

Copper Balance in Bison - Are your Bison Getting Enough?

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First described in the early 1930's, and since recognised worldwide, copper (Cu) deficiency is a well known nutritional problem in domestic ruminants (e.g. cattle, sheep) and deer species. However, it has not been given the attention it deserves in the literature on farmed bison. Every few weeks, I receive a nutrition related telephone call from a bison producer or their veterinarian, and most of these are about probable mineral imbalance or deficiency issues. The signs of Cu deficiency are usually vague and non specific. Chronic diarrhea in spite of testing and treatment for intestinal parasites and bacterial disease is a good example of such a symptom. Many producers want to believe that a stubborn virus or bacteria is at fault, but all too frequently an imbalanced or inadequate mineral intake is at the root of the problem.

Some of the information in this article will not be of interest to many readers, especially the details on biochemical and enzyme malfunctions. If that's the case, skip down to the more practical information about how to recognize, prevent, and treat Cu problems. Many of the facts written below about Cu metabolism and deficiency, come from studies on cattle and sheep and we must make the assumption that these facts are true for bison as well. However, it has been my experience that bison are at least as sensitive as cattle to Cu imbalance, and perhaps more so. Once confined on a farm, bison are not as easy to feed as many people think and nutritional problems, especially mineral imbalances, are not uncommon.

Causes of Cu deficiency

Copper deficiency can be primary or secondary to other factors. Both types result in basically the same problems for the affected animal, but there is a difference in the approach to correcting either type. Primary copper deficiency occurs when dietary copper levels are insufficient to meet metabolic demand. This can happen from eating feed with low Cu-to-molybdenum ratios. In this type, there simply isn't enough copper in the food provided for the bison. Diets very high in protein, for instance 20-30 % in fresh forage, are often Cu deficient diets.

Secondary Cu deficiency develops when Cu absorption or metabolism is inadequate. This type may result when dietary factors inhibit the absorption of Cu from the digestive tract. For example, high levels of molybdenum (Mo) in the diet can bind with Cu in the reticulo-rumen creating an insoluble (won't dissolve) copper molybdates complex. Similarly, in the presence of dietary sulfates, Cu binds to sulfur forming a non-absorbable copper sulfate complex. Inorganic sulfur and sulfur from sulfur-containing amino acids are converted to sulfide in the rumen, which combines with Mo to produce thiomolybdates, which also bind with Cu. Sulfides also react with iron in the rumen. Iron sulfide is carried to the abomasum where the acid environment causes the release of hydrogen sulfide, promoting the formation of insoluble complexes of copper sulfide.

These chemical reactions reduce absorption of Cu in the intestinal tract and effectively make copper unavailable to the animal. Even under normal circumstances only a small fraction (5%) of the Cu eaten by a bison is absorbed by the intestinal tract and, if they persist, high levels of iron, molybdenum, and sulfur, create a secondary state of Cu deficiency.

Signs of Cu deficiency

The clinical manifestations of Cu deficiency in ruminants (presumably bison too), include diarrhea, anemia, nervous system disorders in calves, poor growth rate, poor body condition, changes in hair or coat color and failure to reproduce. Copper is essential for normal elastin and collagen production in cartilage, osteoid (new bone), ligaments, tendons, and blood vessel walls. A lysyl oxidase enzyme deficiency resulting from the lack of available Cu causes defective collagen and the subsequent defects in normal production of cartilage and subchondral (under cartilage) bone. Skeletal abnormalities and lameness resulting from these defects have been documented in young bison. Collectively these lesions are called osteochondrosis, which is thought to develop from the trauma of weight bearing on rapidly growing but poorly formed cartilage and underlying bone. The result is necrosis (tissue death) and trauma to cartilage and associated joint tissues.

The physical signs connected with deficiency are due to its effect on enzyme related activities in various body systems. Copper is a necessary component in many of the enzymes which govern metabolic processes. It is essential for iron absorption and transportation in the body, and is necessary for normal hemoglobin formation. The precise physiologic mechanisms of the syndromes outlined below are not clear, but the central role of Cu in protecting cells from oxidation damage, and its role in sulfur and iron metabolism are important.

