Trace Mineral Supplementation of Grazing Beef Cattle

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Introduction

The nutrient quality of forage, particularly perennial warm-season grasses, is often lacking in trace mineral content to supply the requirements of most all classes of grazing cattle. Since forage is the most significant contributor to the trace mineral nutrition of grazing beef cattle, it is important to consider these deficits and how they may impact the performance of the cattle consuming them. Focusing on grazing beef cattle, this proceedings article will provide an overview of (1) individual essential trace minerals, (2) trace mineral antagonists, (3) methods of supplementation, and (4) assessment of herd trace mineral status.

Review of Individual Trace Minerals Essential to Grazing Beef Cattle

Copper
Copper is one of the most common trace nutrient deficiencies in grazing cattle. Copper is an important cofactor in approximately 30 enzyme systems. Deficiencies occur through the prolonged consumption of forages low in Cu and/or the consumption of forages containing elevated concentrations of the natural Cu antagonist, Mo. As well, dietary S is an important catalyst in the Cu / Mo interaction. Dietary S levels greater than 0.30 % are often considered suspect in their potential for initiating Cu deficiency. Blood Cu concentrations are elevated during instances of stress, suggesting that stressed cattle may have a greater Cu requirement. Copper oxide is poorly absorbed and should not be used as a source of Cu in cattle supplements. Some signs of Cu deficiency include, (1) immune suppression (failure to respond to vaccination), (2) rough, dull hair coat, and (3) anemia.

Zinc
Like Cu, Zn is also an important cofactor in many enzyme systems. In ruminant diets, Zn deficiency has been shown to be an important contributor to male fertility. As well, diets fortified with adequate available Zn have been shown to improve hoof structural soundness in beef heifers. Copper and Zn are absorbed through similar pathways indicating a competition for absorption pathways. Therefore, mineral supplements should be formulated with a Cu:Zn ratio of around 1:2 or 1:3. Some signs of Zn deficiency include, (1) connective tissue degeneration (hoof integrity), (2) bull reproductive failure (especially young developing bulls), and (3) anorexia and weight loss (notably in calves).

Selenium
Selenium deficiency in grazing cattle is widely recognized throughout the world. Unlike most other essential trace nutrients, Se supplementation offers a narrow range between deficiency and toxicity. In fact, many regions in the world are concerned with Se toxicity in pasture forages. Selenium is essential for the maintenance of tissue integrity. Widely recognized deficiency

symptoms include the degeneration of tissue resulting in a condition known to as “white muscle disease”. Selenium supplementation is commonly addressed via the inclusion of sodium selenite in cattle supplements. Selenium inclusion is federally regulated in the United States at a maximum inclusion level not to exceed 3 mg of supplemental Se daily. If adequate mineral intake is achieved, Se deficiency is rarely a problem when adequately supplemented via sodium selenite. Some signs of Se deficiency include, (1) muscle degeneration (white muscle disease), (2) reproductive failure, and (3) immune suppression. Selenium is closely related to vitamin E. In fact, consideration to Se nutrition cannot be made without also considering vitamin E. A lack in either may be compensated by the other.

Manganese

Manganese has been shown to be an important trace nutrient for proper bone formation in young animals and optimization of fertility in female cattle. Although dietary Mn absorption and retention in cattle is low, Mn deficiency in grazing cattle is uncommon. Considering the importance of Mn on cow fertility and young calf development, it is most important to focus on optimal Mn nutrition prior to and following calving. Manganese sulfate is the most available form of Mn, but it is often difficult to find commercially. As an alternative, Mn oxide is an acceptable and widely used source of Mn supplementation. Some signs of Mn deficiency include, (1) bone abnormalities, (2) reduced growth rate, and (3) reduced fertility.

