

ROLE OF TRACE MINERALS IN ANIMAL PRODUCTION

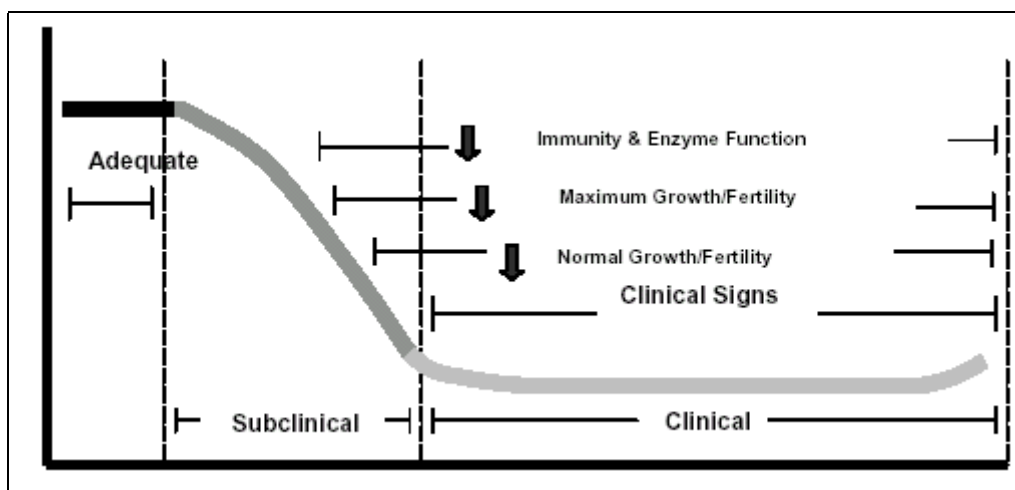
What Do I Need to Know About Trace Minerals for Cattle, Horses, Sheep and Goats?

Introduction

The role of trace minerals in animal production is an area of strong interest for producers, feed manufacturers, veterinarians and scientists. Adequate trace mineral intake and absorption is required for a variety of metabolic functions including immune response to pathogenic challenge, reproduction and growth. Mineral supplementation strategies quickly become complex because differences in trace mineral status of all livestock and avian species is critical in order to obtain optimum production in modern animal production systems.

Subclinical or marginal deficiencies may be a larger problem than acute mineral deficiency, because specific clinical symptoms are not evident to allow the producer to recognize the deficiency; however, animals continue to grow and reproduce but at a reduced rate. As animal trace mineral status declines immunity and enzyme functions are compromised first, followed by a reduction in maximum growth and fertility, and finally normal growth and fertility decrease prior to evidence of clinical deficiency (Figure 1; Fraker, 1983; Wikse 1992). In order to maintain animals in adequate trace mineral status, balanced intake and absorption are necessary.

Figure 1. Effect of declining trace mineral status on animal performance



Trace Mineral Function

To better understand the role of trace minerals in animal production it is important to recognize that trace elements are functional components of numerous metabolic events.

Trace mineral functions can be described by four broad categories (Underwood and Suttle, 1999): structural, physiological, catalytic and regulatory.

Structural function refers to minerals forming structural components of body organs and tissue. An example is the contribution of zinc to molecular and membrane stability.

Physiological function occurs when minerals in body fluids and tissues act as electrolytes to maintain osmotic pressure, acid base balance, and membrane permeability.

Catalytic function is probably the largest category for trace minerals as it refers to catalytic role of metalloenzymes in enzyme and hormone systems. Trace elements serve as structural components of metalloenzymes. Upon removal of the trace element or lack of adequate trace mineral levels the enzyme activity is lost. There are numerous metalloenzymes that are required for a wide range of metabolic activities such as energy production, protein digestion, cell replication, antioxidant activity and wound healing.

Regulatory function is exemplified by the role of zinc to influence transcription and iodine serving as a constituent of thyroxine, a hormone associated with thyroid function and energy metabolism.

Balance among the nutrients, protein, energy, minerals and vitamins, is a key component in striving towards optimum animal production. Balance among the trace minerals themselves is also important consideration and often poses a large challenge due to antagonist interactions that can occur between minerals. The primary interactions that are recognized include the negative impact of high molybdenum and sulfur levels on copper absorption (Suttle et al., 1984; McDowell, 1985; Suttle, 1991), interference caused by high iron levels for absorption of zinc, copper and manganese (Bremner et al., 1987; Gengelbach et al., 1994), and decreased zinc absorption in the presence of high dietary calcium. One trace mineral interaction that is often overlooked is that of zinc and copper. In order to maintain optimal status of both elements, dietary levels should be within a 1:3 up to 1:5 ratio of copper: zinc.

Many of today's animal production systems and expectations for performance induce periods of stress to the animal. In the presence of stress, trace mineral status of the animal is critical in minimizing negative effects on production.

Animal Health

Health concerns are universal in production across all livestock and avian species. Medication costs, lost performance in sick animals and death loss can rapidly reduce profitability in an operation.

Immunity

The immune system is a highly developed mechanism that utilizes a diverse cell population to protect its host against invasion of bacteria, fungi, parasite and viruses. Trace minerals that have been identified as important for normal immune function and disease resistance include zinc, iron, copper, manganese and selenium (Fletcher *et al.*, 1988). A deficiency in one or more of these elements can compromise immunocompetence of an animal (Beisel, 1982; Suttle and Jones, 1989). The first level of defense in the immune system is the skin. Zinc and manganese are key elements for maintaining epithelial tissue integrity.

