A begins to take effect in swine there may be a tendency to failing appetite, but usually the appetite holds up surprisingly well, even when the most severe stage of the disease is reached. One of the earliest symptoms is arching of the back, thus bringing the hind feet farther forward than is normal.

*Mo. Agr. Exp. Sta. Bul. 446, Vitamins (1942) may be consulted for certain additional details.

A fairly characteristic symptom is weakness in the hind quarters. In the next stage the hind legs become too weak to support the body, and the animal drags itself about with the fore feet. Eventually the animal is unable to move at all, though spasmodic kicking is often observed. The sore watery eyes so characteristic of this disease in other animals are not observed at all in swine, or the condition is very mild. It is our experience at Missouri that if an acute deficiency

Fig. 1.—Ulceration of the cornea due to a deficiency of vitamin A. Courtesy of Dr. G. H. Hart, University of California.

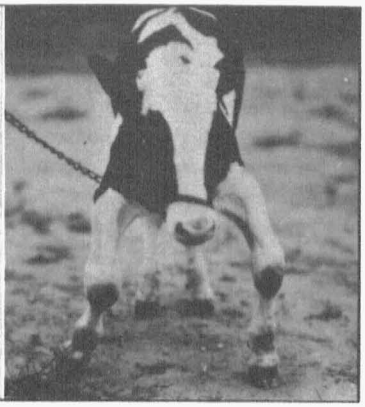

Fig. 2.—Rickets in a calf. Courtesy of Prof. C. F. Huffman, Michigan State College.

is produced in young, rapidly growing pigs, the animals become paralyzed before impairment of vision can be detected. If the deficiency develops more slowly night blindness, and complete blindness, are characteristic symptoms.

The symptoms of a deficiency in mature poultry are very similar to roup, and the disease is often called nutritional roup. Characteristic symptoms are a discharge from the eyes and nostrils, swelling of the eyelids and region just below the eyes, and pinhead-size yellowish pustules in the mouth and throat.

The symptoms just described 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.

Storage.—The liver of all animals can store vitamin A in periods when the supply exceeds the requirement. The storage capacity has an upper limit, but below this level the amount stored is roughly proportional to the excess consumption. If the ration is changed so as to supply no vitamin A or carotene at all, an animal can thrive until the reserve is depleted. The length of time required for the deficiency to become evident depends on the amount of vitamin A in storage at the beginning of the depletion period. If sheep and swine receive a liberal supply of carotene they may store up enough to tide them over a period of 3 or 4 months, when the carotene supply is limited. Cattle and horses can store enough to last 6 months.

Stability.—Carotene and vitamin A itself are slowly destroyed by exposure to air, or oxygen, and high temperatures and sunlight both accelerate the rate of destruction. A theoretical estimate of the rate of destruction is shown in Table 1, merely as a rough guide to what one may expect to happen.

TABLE 1. LOSS OF CAROTENE IN ALFALFA MEAL

Temperature	Original carotene content %	Loss During Storage			
		1 month %	2 months %	4 months %	12 months %
32°F.	100	8	12	15	20
75°F.	100	25	35	45	65
100°F.	100	50	65	80	95+

According to this estimate, at a constant temperature of 75° F., 25% of the carotene would be destroyed in one month, and 65% would be destroyed in 12 months. At higher temperatures the rate is accelerated, at lower temperatures it is reduced. If contact with oxygen could be prevented completely, the destruction would be negligible at all three temperatures. In practice the color of forage is usually a fairly accurate index to the amount of carotene it contains. A deep green color indicates a high retention of carotene. Disappearance of the green color indicates a considerable degree of destruction.

As long as cod-, or other suitable fish-liver oils are stored in a full bottle, away from the light, and in a cool place, the vitamin A is quite stable. However, when the oil is spread out in a thin film, as is necessary when it is incorporated in a mixed feed, some destruction of the vitamin is inevitable. According to a few investi-

gators the rate of destruction is so rapid that it is inadvisable to mix cod liver oil with feed more than about two weeks before it is to be used. Others have reported very little destruction within a year. One investigator has reported that from 50 to 75 per cent of the vitamin A in a mixed feed may be destroyed in six months, and this is regarded as a reliable guide under average conditions. Since the rate of destruction is accelerated by high temperatures, feeds should be stored when possible in a cool place. The practice of storing feed in a warm hatchery or brooder room is decidedly objectionable.

Sources.—Of the concentrates commonly supplied to livestock, yellow corn is the only one that contains any significant amount of carotene. The best source is fresh, rapidly growing forage such as bluegrass or alfalfa pasture. Dried forage is also an excellent source, if cut at the proper stage and cured under favorable conditions. Alfalfa hay is especially reliable, and the grass hays, such as timothy or red top, also contain a liberal amount if cut before they are too mature. Corn fodder, if cut while green and protected from exposure, is a satisfactory source. Good quality forage will supply an adequate amount of carotene. If brood sows are not on pasture their rations should contain from 5 to 10 per cent of a high quality alfalfa meal, or any legume hay may be placed in racks where it is constantly available.

Many of the fish oils, such as cod liver or tuna oil, are excellent sources of vitamin A, and they are supplied to poultry on a large scale. However, one should avoid keeping the mixed feed in storage during long periods of hot weather. As a rule the vitamin A requirement of poultry can be satisfied, in the form of carotene, by including yellow corn and alfalfa meal in the ration. If, however, fish oils are purchased the buyer should secure a guarantee of the vitamin A content, or an estimate of the amount that should be included in a ration.