Iodine

Iodine is critical for the maintenance of proper thyroid function. This occurs through the essential role of I in the regulation and synthesis of thyroid hormone production. The influence of thyroid hormones affects nearly every physiological process in mammals. Ethylenediamine dihydroiodide (EDDI), often provided in trace mineral supplements as a foot rot preventative, provides a quality source of available I. As well, the inclusion of iodized salt in the base mineral mix may provide adequate I supplementation in most cases. Some signs of I deficiency include, (1) reduced fertility, (2) enlarged thyroid (goiter), and (3) stillborn, weak, and/or hairless calves.

Iron

Iron deficiency is seldom a problem in cattle consuming forages. In contrast, the antagonistic impact of dietary Fe on Cu absorption is often more of an important issue when attempting to balance trace mineral nutrients. Further, many ingredient sources of other trace nutrients are naturally contaminated with Fe. Taken together, additional supplementation of Fe to grazing cattle is probably not a concern. Iron deficiency is occasionally an issue in young calves or in adult cattle suffering blood loss usually as a result of parasite infestation. Iron is provided in most all trace mineral supplements in the form of Fe oxide. This inclusion is provided only as a coloring agent, providing the classic dark red appearance of many salt-based mineral supplements. Iron oxide is basically *unavailable* to the animal. If supplemental Fe is needed, Fe sulfate should be considered. Some signs of Fe deficiency include, (1) anemia, (2) immune suppression, and (3) decreased calf weight gain.

Cobalt

Cobalt is essential to ruminants through its participation in the ruminal synthesis of vitamin B12. This metabolic process, unique to ruminants, allows us to virtually ignore the dietary supplementation of B-vitamins in cattle. In fact, since Co is poorly stored in body tissues, Co status in ruminants is commonly assessed via measurements of blood vitamin B12 concentrations. Multiple Co sources are utilized in mineral formulations, including carbonate, chloride, and sulfate. Some signs of Co deficiency include, (1) loss of appetite leading to weight loss, (2) listlessness and diarrhea, and (3) anemia.

Trace Mineral Antagonists (Iron, Molybdenum, and Sulfur)

The requirement for supplemental trace minerals can also be greatly impacted by the presence of mineral antagonists. These antagonists cause trace mineral deficiencies to be grouped into two broad categories depending on the characteristics of their development; 1) Primary deficiency, and 2) Secondary deficiency.

1. Primary mineral deficiencies are the result of the consumption of feeds that are naturally low in one or more trace minerals. These deficiencies usually require an extended period of time for their development, often a year or more. The lack of supplemental mineral is a common characteristic of primary mineral deficiencies, as they are rare under normal well-managed cattle production systems.

2. Secondary mineral deficiencies are the most common. Secondary deficiencies are derived from the consumption of one or more mineral antagonists that interfere with the normal metabolism of another mineral. A simple mineral evaluation of a feedstuff may suggest adequate trace mineral concentrations are present; however, the presence of a mineral antagonist will decrease the availability of the mineral, potentially leading to a deficiency.

Iron Antagonism

Iron is the second most common trace metal in the earth. Iron is found in nearly all sources of cattle feed, including water. As well, a considerable amount of Fe may also be digested through the intake of soil during grazing, as well as the soil contamination of harvested forages. Indeed, with the exception of young animals, Fe deficiency is rare in healthy cattle reared under modern agricultural conditions. The more likely contribution of Fe to cattle is its ability to antagonize other trace minerals, notably Cu and Zn. The maximum tolerable concentration for Fe in cattle diets is 1000 ppm; however, dietary concentrations of 250 to 500 ppm have been linked to Cu deficiency. The antagonistic role of Fe in Cu nutrition is not well understood. One explanation relates to the potential disassociation of ferrous sulfide complexes in the low pH of the abomasum. Under this scenario, sulfide may be able to react with Cu, forming insoluble Cu-sulfide complexes. Reductions in the performance of dairy cattle in New Zealand have been linked to Cu deficiency as a result of the consumption of high-Fe forages.

