Some Phases of Mineral Nutrition

by

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Originally, nature apparently intended that animals should be adapted to exist in an atmosphere of air and to derive their food from plants—directly in the case of herbivora and indirectly in the case of carnivora. Thus, the elements commonly known as minerals were obtained mainly from plants which in turn obtained minerals from the soil. A small and variable portion of the mineral intake from drinking water was and is likewise derived from the soil. Animals of various species were scattered over the earth in areas where the climate and the soil were favorable to their existence. Therefore, one might argue that a natural diet theoretically supplies all the elements required in the nutrition of animals.

However, man has multiplied and has become civilized (supposedly). In this process the natural conditions known to Adam and Eve have been gradually changed, and artificial conditions have been imposed. Man has changed the composition of plants and the requirements of domesticated animals.

Plant Composition Changed

First, the composition of soils predetermines the composition of plants. Man is growing crops for livestock on soils of different natural composition. For example, soils in certain areas are known to be deficient in available phosphorus, iodine, and other elements, with resulting deficiencies in the crops.

Second, crops have been grown on soils to which they were not naturally adapted. This has been done by fortifying these soils with certain fertilizers. Nature never intended that we should import potash from Germany (or now, southwestern United States) or nitrates from Chile (now from the air). Man has done so without complete knowledge of the optimum mineral composition of the soil for each crop or the effect of soil composition on plant composition.

Third, vast areas of land, naturally arid, are now being irrigated artificially. Recent results in Utah have emphasized that the mineral composition of plants on such soils is increased. However, relatively little is known of how much "ditch" water is required, of when it should be applied, or of how subsequent leaching affects soil and plant composition. In periods of water shortage drought in these irrigated districts also has a pronounced effect on plant composition.

Fourth, man has failed to return to the soil those elements removed in crops. Deficiencies of available nitrogen, potash, and phosphorus are well known. Manganese deficiency in poultry is now common on practical rations under certain conditions, presumably partly because of changing composition of soils and hence of feeds.
Fifth, man has caused overgrazing of certain areas, thereby killing off natural herbage and lowering yields through weakened and depleted root reserves. This has allowed weeds to creep in. Such weeds may be of little nutritive value or may be poisonous to livestock through organic properties or through the high concentration of such elements as selenium.

Sixth, new varieties are being developed with primary regard to weight of yield and with little attention as yet to actual mineral composition.

Animal Requirements Changed

Man has intensified the requirements of his domesticated animals for nutritives by breeding for intensive production of meat, milk, and eggs. This has been further aggravated by modern methods of management and feeding. Wild birds may lay a dozen or two of eggs in a year, but man has bred, fed, and managed the fowl to the point where flock averages of 200 eggs per bird per year are the usual expectation. In calcium output alone this has been an increase from about 20 grams to about 400 grams.

Domesticated animals have been placed under unnatural environmental conditions. Range in certain areas has been restricted to barnyards. Sanitary pig pens with concrete floors are common. Individual laying cages and battery brooders are here to stay. The chicken now may live its lifetime without seeing Old Sol or touching Mother Earth. Such animals depend entirely on rations given them by man.

Man has bred his animals for increased production, failing to recognize that nutritional requirements are probably hereditary. Recent experimental evidence with poultry strongly suggests that differences exist among individuals, strains, and breeds in requirements for manganese, vitamin B₁ and riboflavin.

Supplementation Essential

As a result of these changes in plant composition and intensification of the requirements of animals for nutritives, changes which are still going on as civilization continues to become more complex, it has been necessary to supplement rations. Insofar as minerals are concerned, it has been more economical to remedy the deficiencies of feeds directly in the ration rather than by "feeding" the soil, except where crop yield has been affected. Today we recognize that calcium, phosphorus, magnesium, sodium, potassium, chlorine, iodine, sulphur, copper, iron, cobalt, manganese, zinc, and possibly nickel and arsenic are essential elements to animals. Of these elements, deficiencies of calcium and phosphorus are relatively common, owing largely to the high requirement of animals for these elements in the skeleton. A deficiency of sodium (and possibly chlorine) is uncommon since most farmers are feeding salt to their animals. Iodine is a limiting factor in the more deficient areas of the goller-belt, namely, the Northwest, the northern Great Plains, and the Great Lakes Basin. Manganese deficiency is quite common in poultry, particularly under intensive methods of production. Iron, copper, cobalt, and possibly magnesium deficiencies are largely localized and relatively rare. Deficiencies in the other minerals are as yet essentially laboratory phenomena obtained only under carefully controlled conditions.
Supplementation of rations with additional minerals should be done only when deficiencies are found in feeds by comparison with the known requirements of animals, or when deficiency symptoms in farm animals are observed in definite areas.

