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Vitamins

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THE "BIG THINGS" IN NUTRITION

Unless directed otherwise the feed chemist usually makes six determinations on each sample:

Water	Crude protein	Nitrogen-free extract
Ash	Fat	Crude fiber

Anyone of these constituents may be present in relatively large amounts, and everyone is more or less familiar with each of them. It was supposed for many years that these are the only constituents of feeds that are of any significance. Chemists were of course aware that feedstuffs contain what seemed to be insignificant amounts of organic substances other than those listed above. These partially unidentified substances were present though in many excellent feeds in such minute quantities that it seemed unthinkable they could have any significance as constituents of a ration. However, as time went on investigators found that it is necessary in many types of investigations to use rations that are made up of relatively pure nutrients, protein, carbohydrates, fats, and minerals, from which the unidentified substances previously mentioned are rigidly excluded. All investigators in this field, whatever their original problem, had in one respect the same experience. Animals that were limited to these purified rations not only failed to thrive, they even failed to survive if the investigations were continued for any length of time. It was taken for granted at first that these failures were due to the fact that rations of this type are unpalatable, and animals fail to consume them because they are monotonous. Many attempts were made to overcome this difficulty, but every expedient failed and chemists were slowly convinced that the nutrients mentioned are not the only ones that are essential. There must be others, required in such minute amounts that they are ignored completely in the usual type of chemical analysis. Eventually this conviction was justified, and in recent years a very considerable number of these obscure nutrients has been identified. They are now known as vitamins. The six substances commonly determined by chemical analysis are known as the "big things" in nutrition. The vitamins are the "little things."

THE "LITTLE THINGS" IN NUTRITION

We describe the "big things" in parts per hundred, or per cent; but we describe the "little things" in parts per million. For example, 1,000,000 lbs. of whole wheat contain approximately 5 lbs. or 0.0005 per cent, of thiamin (vitamin B₁). The older chemical methods fall far too short in sensitivity to detect such minute quantities of a contaminant. The newer chemical methods can measure this substance with a reasonable degree of accuracy.

The rapid increase in our knowledge of vitamins has brought about a striking shift in emphasis on nutritional problems. Twenty-five years ago students of nutrition were chiefly concerned with the quality and quantity of protein and minerals, and with problems in energy metabolism. The emphasis on these nutrients has not diminished, but the emphasis on vitamins has vastly increased. It is realized now that many of the important problems in the nutrition of men and animals are due to the fact that under certain systems of feeding the supply of vitamins is insufficient. By ordinary standards the amounts required are exceedingly minute, but although only small quantities of the vitamins are required their importance can not be exaggerated. If man or animals receive none at all they soon perish. If they receive insufficient amounts the health is impaired. It should be mentioned that in practice mild deficiencies probably cause higher total losses than do severe deficiencies. It is relatively uncommon for a diet, or ration, to contain so little of a vitamin that obvious symptoms of a deficiency occur. It is reasonable to suppose that when one such case occurs there must be several cases that are too mild to produce characteristic symptoms, but which are sufficiently severe to lower the state of health. Ordinarily we think of people, and livestock, as being either healthy or sick. It is well recognized now that there is no sharp dividing line between health and disease. There are individuals who have not a single characteristic symptom of any disease, and yet do not possess that degree of health they are capable of achieving. The proportion of such individuals is a matter of controversy. Some authorities believe it is small, others with equal experience and training believe it is large. Current reports of medical examiners on the proportion of young men rejected for military service contain weighty evidence that the latter group is more nearly correct. Some of us can never have perfect health, but many of us could attain better health than we have now.

THE NUMBER OF VITAMINS

There has been considerable popular interest in the number of different vitamins, but the exact number is not known. There are eleven vitamins whose existence is undisputed. There is a twelfth compound, choline, whose existence is undisputed, and it undoubtedly has some of the characteristics of a vitamin, but it has not yet been officially classified as such by any official agency. There are two more that have been classified as vitamins by a few investigators, but it is not certain that their claims are beyond dispute. A few attempts have been made to rear animals, including the rat, guinea pig, chick, and swine, on rations that contain no vitamins except those mentioned above. In every case, however, there was evidence of nutritional inadequacy, and it is very certain that there is at least one more. There are probably several more. A list of vitamins, and of compounds that have been announced as vitamins, appears below.