Molybdenum Antagonism

Molybdenum is an essential trace element required by all animals; nevertheless, reports of Mo deficiency are rarely recorded. In contrast, the antagonistic impact of Mo on Cu metabolism has been recognized for many years. Typically, Mo exerts its influence on Cu through the association with S in the formation of ruminal thiomolybdates. However, additional evidence exists which shows that decreased animal performance can be related to Mo toxicity independent of decreased Cu availability. Heifers consuming supplemental Mo (dietary concentration = 5 ppm) have been shown to exhibit signs of Cu deficiency, whereas, heifers supplemented with Fe and at the same Cu status had no signs of Cu deficiency. In these studies, the signs of Cu deficiency included reduced growth and feed efficiency and infertility (Phillippo et al., 1987a,b). More recently, infertility responses have been further linked to the direct impact of Mo and have been shown to be reversible with supplemental Cu (Kendall et al., 2006). In another study (Gengelbach et al., 1997), calves provided diets with supplemental Mo had a lower rate of gain compared to Fe supplemented calves. Both groups of calves had an equivalent extent of Cu depletion compared to Cu-supplemented control calves. These results suggest that some conditions, which are linked to Cu deficiency, might be more accurately described as a toxicity from the antagonist (i.e. Mo toxicity).

Sulfur Antagonism

Sulfur is found naturally in nearly all feedstuffs. The form of S varies widely from inorganic salt to organic S-containing amino acids. Recently, more evidence has been derived from commercial cow/calf production systems suggesting that S may be a primary contributor to secondary Cu deficiencies. Although Mo is an essential component in this antagonism, it will seldom affect tissue Cu stores when S levels are limiting. Sulfur, on the other hand, can impact both Cu and Se metabolism by forming insoluble sulfide complexes – independent of Mo (Suttle, 1974). We have found that a dietary concentration of S of 0.30% (total S) is sufficient for this antagonism to become a concern. The beef cattle NRC suggests a maximum tolerable concentration of dietary S of 0.40 %. Grazing cattle can achieve S from multiple sources including, (1) S-containing fertilizers (Arthington et al., 2002), (2) high-S byproducts (i.e. distillers grains, sugarcane molasses, and feathermeal; Arthington and Pate, 2002), (3) high-sulfate water sources, and (4) atmospheric deposition (i.e. acid rain).

Trace Mineral Supplementation

Supplementation of trace minerals may occur through a variety of means, including free-choice loose mineral mixes, trace mineral blocks, fortified energy and/or protein supplements, injections, boluses, and forage biofortification.

Free-Choice Loose Mineral Supplements

Free-choice mineral supplements are offered with the anticipation of adequate intake to offset nutrient deficiencies. Variation in free-choice intake, however, is a common problem impacting the efficacy of this management system. Although many contributing factors exist (Bowman and Sowell, 1997), variation due to changing seasons of the year is one common factor. When supplementing free-choice minerals it is important to realize that cattle ***do not*** have the nutritional wisdom to consume trace minerals as needed. We have all heard the statements, "My cattle are not consuming mineral, so they must not need it" or, "My cows are eating four times their normal level, I guess they really need it". Cattle only possess the ability to consume salt at the level of their requirement. Consequently, by altering the salt inclusion in mineral mixes, we can both encourage and discourage mineral intake. Remember that the majority of trace mineral intake beyond that nutritionally required by the animal is excreted in urine and feces. Over consumption of trace mineral may be an important inefficiency in beef cattle production systems.

