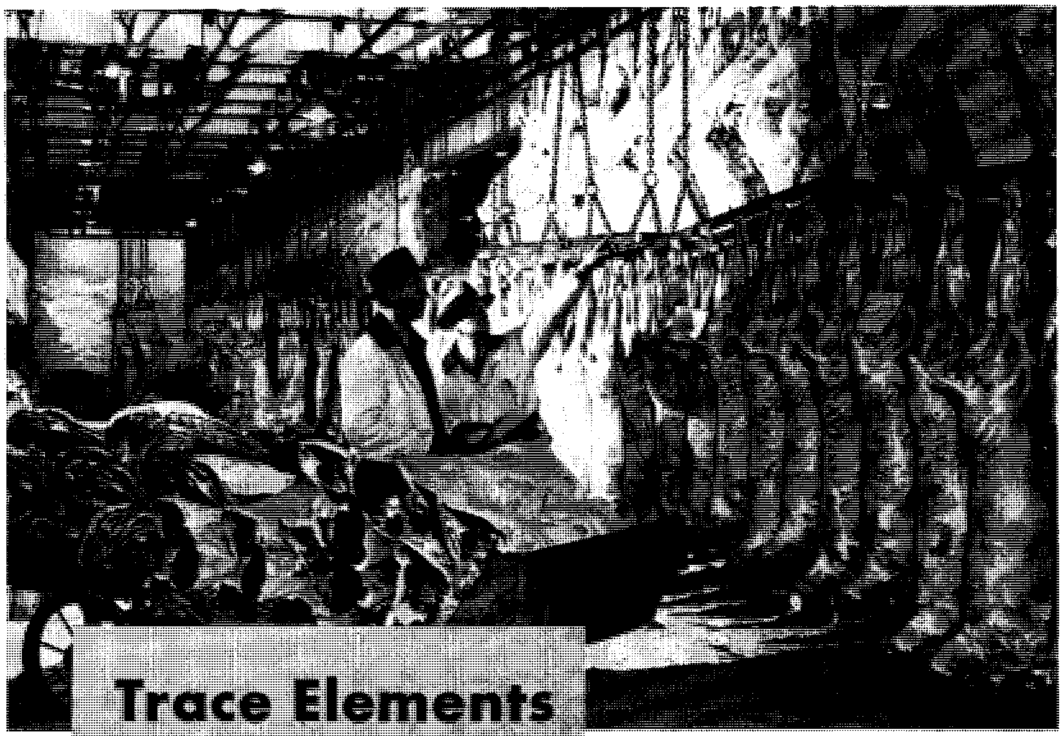

Trace Elements from Feed to Food

Animals suffering serious mineral deficiencies do not furnish meat for our tables

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IODIZED SALT and the control of at least one type of goiter by the use of a very small amount of iodine first put the public spotlight on minor elements in the human diet. It brought attention to other elements that occur in the human diet at levels of a few parts or even a few hundreths part per million. The inorganic micronutrients have been shown to have such remarkable effects on animal metabolism that questions have been raised as to how we can be sure our daily diet is adequate in copper, cobalt, manganese, zinc, and iron.

Startling information about the function of these elements in plant and animal nutrition has come from investigators at research stations in the U. S. as well as other countries. The work of these scientists not only has taught us much about the place of trace elements in animal and plant nutrition, but it also has provided assurance that the human diet built adequately on foods of animal origin combined with vegetable from our commercial growing areas, is well supplied with the trace elements that are the spark plugs of metabolism.

Organic farming on the grand scale provided one of the best laboratories for the study of trace element needs of both plants and animals. The muck and peat soils of the world are some of the most fertile—provided they are adquately supplemented with the mineral elements they lack.

A full story could be devoted to the complete failure of sugarcane in the Everglades until the need for trace elements was recognized. With proper use of those trace elements, sugar cane production has become big business. Similarly, potatoes, peanuts, beans, leaf vegetables, corn, and celery were failures. But with the aid of trace elements, vegetables of superior quality in great quantities have built a multimillion dollar business in the Glades.