VITAMINS WHOSE EXISTENCE IS UNDISPUTED

Of practical importance because many foods contain insufficient amounts

A (carotene)
 B₁, thiamin
 C, ascorbic acid
 G, riboflavin
 nicotinic acid (niacin)
 D

Of less practical importance because most foods contain adequate amounts

E
 K
 B₆, pyridoxine
 pantothenic acid
 biotin

Choline: This substance has many characteristics of a vitamin but has not been officially classified as such

Inositol, para-aminobenzoic acid: There is some evidence that these two compounds are vitamins, but they have not been extensively investigated.

Unrecognized vitamins, at least one, probably several.

Of the total of fourteen compounds in the list, thirteen, all except biotin, can be manufactured in the chemical laboratory. Their physical and chemical properties are as well understood as those of any other common organic compound.

It is possible that the list of vitamins will never be entirely complete. For example, there is every reason to believe that microorganisms of the alimentary tract synthesize certain vitamins, and that these vitamins are later released and recovered by the host. It is entirely

conceivable that in some instances this source of supply is sufficient. In others it might be inadequate, but sufficient to support some approach to a normal nutritional state. It is fortunate that if these circumstances do really prevail to any great extent, the vitamins concerned are probably not of great practical importance.

NOTES ON INDIVIDUAL VITAMINS

A. Vitamins that may be deficient under practical conditions

Vitamin A.—Vitamin A is almost, if not entirely, an animal product. There is little or none in plants. Commercial vitamin A is all processed from certain fish liver oils, as the cod, halibut, shark, or sardine. Since all animals require vitamin A it is obvious that plants contain some substance that can be transformed by the animal body into vitamin A. This substance is carotene, a bright yellow or golden pigment. The color of the carrot is due to carotene, and this substance is present in all green leaves that have been investigated. The yellow vegetables, such as the rutabaga or sweet potato, also contain carotene. Green leaves are preeminent as a source. When consumed by an animal a portion is transformed into vitamin A, and presumably it is only this transformation product that can be used. Carotene is not identical with vitamin A, but since it is the raw material for vitamin A manufacture, the terms carotene and vitamin A are often used interchangeably.

Symptoms of a deficiency: In man, cattle, sheep, horses, night blindness, or poor vision in dim light, is the most easily recognized symptom; in later stages the eyelids are swollen and a sticky discharge flows from the eyes. In poultry, swollen eyelids, and white patches in the oesophagus are characteristic signs.

In swine, weakness in the hind quarters ending in paralysis, nerve degeneration, and blindness are typical symptoms.

The fundamental defect in vitamin A deficiency is impairment of epithelial tissues.

Stability: Carotene and vitamin A are destroyed fairly rapidly at high temperatures, especially when exposed to the light. Average alfalfa hay contains about 25 to 35 per cent of the original amount of carotene. Low grade hay may retain only 10 per cent. If cod liver oil is mixed with ground feed as a source of vitamin A, practically all of the vitamin may be destroyed in 2 or 3 weeks. Feed that contains cod liver oil as a source of vitamin A should be used up within a week after mixing, unless stored at a low temperature.

Sources: Milk, cheese, eggs, and liver are excellent sources. Most vegetables are at least good sources, but the leafy vegetables such as spinach or kale are also excellent. Of the cereals only yellow corn is a good source. The best sources for livestock are fresh green forage and the legume hays.

Vitamin B₁ or Thiamin.—*Symptoms of a deficiency:* Weakness, impairment of nerve function, with various manifestations in different animals of paralysis; poor appetite and digestive disturbances. In practice the importance of this vitamin is most emphasized in human nutrition.

Stability: Is not readily destroyed under ordinary conditions. It is destroyed by prolonged moist heat. It is destroyed by alkali, especially if heated. It is fairly stable in acid solution.

Sources: Milk, eggs, liver, and fresh fruit or vegetables are good sources. Lean pork, and most seeds such as corn, wheat, and soybeans, are excellent or good. High quality forage is a dependable source. A deficiency in the ration of livestock is improbable, but because of poor food habits the diet of man often contains less than the optimum amount.