Commercial vitamin preparations are always sold with a guarantee of vitamin content, but vitamin "units" are confusing to those who are not professional students of nutrition. Most vitamins were discovered before they had been identified or isolated. It was known nearly 30 years ago that cod liver oil contains vitamin A, but it was many years before any one knew how much, by weight, it contained. It was necessary to measure the vitamin content in some manner, however, therefore it was measured by activity, usually the amount required to support a standard rate of growth in the rat. This amount was called a unit. Since each investigator had his own standard there were many units, and in order to eliminate the confusion the unit we have today was finally adopted. One I.U. of vitamin A is equivalent to 0.6 micrograms* of a standard

carotene. I.U. means International Unit, and is identical with U.S.P. or United States Pharmacopoeia unit. Vitamin A content is always specified in units. Carotene content is specified either in units, or by weight.

The circumstances most conducive to a deficiency of vitamin A are long periods of drouth, especially during the summer and early fall when the temperature is high. The vegetation ceases to grow and the carotene already there is destroyed by exposure to light and oxygen. The higher the temperature the more rapid the destruction. Also forage that is unprotected during the fall and winter, such as corn fodder in the field, undergoes a loss of carotene. Straw is a poor source of this vitamin at any time. The most practical method of preventing a deficiency of vitamin A is to provide green pasture throughout as much of the year as is practicable. Winter pasture of barley, wheat, or rye will supply carotene and is desirable for other reasons as well. Well cured legume hay is also exceedingly effective.

An estimate is given in Table 2 of the approximate amount of various feeds that would be required to supply the minimum daily requirement for carotene of various species of livestock, excluding

TABLE 2. AMOUNT OF FEED TO SUPPLY DAILY REQUIREMENT OF CAROTENE PER 1000 LBS. LIVE WEIGHT

Feed	Weight, lbs.
Barley	60.0
Corn, yellow	7.0
Corn, white	contains none
Oats	290.0
Wheat	170.0
Cottonseed meal	39.0
Linseed oil meal	120.0
Soybean oil meal	140.0
Wheat bran	160.0
Wheat shorts	190.0
Tankage	contains none
Alfalfa hay	1.1
Alfalfa leaf meal	0.7
Red clover hay	2.6
Timothy hay	5.6

poultry. It should be pointed out that until very recently at least, all vitamin assays were merely reasonably close approximations. The vitamin content of the same feed is variable, and the assays

*One microgram is 1/1,000,000 of a gram, or about 1/28,000,000 of an ounce.

were very expensive. For these reasons a high degree of precision cannot be expected.

As an example, 0.7 lbs. of high grade alfalfa leaf meal daily per 1000 lbs. live weight, would supply the minimum carotene requirement of cattle, sheep, horses and swine, even if the rest of the ration supplied none at all. The table also shows that 5.6 lbs. of timothy hay, and 7.0 lbs. of yellow corn, would be required to supply that amount. It cannot be emphasized too strongly that these are minimum allowances and that they are grossly inadequate for females during stages of gestation and lactation. During these periods the allowance should be 5 times the minimum requirement. Additional data on vitamin assays, and vitamin requirements, are shown in Tables 7 and 8.

It is the custom to express the nutritional requirement of poultry as a percentage of the ration, rather than as a definite weight per

TABLE 3. CAROTENE (VITAMIN A) CONTENT OF A RATION FOR POULTRY BREEDING STOCK

Ration Constituents	Weight of Constituent	Carotene per pound	Carotene in ration
	lbs.	mg.	mg.
Yellow corn	25	1.91	47.8
Wheat bran	20	0.09	1.8
Wheat shorts	24	0.07	1.7
Alfalfa leaf meal	9	19.20	172.8
Alfalfa leaf meal, dehydrated	1	57.00	57.0
Meat scrap	20		
Common salt	1		
Total	100		281.1
	1		2.8

bird or pen. For that reason it is necessary to make separate estimates for poultry rations. If we use the estimated carotene (vitamin A) requirement of breeding stock, shown in Table 8, as an example we find that each pound of feed should contain 2.8 milligrams of carotene. The average carotene content of a considerable number of ration constituents is shown in Table 7. The calculation of the carotene content of a typical ration is shown in Table 3 as an example.

According to the calculation this ration supplied almost the exact amount of carotene required. It is evident, however, that the requirement could not be met unless the alfalfa meal were of reasonably good quality, about 25 milligrams of carotene per lb.

Before leaving this topic it should be emphasized again that the carotene content of feeds is exceedingly variable. Freshly prepared alfalfa leaf meal may contain 100 milligrams* of carotene per lb., which means one-half pound of the meal would supply more than the daily requirement per 1000 lbs. liveweight. After a year's storage, however, this same sample may contain only 10 milligrams or less of carotene, a loss of 90 per cent. This means that the published assays are merely averages, and the actual content of any one sample may deviate widely in either direction from this average. The assays that have been published are exceedingly helpful, but some discretion is necessary in using them. A fresh, high grade forage may greatly exceed the average. If stored too long or of poor quality originally, it may fall far below the published averages. Furthermore, while the estimated requirements are fairly reliable, there is no pretense that they are strictly accurate.