Today, vegetables from the Everglades area consistently equal or exceed, in trace element content, those from other areas. By their own needs, these vegetables supply a safeguard to human diets (*8*).

Copper

Copper is one of the trace elements with an intriguing story in plant and animal nutrition. For nearly 140 years it has been known that copper is widely distributed in plants and animals. Yet it was less than 30 years ago that conclusive evidence was presented by scientists at the Wisconsin Experiment Station that copper played a vital role in the formation of hemoglobin not as a part of the hemoglobin molecule but as an accessory factor that permitted iron to be used as a part of this most vital pigment of the blood (*10*).

Demonstration that copper played an important part in animal nutrition did not prove that a copper deficiency ever occurred in farm animals, let alone humans. The usual feeds and forages appeared to be adequate to meet animal needs. For many years

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farmers of the countries with high organic soils and farmers of sandy areas that experience high rainfall have known that cattle and sheep on these areas did not do well. The experience of the Everglades farmers is typical and can be duplicated by reports from other parts of the U. S., England, The Netherlands, Australia, and New Zealand.

In 1942 approximately 2000 cattle were on pasture in the Everglades portion of Palm Beach County. Most cattle owners knew that cattle kept longer than six months would "go to pieces" and most animals were kept in the lush abundant pastures for a period of fattening and then moved on to other pastures or to market.

Prior to 1942 copper deficiency had been identified. It was known that good crops of vegetables and improved pastures could not be grown without copper fertilizer supplements. Copper was usually added as copper sulfate but other forms were also used. Very high levels were often added. As much as 50 pounds to the acre frequently was applied and followed by yearly supplements.

But the copper added as fertilizer did not help the animals grazing the pastures. It certainly helped the plants, for tremendously increased yields resulted. In some instances the application of copper sulfate changed a complete growth failure into a yield of 40 to 60 tons of fresh forage per acre.

This was the stage when a series of experiments was begun by the scientists of the Florida Agricultural Experiment Stations in 1942 in an effort to determine why cattle fared so poorly in the midst of such abundance.

Out of this research has come the knowledge that copper levels of some forages may never exceed 12 to 15 p.p.m. of copper in the dry matter, even with heavy copper fertilizer applications. On alkaline muck soils the copper does not remain available and plants of a given species seem to have a ceiling level for the element. But a level as high as 12 p.p.m. is a super abundance of copper for cattle on Florida soils other than the highly organic. Somehow, something was interfering with copper utilization.

Working in England, investigators in 1938 (7), had reported an effect of molybdenum that looked like copper deficiency. So soils, water and forage of the Everglades experimental pastures were analyzed for molybdenum.

Molybdenum was present in small amounts in some areas and in much larger amounts in other areas. Gradually the molybdenum-copper-phosphorus interrelationship began to unfold.

Cattle on these pastures rapidly lost any reserve of copper and developed a characteristic syndrome. First sign was a gradual failure to gain in weight. This was followed by a fading of the hair coat color, a true achromotrichia. Anemia of increasing intensity followed until some animals had a hemoglobin level of about one-third the level normal in the blood. Bone metabolism was changed and multiple fractures were frequent. In very young animals a rachitic-like change appeared in the bones. Death often followed quickly unless supplements of copper were administered to the cattle.

Between 0.5 and 2.0 grams of copper sulfate per day per cow proved to be adequate to protect the cattle and permit a normal animal husbandry enterprise. When the copper was supplied as fertilizer to grow grass and mineral supplements containing copper in increased amounts were fed to counteract molybdenum, cattle production soared.

In 1954 the cattle population of this area exceeded 50,000. Today, gains per acre are excellent and carrying capacity may exceed 3 or 4 animals per acre for much of the year. A trace element study has paid well (*6*, *9*).