Despite challenges with intake variation, free-choice mineral supplementation is the most common supplementation strategy in grazing beef herds. In nearly all cases, it is an effective, cost-efficient means of delivering adequate mineral supplementation. Although formulations vary greatly, the common base mix should contain approximately 20 to 30% salt. Intake is often targeted at two to four ounces per head per day. Unfortunately, achieving this target intake by all animals does not occur. Several animals within a herd will consume very little to no mineral at all. However, on the average, mineral consumption usually meets the desired intake levels. It is this averaging effect, over time, which allows free-choice mineral supplements to be the most practical choice for most cattlemen. Seasonal variation is evident. During the wetter summer months, cattle readily consume salt-based mineral supplements. In contrast, during the dryer winter months free-choice intake may be reduced by 15% or more. Generally, as moisture content of forages increase, intake of free-choice supplements also increases. In one demonstration study, the voluntary intake of a salt-based free-choice supplement among grazing beef cows was surveyed over two consecutive years. Voluntary intake was correlated (R^2 = 0.39) with precipitation events in the two preceding months (data courtesy of Vigortone Animal Nutrition; unpublished data). Similarly, we reported a large seasonally-impacted reduction in voluntary intake of salt-based, free-choice mineral supplements among grazing beef cows in southern Florida (Arthington and Swenson, 2004). In that study, cows were offered supplement in amounts to provide their targeted (assumed) intake on a weekly basis. All unconsumed supplement was measured weekly and the results were calculated as a percent refusal. During the dry season, when forage moisture was low, the percent refusal was high (i.e. voluntary intake was low); however, during the wet season, when forage moisture was high, voluntary intake was at or above the targeted amount. This annual variation in intake is explained by changes in a cow's craving for salt. Annual variation in salt craving differs throughout the world, but is an important consideration with supplementing grazing cows via salt-based, free-choice mineral products.

Trace Mineral Blocks

In most grazing situations, trace mineral-fortified salt blocks cannot provide sufficient trace mineral intake to meet nutritional needs. Formulated as a hard, salt-based block, cattle are unable to consume enough product to achieve their necessary level of trace mineral supplementation. Nevertheless, some grazing situations dictate the need for this type of supplementation. When cattlemen are physically unable to provide loose mineral or fortified supplements on a regular basis, trace mineral fortified salt blocks provide an opportunity to offer long-term mineral supplementation, therefore lessening the potential for trace mineral deficiency.

Fortified Energy / Protein Supplements

One of the most effective management strategies for addressing trace mineral nutrition in beef cows involves the mineral fortification of energy and/or protein supplements. This is a simple approach, which ensures that trace mineral is offered to all animals on a regular basis. This may be achieved by fortifying traditional supplements with your current free-choice trace mineral supplement. Some producers simply fortify their winter supplement and return cows to free-choice product during months when supplement is not offered. This strategy is effective in decreasing the variability in free-choice trace mineral intake and in bolstering trace mineral tissue stores during the winter supplementation period. As well, mineral fortified winter supplements lessen the concern of poor winter mineral intake sometimes realized with free-choice, salt-based mineral supplements.

Injectable Trace Minerals

Injectable trace minerals have been available for many years, but the technology, targeted application, and scientific assessment of efficacy has more recently been a subject of attention. An advantage of injectable trace minerals, compared with traditional oral supplementation methods is the targeted delivery of a known amount of trace minerals to individual animals. This removes the variability associated with annual fluctuations in voluntary intake, which is common among cattle provided free-choice mineral formulations. In addition, injectable trace minerals can be used within production environments that might experience difficulty managing the routine delivery of free-choice mineral mixes, such as extensive rangeland systems, seasonal grazing of mountain meadows, and seasonally flooded pastures. Further, the contribution of wildlife to the overall consumption and disappearance of free-choice mineral mixes also can cause complications in these production environments and add further value to the use of injectable trace minerals.

Most cattle producers and veterinarians associate trace mineral injections with two product formulations that were common during the 1970’s and 80’s. These products were, 1) combined formulation containing Se and vitamin E, and 2) Cu glycinate. Prior to 2005, most of the research involving injectable trace minerals has focused on one of these two applications. These studies have shown enhanced humoral responses to antigens such as *E. coli* and *Mannheimia haemolytica* (Droke and Loerch, 1989; Panousis et al., 2001) and increased or maintained serum Se among Se-injected calves (Reffett-Stabel et al., 1989).

