SDSU Extension

BEEF

Chapter 20

Mineral Nutrition for Beef Cattle

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Chapter 20:

Systems Approach to Beef Cow Herd Management

Introduction

Requirements have been published for 13 different minerals in beef cattle diets. Other minerals such as chlorine, chromium, molybdenum, and nickel are known to be essential for beef cattle; however, there is currently not enough data available to accurately determine requirements. For some of the required minerals, requirements vary depending on cow size and stage of production. This variability results from increased mineral demand for the products of conception and for milk production. For these minerals, requirements are always greatest during peak lactation and lowest for non-lactating cows in mid-gestation.

Minerals are essential for the proper function of numerous physiological processes. From a production perspective, proper mineral nutrition is critical for metabolic function, health, and reproduction. Unfortunately, mineral nutrition is one of the most complicated and least understood components of nutrition. This review will focus on the macro and trace minerals that have been shown to impact productivity in beef cattle.

Calcium (Ca)

Functions

Calcium is the most abundant mineral in the body and 99% is found in the skeleton; however, the small proportion of body calcium that lies outside the skeleton is important to survival. In addition to its structural role, extracellular Ca is essential for nerve conduction, muscle contraction, blood clotting, and as an enzyme cofactor. Relative to beef production, Ca has well-documented roles in reproduction and meat tenderness. Sperm capacitation and motility in bulls are affected by Ca.

Calcium is also responsible for the activation of μ- and m-calpains in muscle tissue. These enzymes play a key role in the post-mortem tenderization of meat.

Key Points

- Proper mineral nutrition is essential to beef cattle growth, health, and reproduction.
- Mineral supplementation programs should begin with identification of the animal's requirements. Producers should then sample their feed resources, including pastures and water, and submit them for analysis to determine which minerals are deficient, adequate, or potentially toxic. Book values are not reliable. Cost-effective supplements can then be purchased or formulated to correct any imbalances.
- Mineral nutrition is not a one-size-fits-all component of beef cattle production. Mineral requirements change with animal size and stage of production and the mineral concentrations in feeds are highly variable. Optimal productivity depends on each operation identifying a mineral supplementation program that best fits their livestock in their environment.

Requirements and Supplementation Needs

Calcium requirements for cows, pregnant replacement heifers, and developing heifers are presented in Tables 1-5. In most circumstances, very little if any supplemental Ca is necessary for cattle grazing early in the growing season. However, as the season progresses and the forages begin to mature, there may be a need for supplemental Ca. The use of distillers co-products in beef cow and heifer diets has become increasingly more common. Consequently, it is important to consider how the use of these feeds might impact the mineral nutrition of the cattle. Distillers co-products are commonly low in Ca and high in phosphorus (P). This, combined with the relatively low concentrations of both minerals in the forages commonly fed with the co-products (e.g., corn stalks, wheat straw, poor-quality grass hay) necessitates re-evaluation of the Ca supplementation strategy for these cattle. In many instances, it will be necessary to supplement Ca when using distillers co-products. Most feed companies have developed mineral supplements specifically formulated to use with distillers co-products. It is important for producers to utilize these products to help maintain proper Ca:P ratios in their diets. The ratio should be maintained between 1.5:1 and 7:1 to avoid an imbalance. However, supplementing Ca to provide a ratio above 2:1 is not beneficial.

Sources

Calcium is relatively high in legumes, fish meal, oilseed meals, and grasses (more so early in the growing season). Grains are commonly very low in Ca. The most common supplemental source of Ca is limestone, but Ca carbonate, dicalcium phosphate, and defluorinated phosphate all provide significant Ca to the diet.

Deficiency

Signs of Ca deficiency include bone abnormalities, reduction in milk yield, and tetany. Long-term effects include osteoporosis and kidney stones. Calcium deficiency is relatively uncommon in beef cattle. However, low Ca concentrations in the diet may contribute to urinary calculi.

Toxicity

Calcium is relatively non-toxic for beef cattle. High dietary Ca may result in reduced feed intake and, consequently, growth and may reduce the absorption of Fe, Zn, and Mg. However, the Ca concentration necessary to antagonize these other minerals is exceptionally high and would be relatively rare under practical conditions.

