Trace Mineral Nutrition Symposium

270 The role of trace minerals in feed stability and swine production. M. D. Lindemann*, *University of Kentucky, Lexington.*

Trace minerals (Cu, Fe, Mn, Zn, I, and Se) must be supplemented to diets of swine of all ages to meet their physiologic need for a variety of body purposes such as energy metabolism, connective tissue growth, bone formation, inflammatory response, immune function, and structural or catalytic involvement with a host of enzymes. The collective effect of these metabolic and physiologic impacts can result in changes in the rate and efficiency of whole animal growth and production. While minimum concentrations of these nutrients are established for growth, relatively less research is available that would establish supplementation needs to optimize the metabolic responses. Additionally, while there is some research that helps to establish the whole animal toxicity levels for the nutrients, there is relatively less research related to the effect of supplementation rates between those of the supposed requirement for growth and the presumed toxicity level on factors related to metabolic efficiency. In addition to the direct effect of absorbed minerals on metabolism, because of the prooxidant nature of Cu, Fe, Mn, and Zn, the supplementation level has the potential to interact with time, temperature, and moisture to affect the stability of various constituents of the feed. The constituents that are potentially affected most by prooxidants are vitamins, fats, and exogenous enzymes. Historic research has demonstrated that all of these can be affected by the level of supplemental trace minerals. The trace mineral affecting stability the most has varied among studies. Additionally, because oxidation is a chemical phenomenon, it would be assumed that the reactivity of the individual minerals should be a function of its chemical properties (e.g., rate and extent of dissociation) and that assumption has been demonstrated to be valid in comparisons of the forms of the minerals that are available to the feed industry (various inorganic forms as well as organic forms). Decisions about trace mineral supplementation should, in many situations then, also involve consideration of the source of minerals and their effect on feed stability relative to its consequent effect on animal wellbeing.

Key Words: trace mineral, feed stability

271 Exploring cellular trace mineral metabolism in bovine and porcine tissues. R. S. Fry*[1], J. W. Spears[2], M. S. Ashwell[2], and S. L. Hansen[3], [1]*Provimi North America, Brookville, OH,* [2]*North Carolina State University, Raleigh,* [3]*Iowa State University, Ames.*

The objective of this presentation is to provide an overview of the metabolic pathways responsible for copper (Cu), iron (Fe), and zinc (Zn) metabolism in mammalian tissues. Rodents and cell lines have been utilized for more than a decade to determine the role and necessity of these cellular mechanisms. These data have provided a foundation for scientists to build upon, and we have conducted numerous trials characterizing gene products responsible for Cu and Fe metabolism in bovine and porcine tissues. Copper transporter 1 is essential for Cu uptake. Mice with intestinal deleted Ctr1 are characterized by high mortality rates and reduced survivability, and liver Cu and cuproenzyme synthesis is markedly reduced in mice with hepatic Ctr1 deletion. Antioxidant 1 (ATOX1) is one of several vital Cu chaperones that prevent Cu deficiency and toxicity. Copper is delivered to Cu-dependent ATPases via ATOX1. While both are present in the intestine and liver, ATP7A is essential for Cu utilization from the enterocyte for synthesis of cuproenzymes, and ATP7B is required for biliary Cu excretion and incorporation of Cu into ceruloplasmin, a Cu-dependent ferroxidase. Divalent metal transporter 1 is responsible for Fe acquisition in the small intestine and liver. Manganese can also be transported via DMT1 and possibly a small portion of Cu. Ferroportin (FPN) is responsible for Fe export from the enterocyte and is regulated by hepcidin, a small peptide hormone that is produced by the liver and secreted into plasma to promote internalization and degradation of FPN in response to increases in body Fe stores. Proteins responsible for Zn absorption are categorized into 2 families. The family of ZnT transporters is responsible for Zn utilization and these transporters may also play a role in sequestering Zn in intracellular compartments. The ZIP family of transporters is responsible for Zn acquisition, especially ZIP4, which is essential for intestinal Zn uptake. Further characterization of these molecular mechanisms will broaden our knowledge of trace mineral metabolism in animal nutrition.

Key Words: copper, iron, zinc

272 Relative bioavailability, immune function, and antimicrobial effects of trace minerals. K. C. Klasing* and V. J. Iseri, *University of California, Davis.*

There are many nutritional and non-nutritional effects of nutrients that are added to feeds to optimize animal performance and health. A subset of nutritionally required lipids, vitamins and trace minerals possess bioactivities that function across a range of mechanisms including substrates or co-factors for key metabolic processes (nutritional effects), regulators of pathways and cellular decisions, and direct activities on the viability of potential pathogens along the mucosa of the GI track (pharmacological or non-nutritional effects). Among trace minerals, iron, zinc, and copper have been shown to possess this range of activities. Investigations of bioactive nutrients must consider each of these mechanisms to understand their net impact on the health and productivity of animals. For example, copper is required at relatively low levels as a co-factor for a variety of enzymes; each of which has a different priority for this cofactor. Studies examining the ability of dietary copper to fulfill its role as a cofactor should focus on those enzymes that have a low priority, such as lysyl oxidase in tendons, and not on enzymes that have a higher priority or can switch to other divalent cations, such as superoxide dismutase in immune cells. Copper also has direct anti-microbial effects on intestinal microflora and these actions occur at levels that are an order of magnitude higher than needed as a cofactor for lysyl oxidase. Studies on the anti-microbial actions of copper should focus on the dietary fraction that remains in the lumen of the distal intestines and is available to influence the microbial milieu rather than the fraction that is absorbed and used as a cofactor for enzymes. At intermediate concentrations, copper influences regulatory decision made by T-helper lymphocytes and macrophages. Thus, bioavailability/bioefficacy is context dependent and the specific function (nutritional versus regulatory versus anti-microbial) needs to be considered when comparing nutrient sources.

Key Words: copper, requirement, immunity

273 Practical applications of trace minerals in dairy cattle. T. R. Overton* and T. Yasui, *Cornell University, Ithaca, NY.*

Trace minerals have critical roles in immune function, oxidative metabolism, and energy metabolism in ruminants. To date, the primary trace elements of interest in diets for dairy cattle have included zinc (Zn), copper (Cu), manganese (Mn), and selenium (Se), although

data also support potentially important roles of chromium (Cr), cobalt (Co), and iron (Fe) in diets. Trace minerals such as Zn, Cu, Mn, and Se have classically and essentially defined roles as components of key antioxidant enzymes and proteins. Available evidence suggests that these trace minerals can modulate aspects of oxidative metabolism and immune function through these roles; recent work has demonstrated that source of Zn, Cu, and Mn fed to dairy cattle during the transition period and early lactation can modulate both aspects of oxidative metabolism and production. Chromium has been shown to have roles in both immune function and energy metabolism of cattle; dairy cows fed Cr during the transition period and early lactation have evidence of improved immune function, increased milk production, and decreased subclinical endometritis. Limited research has been conducted with focus on Co and Fe nutrition; some data do support roles of Co in cow productivity during early lactation. At the farm level, one factor that complicates trace mineral nutrition is the existence of a large number of antagonisms affecting bioavailability of individual trace minerals, thus determining the optimum level and source of trace minerals at the farm level continues to be a challenge. Collectively, increasing evidence supports a role for trace mineral nutrition in modulating production, health, and reproduction in cattle. Furthermore, opportunities for specific modulation of aspects of health, milk production, and reproduction through supplementation strategies for diets of transition dairy cows are attractive because of the known dynamics of energy metabolism, immune function, and oxidative metabolism during this timeframe.

Key Words: trace mineral, oxidative metabolism, immune function