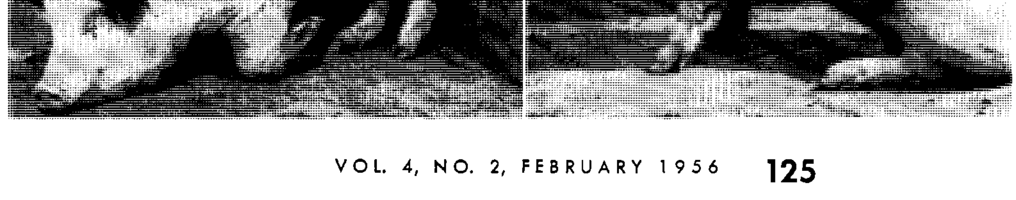
In those experiments, 1 to 2 p.p.m. of molybdenum in the dry matter of the forage fed cattle doubled the need for copper in the diet.

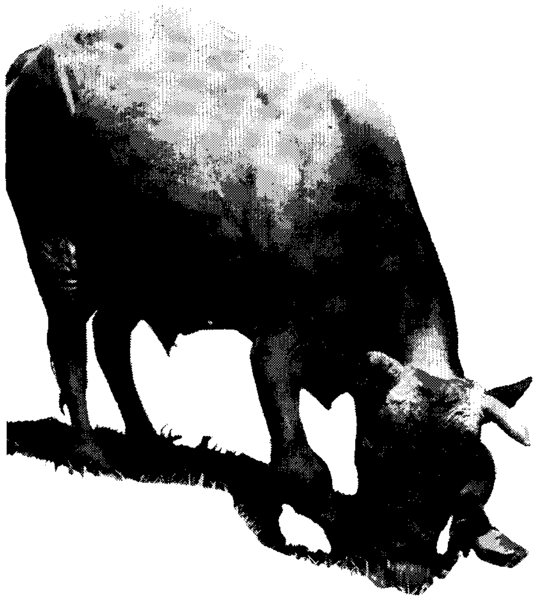
Repeated experiments with swine, rats, and rabbits have demonstrated that molybdenum has much less potential for toxic action in the monogastric animal than in ruminants. In showing the investigators a vital role for copper and an antagonistic action of molybdenum, experiments with cattle have demonstrated a specific value of beef in the human diet. If the meat reaches the market, the cattle have already demonstrated the adequacy of the dietary item so far as copper is concerned. Cattle which have not received and concentrated in their tissues far more than enough copper to supply the needs of humans consuming ordinary quantities of their meat are not able to get to the sales pen.

Cobalt

In 1776 a visitor to Florida (*2*) saw and later reported a condition among the cattle of the Indians that were pastured on the Alachua savannah (now called Payne's prairie) that certainly could have been a description of "salt sick" seen by later Experiment Station investigators. "Salt sick" was a Florida name for a condition called pining, bush sickness, sea sickness, coast disease, vosk, and many other names in as many different parts of the world. Cattle and sheep had to be moved from "sick" to "healthy" pastures or they appeared to starve in the midst of abundant forage. As the cattlemen put it they "dried up and

Pigs suffering from manganese deficiency are unable to get about satisfactorily. Can be caused by increased calcium and phosphorus levels without added manganese





Symptoms of serious dietary deficiencies are obvious in this bull. But his offspring were normal healthy animals which prospered on a sound diet

died." The animals looked starved, reproduction was very low in affected herds, and the hair coat failed to shed out. An anemia developed, the flesh seemed to dry up on the bones, and eventually the animals died.

For a long time research workers made little progress. They discovered that the animals responded to additional feed when it came from other areas. Many factors pointed to a nutritional disease but many suggested parasites and, because one of the symptoms was loss of appetite, there was indication of plain starvation.