Analysis of feedstuffs may not show their true nutritive value because certain minerals, even though present in feedstuffs, may not be assimilated by the digestive system of animals. For example, it is well known that iron varies in availability in different feeds and that phytin phosphorus in plants is not entirely digestible by certain species.

Analysis of soils likewise is not entirely dependable, since chemical determinations do not always express the amount of available elements or the complex relationships between minerals in soils. For instance, a highly alkaline soil may render the manganese present relatively insoluble, or a high manganese soil may render iron unavailable.

**Recognizing Common Mineral Deficiencies**

To be useful, deficiency symptoms must be specific. Growth, reproduction, and apparent health are not diagnostic. A few specific symptoms of common deficiencies follow.

Lack of salt causes no marked deficiency symptoms, but efficiency of feed utilization is lowered and the animals crave salt. As mentioned, the need for salt is almost universally recognized and met.

Calcium deficiency results in lowered inorganic calcium in blood serum of animals. Bones are hard but are thin and brittle. Egg shells become thinner. Such a deficiency is common in ruminants, especially cattle, on non-leguminous hays and grain, and in hens which need so much of this element for egg shells. Developing pullets need calcium supplements, owing to their high consumption of grain. Pigs are prone to calcium deficiency. In pigs this deficiency causes posterior paralysis, a fracture of the vertebrae, unless tankage is used for a protein supplement or unless limestone or bone meal is used in proper amounts.

Lack of phosphorus is indicated by low inorganic phosphate content of blood, and by bone-chewing, soil eating, or abnormal appetite (pica), especially in cattle. It is common in animals on hay or grass, particularly when the soil is low in phosphorus and when the ration is not supplemented with protein carriers. Protein supplements are usually rich in phosphorus. However, poultry or hog rations utilizing large quantities of vegetable protein concentrates may require supplementation with some bone meal. Sheep apparently have about the same requirements for calcium and phosphorus as cattle.

Iodine deficiency is commonly recognized by goiter in farm animals. Hairless pigs are also caused by such a lack. Where these symptoms are found, iodized salt is commonly used or larger amounts are supplied by the use of potassium iodide. More attention is given to iodine later in this talk.
Manganese deficiency in poultry is recognized specifically by perosis in chicks, pouls, and young game birds three to eight weeks old. It is easily remedied by using liberal quantities of feedstuffs rich in manganese, such as shorts and rice bran, by adding manganese sulphate to the ration where need is indicated, and by limiting calcium and phosphorus. Deficiency of manganese in other farm animals is not yet recognized. This element will also be discussed in greater detail later.

Iron deficiency is the commonest cause of nutritional anemia (low blood iron and hemoglobin) in this country. It is not uncommon in suckling animals but it is not yet recognized to be of economic importance except in newborn pigs reared away from the soil. In this case painting the sow's udder with a saturated solution of iron sulphate is efficacious in preventing weak, anemic suckling pigs. Giving the pigs access to fresh, clean soil is another remedy.

Copper and cobalt deficiencies also cause anemia, but fortunately only a small area in Florida is known to be deficient in these elements in the United States. A mere trace of these elements in cheap inorganic forms suffices as treatment and preventive.

How Much Minerals

Much research in State and Government Experiment Stations and in other laboratories has given a fair idea of how much of these essential elements is required in many instances. Recent figures for various farm animals are presented in the 1939 Yearbook of Agriculture, "Food and Life". If it is known how much mineral there is in the feeds used in the ration and what the requirements are, it is usually a simple matter of mathematics to determine whether mineral supplementation is essential. As a rule, tables of average analyses as found in Morrison's "Feeds and Feeding", and in the 1939 Yearbook of Agriculture, suffice in estimating the adequacy of rations in various nutrients including minerals. Of course, chemical analyses of each lot are much more definite. Fortunately, ingredients of a known grade or source tend to be more or less uniform. Thus in poultry rations, the formulas are calculated to satisfy requirements for protein and fiber, calcium, phosphorus, and vitamins A, D, and G, and such analyses rarely fail to be in remarkably close agreement with actual ones.