Vitamin C.—A deficiency of this vitamin produces the disease known as scurvy. None of our domestic animal is susceptible, but man is subject to this disease. The only animals known to develop it are guinea pigs and monkeys.

▪ *Symptoms of a deficiency:* Swollen bleeding gums, loose teeth; tender, swollen joints; fragile bones; weakened blood capillaries, with a tendency to "bruise" easily.

Stability: This vitamin is readily destroyed by oxygen, and the destruction is accelerated by an alkaline reaction, and by certain metals, especially copper. The oxidizing enzymes of plants, after harvesting, are also destructive, and the vitamin C content of many vegetables falls markedly during storage, even in a refrigerator. This applies especially to the leafy vegetables. An acid reaction retards the destruction.

Sources: Dry seeds, and unless extraordinary precautions are taken, any dried food is practically devoid of vitamin C. Fresh fruits and vegetables are reliable sources if not stored too long. The importance of fresh leafy vegetables should receive special emphasis. Eggs contain practically none of this vitamin and cow's milk is undependable. Among meats only the glandular tissues such as liver are reliable sources.

Vitamin D.—The disease caused by a deficiency of vitamin D is known as rickets, therefore the preventive agent is often described as

the antirachitic vitamin. Presumably adult animals require vitamin D, but the requirement of adults has been studied very little and we have very little knowledge of the amount they need. Rickets is a disease of youth, at the time when the bones are growing. If the supply of the vitamin is inadequate the amount of lime phosphate deposited in the bones will be reduced. The result is structural weakness, which leads to the deformities that are characteristic of the disease.

Many infants and young children receive vitamin D in the form of a fish liver oil. Older children, and most young animals, obtain very little of the vitamin D they require from the food they consume. Vitamin D is exceptional in at least one respect, for the required amount is assured by exposure to sunshine, or skyshine, and to artificial ultraviolet rays. The explanation is that just beneath the superficial layer of the skin of animals there is widely dispersed in the tissues a substance which is converted into vitamin D by exposure to ultra violet rays. A similar substance occurs in plants. This substance, in its normal state, has no vitamin D activity, but it is readily converted into vitamin D. Sunlight that has passed through glass is unable to bring about this conversion, because glass absorbs the ultra violet rays. Artificial irradiation is a widely used commercial method of increasing the vitamin D content of human food. Some of the commercial vitamin D concentrates used in poultry feeds are prepared in a similar way. In this connection it should be mentioned that there is more than one vitamin D, though chemically they are very similar. For example the vitamin D of irradiated yeast is an effective source of the anti-rachitic vitamin for man and for some animals at least, but it is very ineffective for poultry. If irradiated products are supplied to poultry the raw material should be obtained from animal and not from plant sources.

Symptoms of a deficiency: Enlarged joints; soft, porous bones, with more or less pronounced deformities.

Stability: This vitamin is not readily destroyed, and losses in storage are usually negligible.

Sources: Egg yolk and liver usually contain an abundant supply. None of the other common foods or feeds is an excellent source, and very few are reliable sources. Sun-cured hay of good quality contains a fair amount. The more common concentrated feeds contain practically none. Fish liver oils are the most widely used commercial sources. A new type of vitamin D concentrate has recently been developed, and is now on the market, prepared by ultra violet irradiation of suitable raw materials of animal origin.

Vitamin G (riboflavin).—There are well authenticated reports that man does at times consume diets that are deficient in riboflavin. In every such case, however, it seems that the diet is also deficient in at least one more vitamin. This means that certain vitamins accompany each other, and if one is deficient it is probable that more than one is deficient. Riboflavin belongs in this group.

Symptoms of a deficiency. In man, fissures or cracks at the corners of the mouth.

In the rat, thinning of the hair and appearance of premature old age; cataract.

In the chick, curled toe paralysis.

In the dog, sudden collapse.

In swine, slight deformities in the feet, and lameness; diarrhoea; during a long continued deficiency the skin becomes scaly and ulcerated. This deficiency has not been reported in cattle, sheep, or horses.

Stability: Riboflavin is relatively stable and a reduction in potency by destruction is not a major problem. It is destroyed slowly by exposure to strong light, and is destroyed rapidly if the vitamin is in an alkaline solution during the exposure.

Sources: Milk, cheese, eggs, and lean meat are excellent sources. Liver is one of the best. Practically all fruits and vegetables are good sources, though the leafy vegetables are preeminent.