Comment.—It is evident from the preceding discussion that the problem of providing livestock with an adequate supply of vitamin A is merely the problem of supplying them with forage of good quality. Swine are an exception at times, as they are occasionally fed in dry lot, on concentrates only. If that practice is followed it is important that they receive a large proportion of yellow corn, but even then it is advisable to include about 5 per cent of alfalfa meal in the ration. If swine are on high grade pasture they will receive all the carotene they require in the grass they consume, and it is then immaterial whether the corn is yellow or white. White corn, barley, oats, rye, wheat, also the common protein supplements, such as tankage, the oil meals, and the wheat bran or shorts, are poor sources of carotene. Vitamin A is especially important in feeding dairy cows. In the first place the cow must consume large quantities of carotene in order to produce milk of high vitamin A potency. Furthermore the secretion of the vitamin in the milk reduces the amount that is available for her own use, and may not leave enough to nourish properly the developing fetus, if she is in calf.

Since it is a common practice to keep poultry closely confined, at least during certain stages, they are more likely than other classes of livestock to receive an inadequate amount of vitamin A. If they have access to green vegetation it can be assumed that they will receive enough. If, however, they are confined to dry lot pens, the feeder must take pains to insure an adequate supply. All corn

*One milligram is 1/1000 of a gram, or about 1/28,000 of an ounce.

in the ration should be yellow. Most poultry rations contain approximately 5 per cent of alfalfa, or alfalfa leaf meal, but the percentage may vary according to the carotene content. As mentioned previously the amount of carotene in alfalfa meal may vary from less than 10 to over 100 milligrams per lb. This susceptibility to destruction is a serious handicap to the poultry feed business. The amount of carotene in alfalfa may be satisfactorily high when purchased by the feed manufacturer. Even if no one is negligent, however, the amount may be too low to meet the optimum requirement by the time the feed is consumed.

Vitamin D

Symptoms of a deficiency.—The bones are soft, and the leg bones especially become bent and deformed. The rate of growth is retarded. Egg production by laying hens is reduced and hatchability of the eggs is lowered.

Storage.—If the supply exceeds the requirement this vitamin may be stored in the liver. It is possible to accumulate a reserve that will supply all requirements for several weeks or months, even if all sources of vitamin D are cut off.

Stability.—Vitamin D is quite stable, and ordinarily no special precautions are required to prevent destruction. If, however, vitamin D is intimately mixed with minerals or with feeds that contain 20 to 25 per cent of minerals, it is destroyed presumably by oxidation.

Sources.—None of the common feeds is a highly potent source of this vitamin. Good quality forages that have been cured in the sun can be depended on to supply all of this vitamin that is needed by cattle or sheep, and probably by horses. However, that may be, exposure of the animal to sunshine affords reliable protection.

By far the most common source is cod-, sardine-, or other fish-liver oil. The potency of these oils is highly variable and the content of both vitamin A and D should be specified for each separate lot. The amount of vitamin A in the oil is of less importance, since the requirement of poultry for this vitamin can be met by including good sources of carotene in the ration. The vitamin D content is highly important for there are very few good sources of this product. Until recently fish liver oils were the only sources suitable for poultry, but exceedingly potent concentrates are now being prepared by ultra-violet irradiation of suitable precursors of animal origin. These are known in the trade as "D-"activated animal sterols. The vitamin D obtained by irradiating plant precursors is not well absorbed by poultry and is only slightly effective. Irradiated yeast, or irradiated ergosterol, are poor sources of vitamin D for poultry.

Comment.—Vitamin D is not an important problem in Missouri except for newly hatched poultry. During this stage of growth they

are exceedingly susceptible to a deficiency of vitamin D, and develop severe rickets. This is due to the fact that baby chicks, or poults, are commonly hatched in cool weather, and are kept inside a building for protection from the cold. If they are not supplied with vitamin D, the bones do not become calcified, and remain soft and pliable. This results in deformities, especially of the legs, and ultimately in death. It is essential therefore to provide young fowls with vitamin D, if they are not exposed to sunshine during the stage of rapid growth. The potency of vitamin D preparations, and the amount that should be included in the ration, is usually specified by the manufacturer. It is also customary to guarantee the vitamin A potency, but under present conditions the content of vitamin D is the most important to the poultry industry. Within recent years vitamin D concentrates that contain no vitamin A have become commercially available, and they are used successfully. Calves, especially of dairy breeds, are sometimes kept inside the barn continuously until they are several weeks of age, and may develop rickets. This condition is prevented by 300 I. U. of vitamin D daily per 100 lbs. live weight. 200 I. U. in a vitamin supplement are enough with the usual system of feeding. Two lbs. of a sun cured legume hay should supply all of the vitamin that is required by a calf. A reasonable amount of exposure to sunshine is equally effective, and in Missouri it should be possible to provide complete protection in that way.

Standard milk is not a dependable source of vitamin D, but the amount may be increased by feeding large amount of vitamin to the cows. Irradiated yeast is frequently used for this purpose.