With our present limited knowledge of actual requirements and as a general rule, feed manufacturers and feeders would do well to formulate rations adequate in protein, fat, fiber, calcium, phosphorus, and vitamins, to supply adequate salt, and not to worry about other minerals unless deficiencies of them occur in their trade area. Lack of iodine and manganese are the two most common of deficiencies.

Manganese

Manganese is known to be required by poultry for normal growth, egg production, and hatchability. A deficiency is manifested by perosis and subnormal bone development in young poultry three to eight weeks old, lower egg production, weaker egg shells, lower hatchability accompanied by nutritional chondrodystrophy (failure or normal cartilage development) in the embryos, and head tremors in newly hatched chicks. Recent evidence shows that excess calcium and phosphorus
supplied by too much bone meal, limestone, or oystershell in chick rations cause more perosis by precipitating in the digestive tract and combining with the manganese there, making it unavailable to the chick although chemical analysis shows plenty to be present in the ration. Excess iron also may render manganese unavailable in a similar manner. Bone meal or bone in meat scrap seems to aggravate perosis less when finely ground than when coarsely ground.

Recent evidence from Wisconsin indicates that direct sunlight aids in manganese utilization. More recent evidence from Missouri and Cornell indicates that there is a specific organic factor aiding in manganese utilization. Manganese deficiency in poultry is common in chicks on wire floors and in batteries, especially in heavy breeds. It is prevented by limiting calcium and phosphorus to optimum levels and by using liberal quantities of wheat shorts or middlings or of rice bran, since these by-products are rich in manganese and are presumably rich in the organic preventive-factor. These steps usually suffice for birds under floor and range conditions with sunshine. Where feeds are designed to be used under all conditions, it is probably advisable precaution to add 50 p.p.m. of manganese to the mash by adding 4 ounces of manganese sulphate powder (at least 90% manganese sulphate) to each ton of feed. This has been shown to be well under any levels caus ing toxic effects. Natural manganese carbonate is not utilized by poultry. A few cases of early perosis are usually found even on the best of rations.

**Iodine**

The physiological necessity for iodine in the formation of thyroxine by the thyroid gland is well known and needs no elucidation. Equally well known is the function of this hormone in regulating body metabolism. Less well established is the possibility of another factor or factors in the thyroid important in the maintenance of the balance between thyroid function and that of the other endocrines. There are some indications of a relationship between iodine or thyroid activity and calcium metabolism. Some evidence has also been presented that the functioning of certain vitamins may be related to thyroid activity. Goiter resulting from iodine deficiency has been recognized in farm animals, including poultry, for many years in the northern states from the Northwest to the Great Lakes Basin. Peculiarly enough, very little has been done to determine the actual iodine requirements of farm animals or even to determine whether the prevention of goiter in itself is sufficient to assure that the animal is receiving enough iodine. Recommendations given at the present time are largely the result of trial and error and have been worked out from such observations and expressed in amounts easily measured with such devices as the farmer has available. Inorganic sources of iodine are as efficacious as organic sources.

No real effort has been made until recently to produce goiter experimentally in a farm animal and then to determine the actual amounts required not only to prevent goiter but also to give maximum and most efficient growth, production, and reproduction. In 1928 such a project was started with poultry at the Colorado Experiment Station, part of the expenses of this investigation being defrayed by the Iodine Educational Bureau. Considerable work had been done previously at
several institutions in this and other countries, but no serious attempt had been made to produce goiter, and the experiments were carried on for only a limited period in the life cycle. The present investigation is designed to study various iodine levels through the complete life cycle for at least two generations.

Thus far, goiters as great as sixty times normal size have been experimentally produced on known low levels of iodine. These studies have been complicated by the discovery that soybean oil meal contains a goitrogenic factor and by the fact that liberal quantities of this feedstuff have been used in this work. At present a practical type of ration is in use. Observations on birds in the second generation on low, medium, and high levels of iodine are in progress. Goiter has been observed on this type of ration, even with a fish oil as vitamin D carrier. A number of common feedstuffs have been analyzed, and many samples have been found to be very low in iodine. The city water in Fort Collins has been practically devoid of this element. As yet it is too early to draw conclusions as to the levels of iodine required by poultry, but this evidence is expected to be available within a year.

In reference to the goitrogenicity of soybean oil meal, this particular effect can be readily overcome by iodine. This Station is still recommending the use of this valuable protein supplement in very liberal quantities in its poultry rations.