A notable and widely recognized problem with injectable Cu is injection-site reactions. Previous studies have reported variability in injection-site reactions among different preparations of injectable Cu supplements, with CuCa-EDTA causing the least and Cu glycinate causing the greatest tissue inflammation (Boila et al., 1984), and the s.c. injection route causing less tissue irritation compared to the i.m. injection route (Allcroft and Uvarov, 1959). Chirase et al. (1994) investigated injectable Cu glycinate (36 mg Cu) in BHV-1 challenged beef steers. Their results revealed a negative impact of injectable Cu on BW gain and feed DMI. The authors suggested that this response may have been due to the development of abscesses in 25 % of the Cu-injected calves, which supports the importance of using injectable trace mineral products which cause as little injection site reaction as possible.

Today, there are injectable trace mineral formulations available that offer several elements in a single product, namely Cu, Zn, Se, and Mn. Reports of injection-site reactions are not as prevalent with these newer formulations. In addition, many studies have reported positive findings such as increased mineral status (Pogge et al., 2012), increased feed efficiency (Clark et al., 2006), improved humoral immune responsiveness (Arthington and Havenga, 2012; Arthington et al., 2014), reduced treatments for illness (Berry et al., 2000), and reduced morbidity treatment costs (Richeson and Kegley, 2011) in stressed feeder calves.

Trace Mineral Boluses

This form of supplementation involves the oral administration of a capsule (bolus) containing specific trace minerals in the form of highly compressed powders, soluble glass materials, or metal needles contained within a gelatin capsule. Administered using a balling gun, these boluses presumably drop into the reticulum-rumen where they dissolve slowly over time. Cobalt supplementation, for example, has been successfully applied to bolus applications for many years. Particularly for Co, bolus supplementation strategies are useful since the rumen microbes will receive a continuous supply of Co for the production of vitamin B12.

Availability of commercial sources of trace mineral boluses varies throughout the world. Reasons depend on, 1) the degree of extensive range utilized for grazing, which favor the benefits of bolus technologies, 2) the prevalence of trace mineral deficiencies in the grazed forages, and 3) local laws that limit the use of certain bolus technologies due to toxicity concerns (i.e. Se in the USA) or food safety concerns (i.e. glass boluses that remain in the rumen throughout the animal's life). Although there are certainly known benefits to the use of intra-ruminal boluses for the delivery of trace minerals, the technology is not without problems. Cows can regurgitate the boluses and the presence of hardware disease in individual animals can cause variation in the liberation rate of mineral from the bolus due to physical scratching of ingested metal against the ruminal bolus.

One of the most widely used forms of trace mineral boluses are Cu oxide needles packaged within gelatin boluses. Copper oxide boluses are effective in rapidly increasing liver Cu stores in cattle (Yost et al., 2002) and are likely more effective than injectable Cu for providing longer-term tissue Cu reserves in cattle (Rogers and Poole, 1988). In some studies, Cu toxicity was diagnosed in calves from Nebraska, Wyoming, and North Dakota beef herds receiving Cu-oxide boluses (Hamar et al, 1997; Steffen et al, 1997). Although toxicity conditions have been reported, particularly in calves, Cu-oxide boluses have continued to be considered among cattle producers as a potential tool for addressing Cu imbalances in grazing cattle.

We previously evaluated the effects of Cu-oxide boluses in two cowherds in southwest Kansas (Arthington et al., 1995). Copper bolus administration decreased calf ADG in Herd 1 (ADG = 0.81 versus 0.96 kg/d for bloused and control caves, respectively) and calf weaning weight in Herd 2 (14.1 and 27.9 kg lighter for bloused bulls and heifers, respectively, compared to non-bolused control calves).