Vitamin D potency is always described in units, partly because there are several vitamins D, and because equal weights of these different vitamins do not always have the same potency for different animals. The standard I.U., or U.S.P. unit is 1/40,000,000 gram of the crystalline vitamin, calciferol, or a little less than 1/1,000,000,000 of an ounce. Strangely enough, calciferol is a very poor source of vitamin D for the chick, and poultrymen therefore use the AOAC (Association of Official Agricultural Chemists) unit. "One A.O.A.C. chick unit of vitamin D is equal in biological activity for the chick to one unit of vitamin D in the U.S.P. Reference Cod Liver Oil in this method of assay."

Riboflavin

Symptoms of a deficiency. Swine develop diarrhoea, and become lame. If the deficiency is long continued the skin becomes scaly and ulcerated. The most characteristic symptom in poultry is curled-toe paralysis. Although a rather severe deficiency is required to produce these symptoms, they have been observed under practical conditions. It is reasonable to suppose that for every case of this degree of severity there must be a dozen or more that are too

mild to produce recognizable symptoms, but are severe enough to affect adversely the growth rate, egg production, and hatchability.

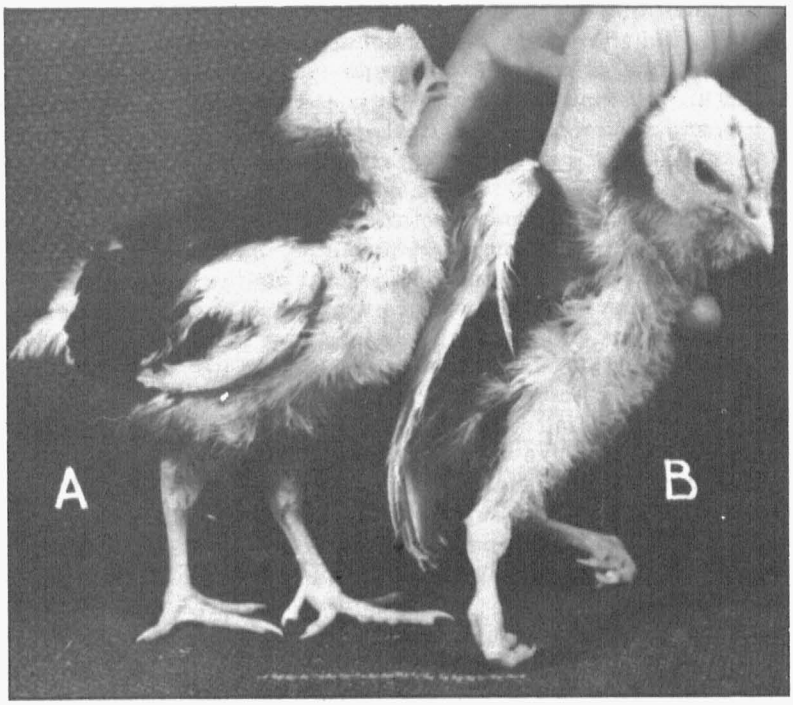

Fig. 3.—Illustrates riboflavin deficiency. When first observed both chicks had curled-toe paralysis. Chick A received 100 micrograms of riboflavin daily for 4 days, when this photograph was taken, and recovered completely. 400 micrograms are about 1/70,000 ounce.
The abnormalities illustrated in these photographs developed on Missouri farms. The chicks were sent to the College of Agriculture for diagnosis.

There are two reasons for supposing that cattle and sheep will never exhibit a deficiency of this vitamin. (1) Microorganisms of the rumen manufacture all the riboflavin these animals require. (2) The rations of these animals normally include a considerable proportion of forage, which is a good source of riboflavin. There is practically no information on the requirement of the horse for this vitamin and it is possible that it is unnecessary to supply any at all. The cecum of this animal has a capacity of 10 or 12 gallons, and the microorganisms may be able to synthesize all that is needed. However this may be, they consume large quantities of forage which should contain enough riboflavin to supply their estimated requirement.

Storage.—The body does not store large quantities of riboflavin, but its reserves are depleted slowly even if the supply is restricted.

Stability.—Ordinarily this vitamin is stable and no special precautions are required to prevent destruction. Exposure to strong light, however, does cause destruction.

Sources.—The best practical sources are leafy forages, especially during the young freshly growing condition. The legume hays are reliable sources; skim milk, buttermilk, and whey are among the best. Fish meal and meat scrap are fair sources, and soybean oil meal contains a significant amount. However, these supplements make up a relatively small percentage of the ration and they seldom contribute more than 25 or 30 per cent of the total requirement.

There is no doubt that swine require riboflavin, but it is doubtful that a deficiency occurs in practice. An estimate is given in Table 4 of the approximate amount of various feeds that would be required to supply the daily requirement of swine.

TABLE 4. AMOUNT OF FEED TO SUPPLY DAILY RIBOFLAVIN REQUIREMENT OF SWINE, PER 100 LBS. LIVE WEIGHT

Feed	Weight, lbs.
Barley, corn, oats, wheat	4.0
Soybean oil meal	1.3
Wheat bran	1.8
Wheat shorts	2.0
Tankage	2.3
Skim milk or butter milk	1.8
Dried skim milk	0.2
Green alfalfa	1.0
Alfalfa meal	0.4

As an example, if a pig weighed 100 lbs. and consumed one pound daily of green alfalfa it would obtain all the riboflavin it needed even if the rest of the ration supplied none at all. If this pig received no feed except grain, such as barley, corn, oats, or wheat, it would have to consume four lbs. daily to obtain the minimum amount required. Since this pig might not consume four lbs. daily, a pig which received grain as the only feed with no supplements, would probably be on a dangerously low level of riboflavin. This fact helps explain why rations of corn only, without a protein supplement and with insufficient pasture, produce such costly gains on swine.