Observations are also under way at the Colorado Station on the need for iodine by lambs, ewes, and steers.

Mineral Mixtures

It is obvious from this presentation that a complex mineral mixture of the familiar "shot-gun" variety is not to be recommended, for economic reasons if no others. However, it should be pointed out that not only is the addition of minerals beyond their required amounts incapable of any additional benefits or of any "tonic effect", but such an addition in excess of requirements may prove to be highly detrimental. The unintelligent recommendation of a mineral mixture for any kind of "leg-weakness" in chickens is an all-too-well-known-example. Very often such leg weakness is perosis and is only intensified by more minerals.

Specifically, excess of the mineral elements most frequently found in the various mineral mixtures is harmful in the following ways. If phosphorus is already approaching the minimum requirement, excess calcium may cause a low-phosphorus type of "rickets" by causing a heavy excretion of phosphorus from the body. Conversely, a large excess of phosphorus may cause low-calcium "rickets". Calcium and phosphorus in excessive quantities render manganese unavailable, as already mentioned, and also interfere with iron and probably iodine assimilation. Excess iron not only prevents manganese assimilation but may cause a phosphorus deficiency by forming insoluble iron phosphate in the intestines. Excess manganese, likewise, may form a relatively insoluble
phosphate and in addition is quite toxic. Cobalt and copper are toxic in amounts which are considered mere traces by the layman. Fluorine is also toxic in trace quantities and has caused heavy losses through the use of rock phosphate and its derivatives which are usually very high in fluorine unless carefully treated. Boron at a level of 0.1% is toxic to chickens. Sodium bicarbonate in excess causes kidney degeneration in chicks. Under certain conditions sulphur will cause rickets in chicks, even with vitamin D oils present.

Not only may excess of minerals be harmful, but certain forms of minerals may be unavailable to the animal. Thus iron oxide, a nearly universal component of such mixtures, is very ineffectively used by animals. Natural manganese carbonate, as rhodochoresite, is not available to the chick, and yet large quantities of it have been sold specifically for poultry feeds, a fact which may account for much of the porosis in chicks and fowls presumably getting manganese supplementation.

Use Your State Experiment Stations

Feed manufacturers, farmers, and ranchmen should remember that the State Experiment Stations were founded to solve the problems of agriculture, particularly in their area. Scientists in these Stations are working on all the problems their funds will permit and in addition are in touch with the results of state, government and industrial research institutions all over the world. In order to get the benefit of this world-wide research, make use of your State Experiment Station. Follow its recommendations in mineral feeding, since your Station knows the mineral deficiencies in your State.
July 13, 1940

Mr. Marvin J. Russel
Station Editor
Administration Building

Dear Mr. Russel:

I am returning herewith the Publications Committee report with an attached letter from Dr. Thorp together with a copy of the final draft of the paper in question. Dr. Washburn also went over this paper and I have incorporated suggestions by both of these gentlemen.

Sincerely yours,

H. S. Wilgus, Jr.
To the Publications Committee composed of [Handwritten]:

Attached is a manuscript submitted by [Handwritten].

of the Poultry Section(s), entitled "Some Phases of Mineral Nutrition"

(general series bulletin
technical bulletin
for publication as a scientific journal series article in
misc. journal series article in

Please submit any recommendations in writing at your earliest convenience.

Date May 22, 1940

U.E. Neebser
Director

To the Director:

Following (or attached) are our recommendations concerning this manuscript:

Date 19

Publications Committee

(5338-40)
Dr. I.E. Newsom  
Campus  

Dear Doctor Newsom:

In going over the article entitled "Some Phases of Mineral Nutrition" by Dr. Wilgus, the following suggestions might be in order:

On page 1, paragraph 5, oat hay poisoning, due to potassium nitrate, might be mentioned in connection with the effect of soil upon plant composition.

On page 3, paragraph 7, the last line might be changed to read "Sheep apparently do not have as an intense requirement for calcium and phosphorus as cattle".

On page 4, paragraph 2, in connection with anemia in pigs, the use of clean soil in the farrowing pens is oftentimes recommended. I appreciate the fact that from the standpoint of sanitation it is sometimes difficult to make a farmer see the necessity of getting soil that has not been in recent contact with animals. For that reason there may be some doubt as to the advisability of incorporating that statement in this article.

Very truly yours,

Frank Thorp, Jr.  
Associate Pathologist