As we consider epithelial tissue, we must also recognize that the lining of the respiratory tract, lungs, gastro intestinal tract and reproduction tract are also epithelial tissue. Maintaining the integrity and health of the tissue in these areas can result in a reduction of infiltration by pathogens.

In order to respond immunologically, whether it be to a foreign antigen that has been given as in a vaccine or one from the production environment, an animal needs to have an immune system that is responsive and capable of meeting any challenge. This defense system must attempt to eliminate these harmful challenges or antigens. Specific cells and proteins are produced to neutralize or destroy these specific antigens. This is the “acquired immune response” in action. The immune system can be divided into two categories:

- 1) Specific immunity referred to as cell-mediated and humoral, or
- 2) Nonspecific immunity action of phagocytes, macrophages and polymorphonuclear neutrophils.

Copper functions in the immune system through the following: energy production, neutrophil production and activity, antioxidant enzyme production, development of antibodies and lymphocyte replication (Niedermaier et al., 1994; Nockels, 1994). The importance of copper for maintaining the functions of the immune system has been demonstrated in several studies. Viral and bacterial challenges have been shown to increase serum ceruloplasmin and plasma copper in copper-depleted cattle indicating a major protective role for copper in infectious diseases (Stable et al., 1993). Low copper status has resulted in decreased humoral and cell-mediated immunity (Jones and Suttle, 1981a and 1981b; Xin et al., 1991 Gengelback et al, 1997), as well as decreased neutrophil bactericidal capability in steers. In vitro activities of T-lymphocytes and neutrophils isolated from adult male rats chronically fed a diet marginally low in copper were significantly suppressed without marked alterations in traditional indicators of copper status (Hopkins and Failla, 1995). Lower than normal tissue reserves in the fetal calf as a result of deficiency in the dam can impair development and growth (Abdelrahman and Kincaid, 1993). Increased incidence of scours, occurrence of abomasal ulcers shortly after birth and respiratory problems have both been attributed to inadequate copper levels in newborn calves (Naylor et al., 1989; Smart et al., 1986).

Zinc functions in the immune system through energy production, protein synthesis, stabilization of membranes against bacterial endotoxins, antioxidant enzyme production, and maintenance of lymphocyte replication and antibody production (Nockels, 1994; Kidd, 1996). Zinc deficiency has been shown to have an important impact on immunity (Gershwin et al., 1985; Droke and Spears, 1993). Decreased cellular immunity, lowered antibody response and disrupted growth of T-dependent tissue have resulted from inadequate intake of zinc (Fletcher et al., 1988). Zinc supplementation for stressed cattle enhanced recovery rate in infectious bovine rhinotracheitis virus-stressed cattle (Chirase et al., 1991). Zinc methionine has also been shown to increase antibody titer against bovine herpesvirus-1 (Spears et al., 1991). Supplementing zinc to dairy cows during lactation resulted in fewer infections of mammary gland (Spain et al., 1993).

Reproduction

Reproductive performance of cattle may be compromised if zinc, copper, or manganese status is in the marginal to deficient range. Common copper deficiency symptoms in cattle include delayed or suppressed estrus, decreased conception, infertility and embryo death (Phillippo et al., 1987; Corah and Ives, 1991). Inadequate zinc levels have been associated with decreased fertility, abnormal estrus, abortion, and altered myometrial contractibility with prolonged labor (Maas, 1987; Duffy et al., 1977). Manganese deficiency in cows results in suppression of conception rates, delayed estrus in post-partum females and young prepuberal heifers, infertility, abortion, immature ovaries and dystocia (Brown and Casillas, 1986; Maas, 1987; Corah and Ives, 1991).

Dairy producers can benefit from year round complexed trace mineral supplementation due to additional effects such as enhanced milk production and reduced somatic cell counts. Improving reproductive performance of dairy cows by achieving confirmed conception rates early in the breeding period could have economic returns to the producer.

Growth

Enhanced profitability of many animal production units is dependent upon optimum gain and efficient feed conversion of livestock or poultry. As illustrated by Engle et al. (1998), one of the first indicators of a marginal zinc deficiency is a depression in gain and conversion that are often present prior to any change in blood or liver levels. Providing adequate levels of bioavailable trace minerals can affect growth performance. In view of the role of trace minerals in growth, zinc, copper and manganese all serve as components in numerous enzyme systems associated with carbohydrate and protein metabolism.

Manganese is also instrumental in skeletal development and growth. **Copper** is required for synthesis of collagen and elastin fibers that provide structure and elasticity to connective tissue and blood vessels. **Zinc** is essential for epithelial tissue integrity, cell division and repair, and uptake transport mechanism and utilization of Vitamins A and E.

Summary

Trace elements are required for numerous metabolic functions in livestock, and optimal production and performance require adequate intake of balanced trace minerals. As trace mineral status of the animal declines from adequate to marginal, immunity and enzyme function are compromised followed by the loss of performance and reproduction. Animals in a subclinical or marginal deficiency status are often difficult to identify; however, changes in a trace mineral program can result in improved production. Immunity, growth and reproduction are influenced by trace minerals. Formulation strategies should account for mineral forms, levels and for possible synergistic combinations such as zinc to copper ratios. Trace mineral nutrition continues to be an area of interest for research and production applications.

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