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 may

prove to be an acceptable substitute. One of the cheapest sources now is alfalfa leaf meal, and it may be necessary to use more than has been customary in the past. As explained previously the vitamin requirements of poultry are calculated in a different manner. According to Table 8 the baby chick requires 1.5 milligrams of riboflavin per lb. of feed. The riboflavin content of the ration constituents is shown in Table 7. The calculation of the riboflavin content of a typical ration is shown in Table 5 as an example.

TABLE 5. RIBOFLAVIN CONTENT OF A RATION FOR BABY CHICKS

Ration	Weight of constituent	Riboflavin per pound	Riboflavin in ration
	lbs.	mg.	mg.
Yellow corn	45.5	0.45	20.48
Wheat bran	5.0	1.00	5.00
Wheat shorts	15.0	0.90	13.50
Alfalfa leaf meal	10.0	7.00	70.00
Meat scrap	7.0	2.70	18.90
Soybean oil meal	15.0	1.40	21.00
Steamed bone meal	0.5		
Common salt	1.0		
Cod liver oil (or substitute)	1.0		
Total	100.0		148.88
	1.0		1.5

According to the calculation this ration contains the exact amount required. Even a brief scrutiny of published data will show that it is difficult to make up a poultry ration that contains as much riboflavin as some of the higher standards specify. In order to meet these standards it is necessary to include about 10 percent of the best grade of alfalfa leaf meal that can be obtained. It often happens that a supplement of skim milk, or of clean buttermilk, will greatly accelerate the rate of growth and reduce the mortality rate.

Niacin (Nicotinic Acid)

Symptoms of a deficiency.—Cattle, sheep, and poultry 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 niacin, and if they do not receive enough they develop a roughened dirty skin, diarrhoea, loss of appetite, and grow slowly. In severe cases the skin is scaly and cracked. In order to have a name for this condition it is commonly called swine-pellagra.

Storage.—This point has received very little study. Judging by analogy though, a pig should be deprived of niacin for several weeks

before symptoms of a deficiency would be detected.

Stability.—This vitamin is stable and no special precautions are required to prevent destruction.

Sources.—Forages are excellent sources of niacin. Of the cereals wheat and barley are excellent sources, oats are only fair and corn is a poor source.

An estimate is given in Table 6 of the approximate amount of various feeds that would be required to supply the daily requirement of swine.

TABLE 6. AMOUNT OF FEED TO SUPPLY DAILY NIACIN REQUIREMENT OF SWINE, PER 100 LBS. LIVE WEIGHT

Feed	Weight, lbs.
Red barley	1.0
Yellow corn	2.2
White corn	2.2
Wheat	0.8
Wheat bran	0.2
Standard wheat middlings	0.4
Linseed oil meal	1.0
Oats	3.3
Rye	4.0
Alfalfa meal	1.3

As an example, if a pig weighed 100 lbs. and consumed 0.2 pounds daily of wheat bran it would obtain all the niacin it needed even if the rest of the ration supplied none at all.

Comment.—There is no doubt that swine require this vitamin, but there is considerable doubt as to the probability of a serious deficiency under practical conditions. If fed in dry lot, on rations made up largely of corn, the supply of nicotinic acid might be deficient. Nearly all other feeds, however, are fairly good sources of this vitamin. It should be emphasized though, that only a few feeds have been assayed for niacin, and exact determinations of the amount required by swine of various ages, at various stages of productivity are almost completely lacking. At present then any calculation is merely a general guide.

Actual experience should be a more useful guide than calculations, but unfortunately the published reports are not entirely conclusive. Several investigators have supplied pigs with experimental rations and produced a severe niacin deficiency. In addition there are a few reports of swine-pellagra under practical conditions, which were improved by supplying the pigs with niacin. It has also

been reported that a deficiency of niacin is a predisposing factor in necrotic enteritis in swine, and that this disease may be partially alleviated by supplying the affected animals with niacin. The Missouri Station has carried out limited studies with weanling pigs on the probability of a niacin deficiency, on a ration made up of natural feeds. This ration was made up to have the lowest content of niacin it would be practical to obtain, but the pigs did not develop any of the characteristic symptoms of a deficiency. A few pigs with necrotic enteritis have been treated with niacin, but in no case did it have any curative action. One cannot be certain why our experience does not agree entirely with that of others. The most probable explanation though is, the feeds used by this institution happened to contain more niacin than did those used by investigators with a different experience. Abnormalities have been observed at the Missouri Station that could be interpreted as indicating a niacin deficiency. In no case, however, could evidence be obtained by supplying niacin that a deficiency of this vitamin was the primary cause. In all probability it is unnecessary to take any special precautions to supply swine with niacin. It is always a good recommendation though to provide swine with fresh forage whenever it can be made available. This precaution would help solve all the major nutritional problems.

Vitamin B_1 (thiamine)

Cattle and sheep.—Vitamin B_1 is synthesized by microorganisms in the paunch of these animals, and it is believed this source of supply is adequate. Even if it were inadequate though, almost any ration they consumed would supply enough. For some time great importance has been attached to thiamine or vitamin B_1 in human nutrition. For that reason attempts have been made to increase the thiamine content of milk by increasing the amount of thiamine in the ration of the cow. Unfortunately this method has not been successful. The amount of thiamine in milk is quite constant, and is independent of the amount consumed by the cow.

