THE ROLE OF COPPER AND OTHER MINERAL PROTEINATES IN RUMINANT DIETS

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Introduction

The National Research Council (1989) recommendations for trace mineral requirements are generally based on the assumption of bioavailabilities reported in common feedstuffs and the use of supplements with good availability. Absorption of copper and a number of other trace elements have a wide range of absorption values which are influenced by homeostatic controls as well as many dietary factors. This can result in a marked change in dietary recommendations if these marked changes in absorption are recognized.

Absorption

Linder (1991) states that absorption of copper can vary from almost nothing to values as high as 75%. Generally, copper is normal feedstuffs consumed at requirement levels range from values of 1% to 30% (McDowell, 1992). Young animals generally absorb greater amounts and deficient animals have a higher absorption rate. This wide range in bioavailability of copper is one of the major problems when determination of dietary requirements is made.

Research (Davis and Mertz, 1987) suggests that copper can be absorbed by two mechanisms. Both an active transport system as well as a simple diffusion process have been reported. At low dietary concentrations, the active transport system appears to be the main source of absorbed copper while simple diffusion plays a larger role with high dietary concentrations of copper. Homeostatic mechanisms regulate the rate of absorption and metallothiones in the epithelial cells of the intestine probably regulate the absorption. The chemical form of copper as well as the concentration of a number of other dietary constituents greatly affects the rate of absorption. Specific studies comparing inorganic with organic forms of copper have not been conducted.

Supplemental Sources

Supplemental sources of inorganic copper that are used in ruminant diets include $CuSO_4$, CuO and $CuCO_3$. In Kentucky the sulfate and the oxide form are the two most common sources in trace mineralized salt, mineral mixtures and complete feeds. Recent studies comparing the oxide and sulfate form for swine (Cromwell et al., 1989), chickens (Baker et al., 1991) and cattle (Xin et al.,

Presented at the 5th Florida Ruminant Nutrition Symposium, Gainesville, January 13-14, 1994

1991a; Clark et al., 1993) clearly show the sulfate as a preferable source because of the very low availability of copper oxide. Some studies would indicate the oxide form was not too different from negative controls. The copper oxide fed at low levels has resulted in copper deficiency in some herds in Kentucky. I do not recommend the use of the oxide form as a source of supplemental copper.

An additional problem which has led to copper deficiency in some herds is the very low amount of copper supplied by some trace mineral salts. For example, a trace mineral salt sold in Kentucky contains only 0.015% copper and that as copper oxide. If consumed at normal amounts, only a few milligrams of copper would be provided when five to ten times that amount would be desirable. However, caution should be taken not to add high levels of an available source such as sulfate because high levels are toxic and can interfere with other elements. The practice of feeding 25 to 35 ppm copper to dairy herds should be questioned.

Interactions

Some of the dietary copper deficiency problems are caused by interactions with other dietary constituents. The copper-molybdenum interaction is very well documented. The formation of thiomalybdate from sulfide, molybdenum and copper is more of a problem with ruminants than with monogastric animals because of the conversion of sulfate to sulfide in the rumen. Additional copper is required when the diet contains molybdenum or molybdenum and sulfur. A recent report (Olkowski et al., 1991) shows that high sulfur diets without molybdenum can cause a thiamine deficiency with increased incidences of polioencephalonacia. Other minerals which can cause reduced absorption for cattle include zinc, iron, calcium and cadmium. High iron levels occurs frequently in diets of dairy cattle.

Chelated Sources

There are a number of organic compounds which can enhance absorption such as amino acids, high dietary protein and citrate. However, not all amino acids enhance absorption of copper because methionine, histidine, and homocysteine have been reported to inhibit absorption at least in the rat (Linder, 1991).

Currently there is a great deal of interest in chelated or organic forms of trace minerals. The Association of America Feed Control Officials define different organic forms. A "metal amino chelate" is the product resulting form the reaction of a metal ion from a soluble metal salt with amino acids with a mole ratio of one mole of metal to one to three (preferably two) miles of amino acid to form coordinate covalent bonds. The average weight of the hydrolyzed amino acid must not exceed 800. A "metal proteinate" is the product resulting from the chelation of a soluble salt with amino acids and/or partially hydrolyzed protein. A "metal polysaccharide complex" is the product resulting from complexing of a soluble salt with a polysaccharide solution declared as an ingredient as the specific complex.

What are the advantages of chelated or proteinated minerals compared with the recommended inorganic sources of trace elements? There are a number of field observations where the addition of the organic form is reported to have improved reproduction, immune response, improved hair and hoof condition, and generally improved animal performance. Zinc methionine has been researched the most and the results suggest a number of benefits. Spears et al. (1991) have reviewed a number of reported benefits in cattle as well as other species. Many of the studies have compared zinc methionine with ZnO. A recent study chick bioassay indicated that oxide form had a relative bioavailability of 44 as compared with 100 for the sulfate. The benefits from zinc methionine could be due to a higher availability, a change in the way it is transported, or an alteration of it's metabolism tissues.

The same questions are asked about organic copper as well as other organic trace minerals. Is the difference in absorption the reason for reported benefits from the use of organic trace elements or do they have some additional activity in tissues that cannot be satisfied by the inorganic forms? Are they beneficial only for some specific problems such as the interference of other elements or will they work under any situation? There currently are not clear cut answers to these questions but a discussion of some of the research may help show some possibilities.

In most situations, the bioavailability of chelated or proteinated copper is higher than from copper sulfate. In our own studies (Clark et al., 1993; Du et al., 1993) with both cattle and rats, liver copper increased more rapidly when fed copper proteinate than when fed copper sulfate. Therefore, one advantage of most forms of organic elements is a higher availability. The study of Du et al. (1993) comparing copper sulfate, copper proteinate and copper lysine also suggests a difference in the normal interaction with zinc. Rats fed the proteinated copper had higher levels of zinc in other tissues than those fed copper sulfate. The opposite effect would be expected if added copper reduces zinc absorption. This could also suggest a different absorption mechanism.

Wittenberg et al. (1990) and Kincaid et al. (1986) have studied the use of copper proteinate as a method to overcome the detrimental effects of high molybdenum diets. Kincaid et al. (1986) did not influence performance but did increase liver copper from 220 $\mu g/g$ for copper proteinate. Wittenberg et al. (1990) concluded that copper proteinate was similar to copper sulfate in bioavailability, however, they had some indication of improved performance for steers fed the proteinate. In a recent study (Ward et al., 1993), copper sulfate was compared with copper lysine with steers fed supplemental molybdenum and sulfur and the results indicated no difference between the sources in animal performance and immune response.

Reports such as a recent study by Rakes et al. (1993) continue to increase the interest in organic forms of trace minerals. They compared equal amounts of inorganic (ZnO, $CuSO_4$ and $CoSO_4$) with organic forms (Zn methionine, Cu lysine and Co glucoheptonate) for dairy cows from 30 days prepartum to 126 days postpartum. The organic forms decreased uterine infections and increased milk protein content. It is not clear whether the effect is due to increased bioavailability or due to some other mode of action.

Summary

Based on research completed, it is not clear when to recommend the use of copper chelates. The evidence for improved bioavailability would indicate that when limited amounts of a trace element are fed, the bioavailability is greater for many of the chelates on the market. If copper proteinate or lysine are compared with copper oxide, a poorly available inorganic source, animal performance should be enhanced. Research is needed to determine if the mode of action or metabolism of organic forms of copper and other trace minerals is different from inorganic sources.

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