Workers in Australia found that a crude soil amendment of limonite, applied as a source of iron, gave remarkable results with the sheep. But iron salts did not. Thus it was discovered that cobalt was a necessary element in the nutrition of ruminants. This discovery was announced in 1933 and began a long series of reports (*15*). But for many years the only real test for cobalt deficiency was to feed cobalt salts and observe the results: if the animals recovered they had needed cobalt. The methods of analysis available were not sensitive enough to detect the small differences between adequate and inadequate levels of cobalt. Despite this, Florida workers demonstrated that much of the condition known as "salt sick" was actually caused by cobalt deficiency (*3, 16*).

Today, with better methods, it has been shown that a level of 0.07 p.p.m. of cobalt in the dry matter of the ration is necessary to prevent cobalt deficiency under any conditions. A level as low as 0.04 p.p.m. will do the job most of the time. These methods have also shown that vast areas of the country have forage that does not contain this much cobalt, for levels of 0.01 p.p.m. are common.

To date no one has demonstrated that cobalt has a function in plants. However, it is well established that cobalt fertilizers increase the content of the pasture forages and in many parts of the world this has become a satisfactory means of preventing cobalt deficiency.

In Florida it is well known that most of the grazing land is deficient in cobalt and that element is supplied by mineral supplements which contain 0.01% or more of cobalt. Cobalt salts applied as fertilizer remain effective for perhaps three to four years. A pound of cobalt sulfate or other salt per acre is the usual application and the cost of spreading is considerable. Since a pound of cobalt sulfate will take care of the needs of a thousand cattle for a year in the form of a mineral supplement this has proved the most economical method of meeting cattle needs.

With the report that cobalt was an integral part of vitamin B_{12} (*19, 20*) it assumed a new importance in nutrition. B_{12} was effective in the treatment of pernicious anemia and the whole problem of cobalt nutrition of ruminants was reexamined.

Early work seemed to show that vitamin B_{12} would not take the place of cobalt, but the difficulty was one of degree. When Cornell workers injected sufficient quantities, vitamin B_{12} corrected a cobalt deficiency (*4, 21*). Cobalt appears to be converted to vitamin B_{12} in the rumen and the high requirements of ruminants are met in this way. When the cattle and sheep prosper well enough to become slaughter animals they have become rich sources of a vital nutrient for the human diet.

Iron

The need for iron in the diet of animals and humans has become common knowledge. Yet the information regarding minimum levels that are satisfactory for adults is limited.

A deficiency of iron does cause the dramatic change in hair coat color, broken bones and quick death of copper deficiency, nor does iron deficiency present the picture of starvation that accompanies cobalt deficiency. In fact, producing a severe iron deficiency in mature animals or humans that have had ample iron is very difficult unless hemorrhage occurs.

Since hemorrhage is the rule rather than the exception, iron in the diet is a necessary factor in maintaining the hemoglobin level. Meat and eggs are again a safety factor in insuring adequate iron intakes.

Iron deficiency is principally a problem of young growing animals because of the need for growth and hemoglobin formation. This very fact provides us with a safety gage: animals that reach maturity have in their tissues iron enough to meet human needs with some to spare.

The new born young of most species have abundant stores of iron in the liver. This is one of the reasons we use calf liver in our diets. Because milk is low in iron the nursing young must draw on the reserves of iron until they can start eating other feeds. The need for iron to prevent chlorosis in plants serves also as an indicator that the animal that eats good pasture or the human eating green leafy vegetables is getting at least a minimum amount of iron.

The human in his varied diet supplements the iron of plant-origin foods with the iron of animal-origin foods and provides more than adequate amounts for metabolic requirements.

In animals the problem is complicated by the hemorrhage that comes with parasite attack and in swine with low stores in the livers of baby pigs. Baby pig anemia or "thumps" long has been recognized by farmers and before iron need was recognized it was known that putting the pigs on soil or putting a piece of sod in the pen prevented the anemia.