One explanation for the negative impact of Cu-oxide bolus administration on calf gain relates to the potential antimicrobial effect of Cu in the rumen. Copper may be altering the ruminal microflora in such as manner as to negatively impact forage digestion. To investigate this, we examined the effect of Cu-oxide bolus administration on forage nutrient digestion in yearling crossbred steers (Arthington, 2005). In this study, intake of the forage fiber (NDF and ADF) and CP did not differ between treatments, however, digestibility of NDF and CP were greater and digestibility of ADF tended to be greater for Control steers vs. steers receiving Cu oxide boluses. One explanation for the decrease in apparent digestibility of forage nutrients in bolused steers relates to the potential toxicity of Cu to the ruminal microorganisms. Hubbert et al. (1958) conducted *in vitro* studies aimed at determining the mineral requirements of ruminal microorganisms. In their study, Cu was found to be particularly toxic to ruminal microorganisms. Depression in forage digestion was noted with fermentation media containing 1.5 mg Cu/L. Similarly, the ability of ruminal microorganisms to convert non-protein nitrogen into protein has been shown to be significantly reduced when ruminal liquid contained 10 mg Cu/L (McNaught et al., 1950).

Pasture Se Biofortification

One potential method for addressing Se nutrition in grazing cattle is the implementation of pasture Se applications with the intent of increasing plant Se content (biofortification) and thus the Se status of cattle grazing these forages. In Florida, spraying bermudagrass with Na selenate at Se application ranges of 120 to 480 g/ha resulted in substantial increases in forage Se content by 2 wk after application, decreasing rapidly by 12 wk post-application (Valle et al., 1993). Feeding forages grown on Se-fertilized hay fields impacts both Se status and performance of grazing cattle. In one study (Hall et al., 2013), weaned Angus-type calves were fed Se-fertilized alfalfa hay over a 7-week period. Alfalfa hay was grown on fields receiving applications of Na selenate in amounts providing 0, 23, 45, or 90 g Se/ha. These application rates resulted in a linear (R^2 = 0.997) response for Se application rate and subsequent Se content of alfalfa hay harvested 40 d after Se application. In addition, calves consuming these hay treatments (approximately 2.5% BW daily) experienced a linear (R^2 = 0.979) increase in whole blood Se concentrations as Se application rate (and Se content of hay) increased.

In a recent Florida study (Ranches et al., 2017), we produced a high-Se hay crop by spraying a Jiggs bermudagrass hayfield with Na selenate at a rate of 257 g Se/ha. Selenium content of hay, harvested 8 wk after Na selenate application, was greater for Se-treated vs. control pastures (7.73 ± 1.81 vs. 0.07 ± 0.04 mg/kg DM; $P < 0.001$). This hay crop was fed to weaned calves and Se status was evaluated over a 42-d study. A pair-feeding design was utilized, whereas each pen of high-Se hay calves was paired to a pen of Na selenite - supplemented calves. Liver Se concentrations remained unchanged for the negative control calves receiving no supplemental Se over the 42-d feeding period, but they were increased ($P < 0.001$) in calves receiving both high-Se hay and Na selenite treatments. Calves receiving high-Se hay had greater ($P < 0.05$) liver Se concentrations on d 21 and 42 than calves receiving Na selenite. Interestingly, this difference was attributed only to the paired pens consuming < 3 mg Se daily.

Analysis of Herd Trace Mineral Status

If a trace mineral deficiency is suspected, a producer may wish to conduct an evaluation of herd trace mineral status. With today's technologies, this task is fairly simple and cost efficient. The following steps should be considered with attempting to evaluate herd trace mineral status and effectiveness of the trace mineral supplementation program.

A. Rule out other influential factors

The first step in identifying trace mineral deficiencies is to attempt to rule out other more directly contributing factors. For instance, if average cow body condition score is less than 4 ½, chances are far greater that decreases in reproductive performance and/or immune function are a result of energy/protein deficiency versus trace mineral deficiency. Also, be sure to evaluate the basics of your current supplementation program. Does the product provide a balanced mineral profile using quality ingredients? Are the cattle being provided with a consistent supply of fresh, dry mineral? Are the cattle consuming the mineral at an appropriate level?