Of the common feeds, forages with a high proportion of leaf are the most reliable source. Soybean oil meal is a good source and skim-milk is one of the best. As a rule the cereal grains and milling by-products, such as wheat bran or middlings, are poor sources. Yellow corn contains a fair amount. If an abundance of green pasture is provided both swine and poultry will receive all they need.

Nicotinic Acid (niacin).—The disease, pellagra, has long been prevalent in the Southeastern part of the United States. As has been known for some 25 years it is due to an inadequate diet. Some medical men believe the disease diagnosed as pellagra is often due to a multiple deficiency, that is to a deficiency of two or more vitamins at the same time. It is the general opinion, however, that the more characteristic symptoms of the disease are due to a deficiency of nicotinic acid. The other vitamin most likely to be deficient, along with nicotinic acid, is riboflavin.

Unfortunately, the term nicotinic acid is sometimes confused with nicotine, and this confusion has led to some prejudice against the use of the vitamin. The two substances are not identical, either chemically or physiologically and the name nicotine acid is a historical accident.

In order to avoid prejudice the name niacin has been adopted for popular use.

Symptoms of a deficiency: In man, the most characteristic feature is an "eruption" or dermatitis, on the backs of the hands, feet, and forearms. A burning sensation in the mouth, and reddened tongue are frequently reported also. A long list of other symptoms has been reported as present in some cases.

In the dog, characteristic symptoms are reddening of the mucus membrane of the lip, cheeks, and floor of the mouth. Within a very few days the reddened areas become necrotic, with an exceedingly foul odor, accompanied by drooling of a stringy secretion from the mouth. This disease in dogs is known as blacktongue.

In swine, the symptoms are unhealthy skins with scabby patches; diarrhoea; inflammation and necrotic areas in the intestines.

Poultry do not require nicotinic acid at all. There is no reason to suppose it is required by cattle, sheep, or horses, though this point has received very little attention.

Stability: Nicotinic acid is quite stable.

Sources: This vitamin is so widely distributed that only poor food habits, or poor feeding practices, would ever permit a deficiency. Human beings who contract the disease are said to subsist largely on corn bread, salt pork, and molasses. If, however, such a diet were reinforced by diversified garden products, pellagra would disappear. Milk, cheese, eggs, and lean meat are excellent sources. Vegetables, fruits, and most seed foods, such as wheat, peas, and beans are reliable sources. Corn is almost the only conspicuously poor source. Green leaves, such as turnip tops or spinach are especially dependable.

Swine pellagra, usually in mild form, occurs when the animals are restricted to a ration made up chiefly of corn. The other cereals, if consumed in quantity, provide a reasonably adequate supply of nicotinic acid, and good quality forage in moderate amount is a reliable source. When pasture is available corn can be supplied to swine in unrestricted amounts.

Considerable information has been accumulated concerning the other known vitamins, but this is still largely restricted to experimental laboratories. Except for isolated examples there is no reason to believe they are likely to be deficient, and in that sense they are of limited importance. Needless to say, they are just as important to the animal that requires them as are those that are less widely distributed.

B. Vitamins that are not deficient under practical conditions.

Further study may show that some of these should be transferred to Group A.

Vitamin E.—It was observed 20 years ago that on certain diets rats, of both sexes, become sterile. Later it was shown that the sterility was due to the lack of a certain vitamin, later known as vitamin E. It was also shown that if hens receive insufficient vitamin E their eggs will not hatch. The protective substance came to be commonly known as the anti-sterility vitamin, though as it developed later the term was unfortunate. Vitamin E has other functions than that of preventing sterility. In time it became known that under certain conditions rats become paralyzed if deprived of vitamin E for a sufficiently long period of time. Under certain conditions guinea pigs and rabbits may also develop paralysis if their rations do not contain this vitamin.

Symptoms of a deficiency: In the rat, sterility and paralysis.

In the chick, paralysis.

In the rabbit and guinea pig, paralysis, especially if cod liver oil is present in the diet.

Stability: This vitamin is destroyed readily by oxidation, especially in the presence of rancid fat. Under practical conditions of feed storage, however, it is preserved for months.

Sources: Green forage, whole grains or other seeds. The vitamin is so widely distributed that a deficiency seems improbable.