Which organ system shows signs of failure is determined by which Cu dependent enzymes are affected in a particular animal. Symptoms can be observed in the gastrointestinal (diarrhea), reproductive (infertility), hematopoietic (blood forming - anemia), skeletal (lameness) and cardiovascular (heart enlargement) systems. The severity of signs in bison is not a generally good indicator of the degree of deficiency. A faded, scruffy hair coat might be as important as an obviously lame calf when looking for Cu problems. Moreover, not every animal in a herd will show signs or the same severity of signs. The diagnosis of Cu deficiency is impossible to make without testing a few animals, the feed and water, or both, for Cu and other mineral levels.

In the intestinal tract, the Cu dependent enzyme system involves cytochrome oxidase. Disruption of enzyme activities causes defects in the integrity and function of intestinal epithelium (mucosa) which lines the entire tract, absorbing nutrients and other good things, and keeping out bacteria, toxins, and similar bad things. Without cytochrome oxidase activity, mitochondria (the powerhouse of each cell) can't function, resulting in cell death and villus atrophy. In addition, there are toxic effects on the gut mucosa from tetrathiomolybdates formed in secondary Cu deficiencies. Damage to the lining of the gut prevents the absorption and secretion of fluids, and diarrhea is the result.

Copper deficiency results in poor semen quality in bison bulls. In cows it causes decreased conception rates, anestrous (no cycling), and decreased productivity. When conception does occur there can be fetal absorption and retarded growth of offspring. There is no obvious biochemical link between infertility and Cu deficiency but scientists believe that it is molybdenum related. Poor calving rates in apparently healthy bison with adequate protein and energy in their diet might simply be from Cu deficiency, although infertility usually has many factors involved and is unlikely to respond to an increase in Cu alone.

Anemia through altered hematopoiesis (blood cell creation) can result from Cu deficiency. In simple terms, old red blood cells are not replaced by new ones after they are removed from circulation. Red cell formation is mediated through the Cu dependent enzymes ceruloplasmin, iron transferrin, ferrochelatase, and cytochrome oxidase. Copper is the rate limiting element in the synthesis of ceruloplasmin (ferroxidase) which is a major player in iron transport in the body. The result is a decrease in iron transport and utilization and decreased production of red cell membrane phospholipids as well as a decrease in the amount of iron available for heme synthesis. The mechanism also involves decreased mitochondrial activity in maturing red cells and a shortening of the red cell life span. The anemia is a late sign of Cu deficiency along with iron accumulation in various body tissues.

Cardiomyopathy (heart problems) in the form of hypertrophy (enlargement) is also related to the impaired function of the Cu dependant enzymes named above, as well as lysosyl oxidase and monoamine oxidase. The result is an attempt at adaptation through enlarged mitochondria in myocardial fibers (heart muscle cells). If that were not enough, there is defective formation of elastic tissue in the body which can ultimately result in aortic rupture (major artery) and sudden death.

Pale, scruffy, reddish hair coats from Cu deficiency in bison are actually because of imperfect oxidation of free thiol groups during hair growth and keratinization. Also, a copper dependant enzyme called tyrosinase is needed to produce melanin from L-tyrosine, and in Cu deficiency this conversion is slowed, creating lighter and weaker hair.

Copper and the immune response

One of the reasons that Cu imbalance can be difficult to identify in bison herds is the fact that marginal or deficient Cu metabolism indirectly results in so many non-specific production problems such as a poor weight gain, and what bison legend Doc Throlson calls ADR disease (Ain't Doin' Right) in bison. Thanks to widespread information about AIDS in humans, most readers will be familiar with the concept that serious and complex health problems result from depression of the immune system. Copper deficiency isn't the only cause of inadequate immune function in ruminants, but it is an important one.

Copper plays a role in the effective function of immune system cells called lymphocytes (T and B types), neutrophils and macrophages. These cells are involved in nonspecific immune functions such as the phagocytosis (eating) and chemical killing of infectious bacteria, and specific immune functions such as the production of antibodies (humoral immunity) and cell-mediated functions of T and B lymphocytes.