B. Forage trace mineral concentrations

Grazing cattle selectively consume forage with 25 to 30 % more crude protein than hand-clippings of the same pasture. In a field study, we attempted to collect the same forage being consumed by grazing steers. Prior to grazing controlled areas, we emptied the ruminal contents from four rumen-cannulated steers. During the grazing periods, we attempted to clip that forage which the steers were consuming. Later, the rumen of each animal was again emptied and the consumed forage rinsed with water. Even though we made attempted to clip exactly the forage being consumed, the steers selected forage higher in crude protein (30.0%), calcium (52.6%), and phosphorus (36.8%), compared to hand-clipped samples. However, no differences occurred in the trace mineral content of steer selected vs. clipped forage, suggesting that hand-clipped forage samples are a good reflection of the trace mineral concentration of animal-selected forage.

When collecting forage samples for trace mineral analysis it is important to collect the sample from areas where animals are grazing (selecting). Do not collect from non-selected forage areas and be careful to not contaminate your sample with weeds or dirt. Prior to collection, find a laboratory that will test forage for trace mineral levels. Many commercial laboratories offer an analysis package containing a group of trace minerals for $25 to $50 per sample. The laboratory will provide directions for collection, handling, and shipping. It is important to test for Cu, Zn, Se, Co, and Mn. It is also important to consider including antagonistic trace minerals, which may interfere with the normal absorption of other minerals. Three commonly recognized antagonists in forages are Mo, Fe, and S.

C. Herd trace mineral status

Often, it is possible to establish a reasonable plan of action by addressing points 1 and 2. However, in some instances it may be important to further explore a potential trace mineral deficiency by examining animal blood and/or liver mineral status. For two of the most commonly deficient trace minerals, Cu and Se, liver samples provide the most reliable indicator of actual animal stores. Blood samples are an unreliable approach for the measurement of these elements unless the cattle are severely deficient. Modern laboratory technology allows for the use of very small tissue samples for the analysis of multiple trace elements. Today’s liver biopsy collection technique is simple, inferring very little stress to the animal. A summary of common indicators of trace mineral status for cattle is provided. Actual values are not provided. These will vary depending on the laboratory technique, moisture content of sample, and sample preparation processes. It is important to visit with your diagnostic laboratory prior to sample collection for information on how to handle and ship the sample. This laboratory should also be able to share with you their ranges of deficiency to sufficiency for the samples and minerals being tested.

Indicators of trace mineral status

Mineral	**Indicator**
Copper	Liver is the best indicator. Blood is a very poor indicator and should not be used. Ceruloplasmin enzyme activity can be used, but will be misleading in stressed animals.
Zinc	Zinc status is difficult to assess in living animals. Liver is a relatively poor indicator. Plasma or serum is the most commonly used indicator, but is reliable only for very recent dietary intake. Reduced feed intake is a common indicator of Zn status.
Selenium	Liver is the best indicator. Whole blood is a good indicator and better than plasma or serum. Glutathione peroxidase enzyme activity in red blood cells is fair to good indicator.
Manganese	Similar to Zn, Mn is also difficult to assess in living animals. Blood plasma or serum are poor indicators, both representing the Mn concentration of the most recent meal. Liver and hair Mn concentrations are fair indicators of deficiency and toxicity, respectively.
Iodine	Presence of goiter is a primary indicator of severe I deficiency. Diagnosis of subclinical I deficiency is difficult. Some reports indicate that milk I concentrations may be of some benefit.
Iron	Blood hemoglobin concentration is a good indicator of Fe status. Liver Fe concentration is also a good indicator.
Cobalt	In ruminants, functional Co appears in the form of vitamin B12. Therefore, blood and tissue vitamin B12 concentrations are a good indictor of Co status in ruminants. Liver Co concentrations are fair indicators of Co status.

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