Vitamin K.—Although this vitamin is placed in the list of those that are unlikely to be deficient, it is known that pathological conditions may occur that are remedied by administration of vitamin K. New born babies sometimes develop a defect in the blood-coagulation mechanism and die of hemorrhage. This is one of the more common causes of infant mortality, but it is easily controlled by administering the vitamin. Cattle, also rabbits, sometimes develop a similar defect, caused by consuming spoiled sweet clover hay. In severe cases the animals die from internal hemorrhage. Recent experimental work indicates that the disease can be cured by treatment with vitamin K. It is possible to produce this same bleeding abnormality in chicks by supplying them with experimental rations from which the vitamin is rigidly excluded, but the preparation of such a diet requires elaborate precautions, and considerable skill. The disease can also be produced in the new born young of guinea pigs, or rabbits, but only by employing a rather difficult technique. The disease occurs but seldom, or never, under practical conditions.

Symptoms of a deficiency: In man and in chicks, hemorrhage due to a defect in the blood-coagulation mechanism.

Stability: The vitamin is not readily destroyed.

Sources: It is probably present in all practical feeds. Alfalfa is an excellent source and probably all forages contain liberal amounts.

Choline.—*Symptoms of a deficiency:* In rats, fatty livers; hemorrhagic kidneys; retarded growth.

In the chicken, fatty livers: interference with egg laying; perosis in the baby chick.

Stability: Choline is not readily destroyed.

Sources: Little information is now available, but the supply of choline is probably not an important problem. There is reason to believe that the inclusion of soybean oil meal in the ration of growing poultry will supply the choline required to prevent perosis.

Vitamin B₆, or Pyridoxine.—*Symptoms of a deficiency:* In the rat, reddened, inflamed paws, muzzle; swollen eyelids; fits. In the chick, jerky, abnormal gait; collapse.

In the pig, fits.

In the pigeon, anemia; dermatitis of the legs and feet; poor feathering.

In the dog, anemia; convulsive fits.

In man, fissures, or cracks, in the corners of the mouth. There are reports that a few obscure diseases in man have been partially relieved by the administration of pyridoxine.

Stability: Pyridoxine is not readily destroyed.

Sources: Is widely distributed in all natural foodstuffs and a deficiency is improbable.

Pantothenic Acid.—*Symptoms of a deficiency:* In the rat, reddened, inflamed paws, muzzle; swollen eyelids; necrosis of the adrenal glands; black haired rats turn gray.

In the chick encrusted skin at angle of mouth, rough skin on legs and feet; cracks in the skin occur around the mouth and on the toes and feet.

In the pig, loss of hair; diarrhoea; inflammation of stomach and intestines; abnormal gait (goose-step).

It has been asserted that gray hair of man can be restored to its natural color by the administration of pantothenic acid, but this sounds improbable, and satisfactory data in support of the assertion are lacking. At present this method of restoring natural color to gray hair is not recommended.

Stability: Pantothenic acid is not readily destroyed by the ordinary manipulations of preparing food or feeds. It is destroyed by either strong acid or alkali.

Sources: It is widely distributed in all natural foodstuffs and a deficiency is improbable.

Biotin.—*Symptoms of a deficiency:* In the rat, awkward gait, humped back; loss of hair, closed eyelids; dark, roughened skin.

In the chick, redness and encrustation around eyes and corners of the mouth; legs and feet scaly and rough; perosis.

The amount of biotin that is required is very small, and it is difficult to remove biotin from a diet with sufficient completeness to permit a deficiency to develop. If uncooked egg white is included in the diet it makes this biotin unavailable to the animal and a deficiency is developed with ease. This observation supports the commonly held opinion that egg white should be cooked before it is consumed.

Stability: Biotin is quite stable.

Sources: It is widely distributed and a deficiency is improbable.

Inositol.—*Symptoms of a deficiency:* In the mouse, failure to grow; almost complete loss of hair.

Observations on other animals are too recent, and too few, to permit any positive statement. It has been asserted that inositol prevents one type of fatty liver in the rat, and that it accelerates the growth of the chick.

Stability: Inositol is quite stable.

Sources: It is widely distributed and a deficiency is improbable. There is no reason now to believe this substance is of any practical importance.