Copper deficient cattle have been shown to have reduced neutrophil bactericidal capacity. In other words, they can't eat and destroy bacteria, which is their job. This may be a direct consequence of the reduced Cu dependent enzyme activity of superoxide dismutase and ceruloplasmin, which recycle the chemicals necessary to kill bacteria in these cells. Superoxide dismutase and glutathione peroxidase are enzymes involved in the neutralization of oxygen free radicals which are highly toxic, electrically charged oxygen molecules created by the bacterial killing activities of neutrophils, turning them into hydrogen peroxide to kill more bacteria. Problems in bison from reduced superoxide dismutase activity in Cu deficiency may be most evident following stressful situations. Increased adrenaline production during stress causes an increase in oxygen use and subsequent oxygen free radical production, creating a situation where there is both an excess toxic metabolic waste and a decreased capacity to deal with bacterial pathogens (disease causing bacteria).

With regard to specific cellular and humoral immunity, in Cu deficient animals there is depressed production of lymphocytes in response to antigens (immunity stimulating compounds in bacteria and viruses), and reduced concentrations of antigen-specific antibodies. The exact details of the role Cu plays in humoral immunity are unclear.

It is easy to see that bison spend a lot of energy defending themselves against bacteria, viruses and parasites, and that Cu deficient animals are prone to infections that prevent them from fully participating in growth, reproduction, milk production for calves and other important biological activities. Also, diseases like pneumonia, pinkeye, and scours are perhaps more likely to affect Cu deficient animals than others.

Dietary requirements for copper

Cattle diet requirements for Cu have been determined to be a minimum of 8-10 mg/kg (or parts per million, ppm) of feed. This is only the minimum requirement, and the need for Cu can be affected by increased metabolic demand for such things like milk production, rapid growth, and stress. The availability of copper to meet these demands can be affected by interactions with minerals, nitrate, sulfate, and protein. The truth is that we don't actually know the minimum requirements for bison. They have never been determined, but we must assume that they are at least that of cattle under the same conditions.

Some average copper concentrations of feed are: grass hay 10 mg/kg, legume hay (alfalfa) 9.5 mg/kg, cereal silage 10 mg/kg, oats 3 mg/kg, and barley 5mg/kg. It should be obvious that under most management systems Cu levels in the feed are only just enough, and when mixed rations are fed, mineral supplementation is required. If the feed or water contains molybdenum, iron, or sulfates, then Cu supplements become very important.

A recent case in Saskatchewan resulted in joint abnormalities in yearling bison. The problem was traced to the water supply. Excessive levels of sulfate in the well water, which was the only source of water for the calves, and the pathology findings suggested a diagnosis of secondary Cu deficiency. Absorption of dietary Cu in these cases was impaired by the formation of Cu sulfate through the interaction of Cu in the feed and sulfates in the drinking water. The adult animals on the farm had a similar diet but did not suffer a deficiency because they were free-ranging and used snow as their water source. However, under such conditions dietary intake of Cu could be ensured by way of trace mineral supplementation to a level of 25 mg of Cu per kg of total feed intake.

Diagnosis

A diagnosis of Cu imbalance is made on the basis of history, clinical signs, testing of feed, water, and tissue samples. ***Test your feed!*** There is no other way to know what minerals, and in what amounts, the feed is providing to your bison. Feed should be evaluated whenever new stocks are brought in until the feed source is predictable. ***You can't tell the actual contents of the feed by just looking at it!*** Yes, this is expensive, but so are infertile or slow growing animals. When analysing feed, the amount of copper, molybdenum, and sulfur compounds are important. Look for excess phosphorous, nitrate, iron, zinc, and dietary protein. Forages with less than 3 ppm of copper are deficient, and those with 3-6 ppm are marginal. Anything greater than 8 ppm might be adequate IF the amount of copper is greater than 4.5 times that of molybdenum.

Water testing is always indicated when there are signs of Cu deficiency but feed levels are normal. Rule out the possibility of high nitrate or sulfate levels acting as Cu inhibitors. Levels of 6000 ppm (mg/litre) of nitrate and 1000 ppm of sulfate are considered high, and

ingestion of water containing 600 mg of sulfate per litre of water (600 ppm) has been reported to induce Cu deficiency in Saskatchewan beef cattle.

Blood testing should include a complete mineral profile. Serum levels are not generally a good indicator of the true Cu status and testing for Cu alone will not provide much information. One has a better opportunity to diagnose herd problems, and more useful information can be obtained, if 10% (or at least more than 10) of the animals in the herd are tested. Be warned that serum concentrations can be normal in spite of obvious clinical symptoms and a Cu deficiency. Serum Cu concentrations of 0.4 to 0.7 ppm (micrograms/ml) are marginal and hard to interpret but anything less than 0.6 ppm might be considered deficient. Serum levels generally won't fall until liver Cu reserves have been used up.