Iron Supplements Needed in Diets of Young Animals

While young animals may get adequate amounts of iron from plants that make up their diets, often iron supplements are needed in order to take care of blood loss. Few indeed are the areas where animals do not suffer from parasites ranging from internal microscopic worms to biting flies and mosquitoes. This blood loss may be excessive at certain periods of the year and to permit rapid replacement

Slipped tendon or perosis in a chicken fed an inadequate level of manganese.

additional sources of iron prove valuable.

Commonest of the iron supplements probably is ferrous sulfate, but many other forms prove valuable, including the relatively inert iron oxide which still serves as a source of iron when the animals have a dietary need.

From the standpoint of human food the need that animals exhibit for iron is a first line of defense. Because of this need, meat and eggs ensure us of a good iron containing diet.

Manganese and Zinc

Manganese and zinc are two trace elements known to play an essential part in animal, plant, and human nutrition. The detective story of their function and importance in many respects is still in the beginning chapters.

As the tempo of chicken production increased, the level of calcium and phosphorus in the diets of the birds frequently was increased and often perosis or "slipped tendon" developed. This problem of apparent nutritional origin was found to be largely caused by inadequate manganese level in the diet (*11, 23*)

Manganese that could be shown to have a vital role in nutrition in rats, only where specially purified diets were prepared, (*18*), had been shown to prevent most "slipped tendon," to improve egg shell quality, and egg production, and to increase fertility in poultry. Under the pressure for greater production, the needs of poultry were shown to be high and the deficiency of poultry diets became a safeguard for humans who eat poultry and eggs.

In swine, the feeding of a new source of protein supplement occasionally increased the level of calcium and phosphorus well beyond usual levels. A lameness developed that suggested to Pennsylvania State University workers similarity to a change in growing chicks. The investigators were able to show manganese valuable and necessary in the diet of swine (*13*).

Since that work was reported trace elements have proved helpful in improving swine production through small increases in dietary levels and added ensurance is given to the human diet (*17*).

Manganese has a beneficial role in plants, also. Vegetables grown on organic and marl soils benefit from applications of manganese in fertilizers. The vegetables that come to the table have had satisfactory manganese nutrition in order to get there.

Zinc has been shown to function as a part of carbonic anhydrase, a vital enzyme of the animal body (*12*). And its close association with insulin may mean that it serves a useful function in the pancreas.

Zinc is an essential element in nutrition but does a deficiency ever occur naturally, that is, on diets that have not been purified to eliminate zinc? Zinc occurs very widely (*14*) and purified diets have demonstrated a zinc requirement of animals well below that required for normal plant (vegetables and pastures) growth and below the normal zinc levels in the feed and food products. Because of this zinc was generally considered an element that need not concern nutritionists. Plants indeed demonstrated zinc deficiencies and zinc fertilizers have made marvelous improvements in fruits and vegetables. Pastures too are more easily established when zinc is included in the fertilizer applications. The safety barrier to the human and animal diets seemed impregnable so long as plants had such a high requirement for zinc and animals and humans eat naturally occurring food ingredients.

Swine Parakeratosis

But in seeking ways of improving swine diets to obtain better production, investigators found a troublesome skin disease of swine. When the level of calcium was raised to twice the usual level of 0.4%, parakeratosis developed. Since it was unbelievable that calcium at such levels could be toxic, it occurred to research workers at Alabama State Experiment Station that perhaps the calcium was tying up a trace element and creating a functional deficiency. Zinc was certainly adequate by ordinary standards but when zinc excesses were added the parakeratosis disappeared (*22*). How the zinc functions or how the high calcium levels cause increased needs for zinc remain for chapters in research as yet unwritten.

Copper, iron, managanese and zinc are trace elements needed by plants and animals. Cobalt is also needed by animals. With the solution of each portion of this mystery story of agricultural production another trace element moves into the armament of the farmer in his battle for higher production and better quality. And each time the needs of plants and animals are discovered and met not only is production improved but the assurance of the quality of the human diet is more certainly increased.

Malady is obvious immediately in the cobalt deficient calf at right, compared with healthy animal of same age

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