Para-Amino Benzoic Acid.—Comparatively little has been published concerning the activity of this compound as a vitamin, and it is too early to decide whether the claims that have been made can be substantiated. As yet none of these claims has passed beyond the controversial stage.

Symptoms of a deficiency: In the rat, black-haired rats turn gray; interference with lactation.

In the chick, the growth rate is retarded.

In man, it has been reported that the administration of this compound will restore normal color to gray hair. A prudent person will not try this treatment until it has been shown that it is effective, and harmless.

Stability: The compound is stable.

Sources: Very little information.

Unrecognized Vitamins.—Thus far fourteen different compounds have been described, which are vitamins, or have been reported to be

vitamins. Similar claims have been made for a few other substances, but since they have received scant attention even by specialists in vitamin chemistry, they are omitted from the list. There is no doubt that other vitamins do exist, because a diet which contains no vitamins except those now recognized is partially deficient. This has been demonstrated with rats, guinea pigs, chicks, and swine. If these diets are reenforced with suitable crude sources of vitamins, such as liver extracts, they become complete in every way, presumably because the extracts contain unrecognized vitamins that are essential. Several investigators have studied these vitamin extracts, and have found that they contain a factor that prevents, or cures the particular deficiency disease under observation. For convenience each of these factors is given a separate designation, usually a letter of the alphabet. In all probability several investigators have found need for each separate factor, or unrecognized vitamin, and as a result there are probably more names than there are unrecognized vitamins. As to the actual number of these factors, it would be hazardous to make a prediction. There is certainly one, there are probably at least two or three, and it is possible that there are several times that number.

Unpublished data of the Missouri Agricultural Experiment Station indicates that at least one of these unrecognized vitamins is of limited distribution, and that it is of considerable practical importance. Although we know very little about the vitamin, we do know how it can be supplied. It is certainly present in adequate amount in fresh growing grass, and whenever possible this kind of feed should be supplied in abundance to all types of livestock. If this is done there is convincing reason to believe that there will be no deficiency of vitamins. The provision of high quality pasture would solve many difficult nutritional problems. There are equally convincing reasons to believe that vegetables, especially the leafy vegetables, would vastly improve the diet of many human beings. Although there are unrecognized vitamins concerning which we have little information, there is justification for some confidence that we know how all of them may be supplied. In this connection it should be emphasized that food is the proper source of vitamins and proper dietary habits will supply them. Pure vitamins and vitamin mixtures, have their proper place, if taken under the guidance of a dietitian or physician. They may be helpful to many individuals with bad food habits, but they are not a substitute for proper food, and they cannot be depended on to maintain optimum health.

THE PROVISION OF AN ADEQUATE VITAMIN SUPPLY NEED NOT BE A BURDENSOME TASK

One finds a wide variety of attitudes to the precautions that should be taken to secure an adequate vitamin supply. At one extreme is the individual who is completely indifferent and gives the problem no thought at all. At the other extreme is the individual who is too much concerned, and almost makes a profession of counting vitamin units. Other publications should be consulted by those seeking assistance in planning diets, but a few remarks may be helpful to those who make a burdensome task of their personal vitamin supply.

It is not necessary that each meal should provide its mathematical quota of any vitamin. In fact it is not necessary that any three meals should do so. The body carries some reserve of every vitamin, though there are enormous differences between vitamins in the amounts that may be accumulated, and in the tenacity with which they are retained in the body. Presumably the body can retain enough of each of the fat-soluble vitamins, A, D, E, to tide it over a long period of scarcity, certainly for several weeks. It is commonly assumed that the amounts of the water soluble vitamins in the body can not be greatly increased over the normal level, and that reserves are retained for comparatively short periods. However, our information on this point is very meager. It seems certain though that if the vitamin supply had been generous previously, it would do no harm if, for three or four days at least, the diet were completely devoid of any specific vitamin. Such periods of deprivation are ordinarily unnecessary and should be avoided, but the fact that they are not attended with detectable injury demonstrates that constant preoccupation with the vitamin supply is a useless waste of time. Either extreme then is to be avoided. A more reasonable attitude is to adopt a flexible but consistent daily dietary regimen that includes approved quantities of the protective foods. Other publications of this institution contain detailed specifications for such diets.