Horses, swine, poultry.—All seeds such as the cereals corn, oats, rye, barley, wheat, are good sources of this vitamin. Wheat shorts and bran are excellent sources. If processed seeds, such as hominy or corn grits made up a large part of the ration a deficiency would be possible, but nearly any practical ration will provide enough vitamin B_1 for any animal. A unit is 3 micrograms of thiamine.

Vitamin C (ascorbic acid)

It is commonly stated that farm animals do not require this vitamin, and certainly none of them ever develops the symptoms that are characteristic of scurvy. There are well authenticated reports, however, that certain types of sterility in cows and bulls are treated

successfully by intravenous or subcutaneous injections of vitamin C. This treatment should be administered only by those with proper training. Supplying vitamin C in the feed is ineffective, because this vitamin is destroyed in the rumen. It has also been reported that lowered fertility in stallions, jacks, boars, and mares has been corrected by the administration of vitamin C. Since these animals have only one stomach the vitamin can be supplied to these animals in the feed. Young, vigorously growing forage would ordinarily be the most convenient source.

Vitamin E

Symptoms of a deficiency.—If baby chicks do not receive enough vitamin E they become paralyzed. If laying hens receive an insufficient amount their eggs will not hatch. Symptoms of a deficiency in cattle, sheep, swine, or horses, have not been reported.

Storage.—When the supply is liberal, it is believed that animals can store up enough to meet any requirements over a long period of deprivation.

Stability.—The vitamin is probably fairly stable as it occurs in natural feeds. It is destroyed under certain conditions by exposure to oxygen, and it is possible that there is considerable destruction if ground feeds are stored for too long a time. The rate of destruction is accelerated by high temperatures. In the presence of rancid fat it is destroyed rapidly. Under practical conditions protection of the vitamin E content of feeds is not an important problem.

Sources.—Vitamin E is so widely distributed that a deficiency is improbable. The cereal grains and other plant seeds, also the forages, are reliable sources.

Comments.—Vitamin E was discovered through investigations on the nutritional requirements of the rat. These animals become sterile on rations that do not contain vitamin E. Later it was shown that if the deficiency is severe young rats become paralyzed. Paralysis is also easily produced in guinea pigs and rabbits by withholding this vitamin. If baby chicks are deprived of vitamin E they too become paralyzed, probably through injury to the brain cells. It has been asserted that under practical conditions, on rare occasions, baby chicks may receive insufficient vitamin E to prevent this type of injury. However, positive and indisputable evidence on the requirements of cattle, sheep, swine, and horses, for this vitamin has not been produced. A considerable number of goats, through several generations, have been reared on rations that contained too small an amount of vitamin E to be detected. It is possible then that at least some of the common domestic animals do not require vitamin E at all. Whatever the facts may be there are numerous reports of successful treatment for sterility, or lowered fertility, in farm animals with vitamin E carriers. Wheat germ oil is the richest known source of the vitamin, and this oil is commonly used

for vitamin E medication. According to common report, cows, mares, and sows that had been barren for months were given the wheat germ oil treatment and subsequently conceived and gave birth to living young. Bulls and stallions of a low order of fertility became highly fertile after treatment.

It should be made very clear that the Agricultural Colleges have never recommended the wheat germ oil treatment for sterility in livestock, though they do not actively oppose it. Whether the treatment is helpful or not, it is at least harmless if properly applied. The reasons they do not recommend the treatment are as follows. (1) The reports of success may not be a fair sample of the treatments actually administered. There may be a tendency to remember and report the successes, but to forget the failures. Even if the treatment seems successful, the more skeptical will feel that the result would have been the same if the treatment had been omitted. In order to decide whether the wheat germ oil treatment is effective or not, it would be necessary to study a considerable number of animals, observed under similar circumstances. Approximately half of them should receive the oil treatment, the others should not. A comparison of two such groups is the only way to decide whether or not the treatment had been helpful. (2) A second reason for questioning the usefulness of the vitamin E treatment, is the fact that this vitamin is widely distributed. It is believed that livestock will secure much more than they need from any practical ration. A deficiency of this vitamin would be difficult to explain.

Choline

This substance has not yet attained popular recognition, but it is regarded by some as a vitamin, and it certainly has some of the properties of a vitamin. It has been reported that on a ration of natural foodstuffs, though one of unusual composition, pullets developed fatty livers and there was serious interference with the egg laying mechanism. These symptoms were prevented by the administration of choline. Poultry rations have been prepared on which baby chicks, and turkey poults especially, develop perosis. It was discovered several years ago that a deficiency of manganese will cause this condition, and it was supposed for some time that this was the only cause. It was discovered recently that deficiencies other than manganese will also cause the abnormality. One of these is choline, but recent work indicates that there are at least two vitamins in addition to choline that are required to prevent perosis, or hock disease. There is no doubt that choline is useful in several respects as a nutrient, but our knowledge of its activity is very recent and there has been insufficient time to decide whether it is of practical importance. In order to prevent perosis there are several precautions that should be taken. (1) The inclusion of excessive amounts of mineral matter in the ration, especially of

calcium and phosphorus, should be avoided. It is commonly recommended that the rations of baby chicks should contain about 7, and not over 10, per cent of meat scrap. It is impossible to state what percentages of calcium and phosphorus are to be preferred, but it is believed that 0.6 to 1.0 per cent of calcium, and 0.4 to 0.8 of phosphorus are satisfactory. (2) The ration should contain 50 parts per million of manganese. If about 15 per cent of soybean oil meal, and 5 to 10 per cent of alfalfa leaf meal, are included in the ration it should contain enough choline to prevent perosis. There is reason to believe such a ration would also contain any other vitamins that might be required to prevent this disease.