The best tissue to test for an indication of Cu status in the bison is the liver. Liver can be obtained at the time of slaughter of market animals, or from animals dying on the farm in the event of an immediate problem. Save some liver from slaughtered animals to monitor mineral status in your herd. They can be frozen and submitted in batches when convenient. Literature on Cu deficiency in cattle and sheep encourage liver biopsies but because of bison behaviour when closely restrained, this is sometimes easier said than done. Having said that, liver biopsy is routinely practised to monitor Cu levels in farmed NZ red deer, and at one time that was thought to be impossible. The stores of Cu in the liver maintain blood concentrations until deficiency is long standing or severe. In cattle, and presumably bison, Cu deficiency occurs at levels less than 40 mg/kg of liver (40 ppm).

Treatment

Injectable copper compounds may be indicated in severe cases where immediate results are needed. Injectable Cu is Cu glycinate or Cu edetate which is best given according to the manufacturers directions either sub cutaneously or intramuscularly. Injectable copper has the disadvantage of injection site reactions, toxicity and rupture of red blood cells from overdoses, and rapid deaths have been reported in cattle.

In most instances, Cu supplementation is best accomplished by mouth. Gelatine capsules full of Cu oxide "needles", which look like a pencil lead, can be given by mouth using a balling gun providing adequate and uniform consumption. This could be a challenge with adult bison, and would require a good bison chute and some courage. Once inside the animal, these Cu oxide "needles" sink into the reticulum chamber of the ruminant stomach and slowly release Cu. In cattle, they raise the liver copper concentration significantly and are relatively long lasting (6 mos).

Otherwise, Cu can be provided in mineral or salt mixes, or through water sources. Water supplementation is effective if minerals are added to the sole water source and there is no alternative for the bison to drink but this can be complicated if forages being used also have a high mineral content. Feed mineral or salt mixes generally provide inorganic Cu in a variety of forms. Organic sources may have increased bioavailability, but these are expensive. These are fed free choice or are added to the total feed intake in the form of formulated supplements. Both ways are convenient but there is no assurance of adequate or uniform consumption, and this can be a problem especially, it seems, with bison. Producers have complained that salt mixes added to feeds such as grain, either blow off in the wind, or remain at the bottom of the feeder after the bison have cleaned up the food. As with salt blocks, some bison will eat it, others won't touch it. It is one thing to provide the minerals but quite another to ensure that they actually eat enough to make a difference. For this reason many producers add Cu supplements in the form of pre-mix

containing pellets.

Recommended Cu levels provided in publications can be stated in two different ways; levels in the supplement, and levels in the total ration. A supplement might have Cu at 250 ppm (250 mg/kg of supplement) but this is not given to the bison directly. The supplement becomes part of the total ration which is mixed so that Cu is present at the currently recommended dose of 25 ppm (25 mg/kg of feed). Recipes for making Cu salts and supplements are beyond the scope of this article, but a qualified animal nutritionist should be able to help you with the arithmetic if you want to mix your own using copper sulfate (CuSO_4) or copper oxide (CuO). The easiest way to formulate a ration that when consumed in adequate amounts by a bison will provide an adequate daily intake of Cu, is to have a feed company do it for you.

Bison can theoretically be poisoned with too much Cu but it would be difficult to get them to eat that much. Copper toxicosis results when liver concentrations rise to greater than 900 ppm (900 mg/kg of liver) and result from feed concentrations of greater than 115 ppm (115 mg/kg of feed). The symptoms are nausea, regurgitation, salivation, abdominal pain, convulsions, paralysis, collapse death. Sheep are particularly susceptible, but poisoning is uncommon in cattle, and as far as I know it has never been reported in a bison.

In summary, Cu deficiency is not usually about a lack of Cu but an imbalance of Cu and other minerals in the diet. Bison generally need to be supplemented with minerals and failure to do so may inhibit their potential to produce and can lead to illness. Diagnostic testing is rather expensive, but so are production losses. Remember to routinely have your feed tested for nutritional value. Your hay may look excellent this year, but that is no guarantee that it meets any sort of nutritional standard. Problems are usually not associated with providing supplemental Cu, but with getting bison to eat enough of it.