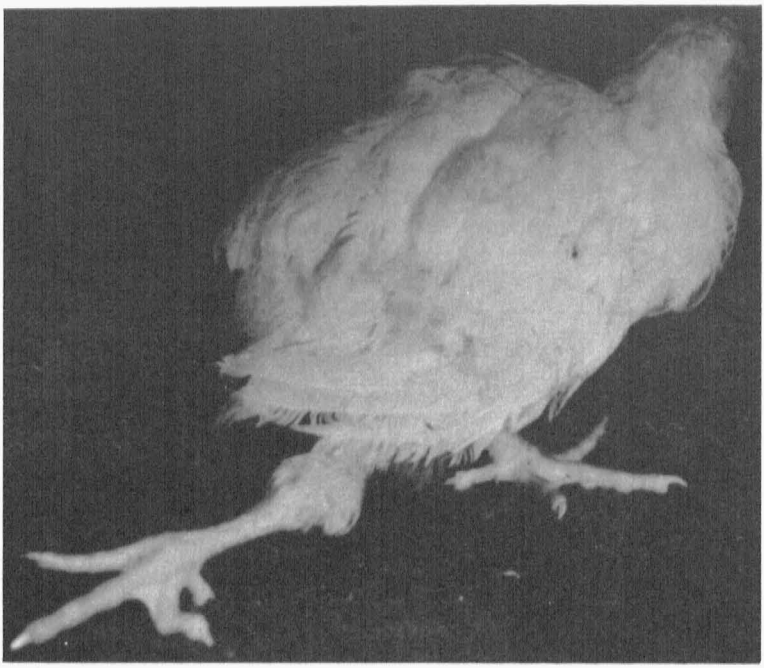

Fig. 4.—An example of "slipped tendon" or perosis. The disease is caused by a deficiency either of manganese or of a vitamin such as choline.

Discussion

It is apparent from the preceding discussion that good feeding practices will supply the recognized vitamins, in adequate amount, that are required by the larger animals. For various reasons, however, there are times when the feed supply is limited and it is difficult to follow approved practices. The vitamin most likely to be deficient under those 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. 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.

Fig. 5.—Example of muscular incoordination in a suckling pig.

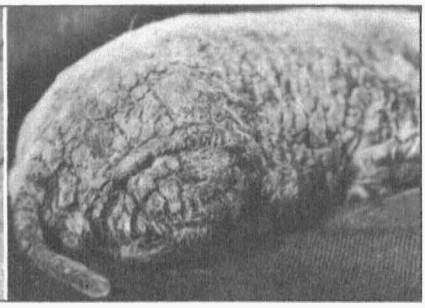

Fig. 6.—Example of cracked, scaly skin in a weanling pig.

The pigs shown in these two photographs never had access to forage, and presumably the abnormalities are due to a deficiency of an unrecognized vitamin.

It should be pointed out that the amount of the vitamins that are required, as estimated by different workers, do not always agree well and there are no official standards. The standards selected for this publication are merely averages of estimates that were regarded as reliable. Some may be too low, others may be higher than is necessary. The standards for poultry have received the most study and are probably the most accurate.

In addition to the eight vitamins that have been discussed there are four more, vitamin K, vitamin B_6, pantothenic acid and biotin. Two other substances, inositol and para-amino benzoic acid, have been announced as vitamins, but it is still uncertain whether they should be so classified.

Whatever may be the number of vitamins one accepts as identified it is certain that there are still others, which have not yet been identified, and concerning which we have no specific information. It is believed that at least one of these is of practical importance.

It has been shown that the concentrates commonly used in swine rations are not adequate for brood sows during gestation and lactation, due to a deficiency of one or more unrecognized vitamins. The most characteristic symptom of the deficiency is a very high rate of mortality among the new born pigs, and a slow rate of growth during the suckling stage. A liberal supply of fresh forage is the most practical method of preventing this type of deficiency. This observation is of considerable practical importance to those who keep animals, especially swine and poultry, in dry lot or in confinement without access to fresh forage. It is very difficult to be certain that a ration made up of the common concentrates will be satisfactory if it is the only source of feed for long periods of time. Chicken or turkey hens may produce eggs that are satisfactory in number, but which are of low hatchability, or if hatched the vitality of the chicks or poults is reduced. These troubles can often be prevented by providing the hens with a range, that has a good stand of grass. It often takes several weeks for the effects of a deficiency to develop, and considerable damage may be done before the cause of the difficulties is established, and the deficiency can be corrected. It is always hazardous to rely on a dry feed mixture, unless an actual trial under the same conditions has shown that it is satisfactory. Even then the trials should be repeated occasionally, for it has been observed in investigations on swine nutrition at the Missouri Agricultural Experiment Station that the vitamin content of feeds is variable. For example, brood sows in dry lot may make an unusually good record in one particular season. They farrow large litters, and lose very few pigs; the pigs are thrifty and are above the normal weight at weaning time. During another season, on rations made up by the same formula, the sows may make an unusually poor record. The litters are small or contain many dead pigs, and the mortality rate is high; the pigs are very unthrifty and are below normal weight at weaning. Growth is a good test of a ration's adequacy, but reproduction is a still more exacting test. Good quality forage will repair many of the deficiencies of rations made up of dry concentrates.

TABLE 7. AVERAGE VITAMIN CONTENT[1] OF FEEDSTUFFS, IN MILLIGRAMS[2] PER POUND

Feedstuff	Carotene (Vitamin A)	Vitamin B[1]	Vitamin G (riboflavin)	Niacin (Nicotinic acid)
Seeds and Grains				
Barley	0.24	0.75	0.40	21.0
Corn, yellow	1.91	0.81	0.45	9.0
Corn, white	0.00	0.81	0.45	9.0
Corn gluten meal (yellow)	4.08	---	0.00	---
Cottonseed meal (41% protein)	0.36	5.40	0.30	---
Kafir	0.15	---	---	---
Linseed oil meal (old process)	0.12	6.00	0.90	20.0
Oats	0.05	0.81	0.40	6.0
Peanut meal, no hulls (old process)	0.15	2.70	1.20	---
Rice bran	---[3]	4.50	0.90	---
Rye	---	0.75	---	5.0
Soybeans	0.36	3.30	1.30	---
Soybean meal	0.10	2.70	1.40	---
Wheat	0.08	1.02	0.40	27.0
Wheat bran	0.09	1.35	1.00	140.0
Wheat shorts	0.07	3.00	0.90	50.0
Seeds of animal origin				
Buttermilk, liquid	0.02	0.12	1.20	---
Buttermilk, dried	0.12	1.20	9.00	---
Fish meal, white	---	---	4.50	---
Fish meal, menhaden	---	---	2.25	---
Meat scrap	---	---	2.70	---
Skim milk, liquid	0.01	0.12	1.00	0.40
Skim milk, dried	0.08	1.20	9.50	4.00
Tankage	---	---	0.80	---
Whey dried	---	---	12.00	---
Greed feeds, etc.				
Alfalfa (green)	38.14	0.68	2.00	---
Alfalfa-leaf meal, dehydrated	57.00	1.35	8.00	18.00
Alfalfa-leaf meal	19.20	1.20	7.00	18.00
Alfalfa-hay	13.00	1.00	5.00	16.00
Red clover hay	5.40	1.35	---	---
Timothy hay	2.50	---	---	---
Yeast, brewers' dried	---	13.50	16.00	225.00

[1]The data on nicotinic acid were calculated from a publication of the Wisconsin Agr. Expt. Sta. The others were taken with some modification from the U.S.D.A. Yearbook for 1939.

[2]One milligram (mg) is 1/1000 gram or about 1/28,000 ounce.

[3]Blanks indicate no data.

TABLE 8. VITAMIN REQUIREMENTS OF FARM ANIMALS[1]

Animal	Vitamin A	Vitamin D	Vitamin B_1 (thiamin)	Vitamin Riboflavin	Vitamin Niacin (Nicotinic Acid)
Swine	1.4 mg. carotene daily per 100 lbs. live weight ---------- 35 mg. carotene per 100 lbs. feed	200 I. U. daily per 100 lbs. live weight	50 mg. per 100 lbs. feed	1 to 3 mg. daily per 100 lbs. live weight 60 mg. per 100 lbs. feed	20 mg. daily per 100 lbs. live weight
Cattle	14 mg. carotene daily per 1000 lbs. live weight ---------- Cow in calf, 60 mg. carotene daily per 1000 lbs. live weight ---------- Cow in milk, 200 mg. carotene daily per 1000 lbs. live weight	Calves 300 I. U. daily per 100 lb. live weight	None	None	None
Poultry					
growing chicks	0.9 mg. carotene or 1500 I. U. per lb. feed	180 AOAC chick units per lb. feed	0.5 mg. per lb. feed	1.5 mg. per lb. feed	None
Laying hens	1.9 mg. carotene or 3200 I. U. per lb. feed	360 AOAC chick units per lb. feed	0.5 mg. per lb. feed	0.7 mg. per lb. feed	None
Breeding stock chickens turkeys	2.8 mg. carotene or 4700 I. U. per lb. feed	540 AOAC chick units per lb. feed	0.5 mg. per lb. feed	1.3 mg. per lb. feed	None
Turkey poults	2.2 mg. carotene, or 3600 I. U. per lb. feed	360 AOAC chicks units per lb. feed	0.5 mg. per lb. feed	1.5 mg. per lb. feed	None
Dog	0.75 mg. carotene, or 1250 I. U. of vitamin A, per lb. feed	Puppies, 180 I. U. per lb. feed; Mature, 90 I. U. per lb. feed	0.5 mg. per lb. feed	1.5 mg. per lb. feed	5 mg. per lb. feed

[1] Most of the standards for poultry were taken from the U.S.D.A. Yearbook for 1939, page 818. The others were drawn from miscellaneous sources. There are very few data on the vitamin requirements of sheep and horses.