Phosphorus (P)

Functions

Phosphorus is the second most abundant mineral in the body and approximately 80% is found in the bones and teeth. However, P is also an essential component of DNA and RNA, phospholipids, and has a key role in a host of metabolic processes. Among the most commonly discussed components of P nutrition is its effect on reproduction. Early experiments documented tremendous responses to P supplementation in the form of meat and bone meal; however, subsequently, it was determined that these responses were more likely due to the protein content of the feed rather that the P. In other research, range beef cows in North Dakota that were supplemented with P had slightly greater conception rates than control cows in one year, but not in a second. While supplemental P did not have an impact on reproduction, it did consistently increase calf weaning weights. Other researchers have observed no response to supplemental P or responses only in drought years.

Requirements

Phosphorus requirements for cows, pregnant replacement heifers, and developing heifers are presented in Tables 1-5. In most pasture settings, early growth forages may contain enough P to meet the needs of the cattle. However, as the season progresses and the forages begin to mature, there will be need for supplemental P. Historically, producers utilized meat and bone meal and dicalcium phosphate to provide supplemental P to grazing cattle. More recently, the increased use of distillers co-products in beef cow and heifer diets has reduced the need for supplemental P. Depending on the amount of distillers co-products being fed, it is very possible that most, if not all, of the supplemental P requirement will be met without supplementation. This is true not only for distillers co-products, but a host of other feeds. Table 6 illustrates what % P is contributed to the total diet of beef cows based on various amounts of different feed ingredients. Utilization of these feeds can substantially reduce

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the amount of supplemental P necessary to meet the requirements of the cattle.

Sources
Grains and plant protein sources are generally high in P. The most common supplemental sources include dicalcium phosphate and monocalcium phosphate; however, defluorinated phosphate, diammonium phosphate, and monosodium phosphate may also be used.

Deficiency
Phosphorus deficiency generally manifests as bone disorders, reduced appetite and growth, reduced heat tolerance, and impaired reproduction. Cattle that are deficient in P may exhibit pica (i.e, craving for unusual foods such as wood, bone, dirt, etc).

Toxicity
Although direct toxicity is relatively rare, high dietary P concentrations can contribute to loss of bone, low blood calcium concentrations, and urinary calculi in beef cattle.

Magnesium (Mg)
Functions
Approximately two-thirds of the Mg found in the body is associated with bone. Another one-third of the Mg found in the body is complexed with nucleic acids and proteins in muscle and other soft tissues. A small fraction of Mg is found in the extracellular fluid. Magnesium has essential roles in numerous physiological systems including activation of over 300 metabolic reactions, stabilization of nucleic acid and ribosome structures, membrane function, and regulation of ion channels.

Requirements
Magnesium requirements for various classes of beef cattle are presented in Table 7. Magnesium is one of the few nutrients that is absorbed in large quantities from the rumen. Absorption is dependent upon ruminal pH and the concentrations of various antagonists. As the pH of the rumen fluid rises (i.e., becomes more alkaline), the solubility of Mg decreases. The fact that growing and finishing cattle have lower Mg requirements than gestating or lactating cattle is partially in response to this phenomena. High levels of potassium (K) will inhibit active absorption of Mg, a contributing factor to grass tetany.

Cattle do not store Mg to a great extent, so it is important for it to be provided in the diet on a daily basis, either from feeds or supplemental sources.

Sources
Other than lush, rapidly growing grasses, forages are generally high in Mg and will likely supply a majority of the requirement. Cereal grains and oilseed meals also tend to contain appreciable amounts of Mg. When supplementation is necessary, Mg oxide and Mg sulfate are the common sources used. Both are highly available to the animal; however, Mg oxide is generally not as palatable and may reduce consumption of free choice mineral supplements.

Deficiency
The primary condition associated with Mg deficiency is grass tetany or hypomagnesemia. Grass tetany is most commonly observed in grazing cattle on lush, rapidly growing forages in the spring or fall. These forages are not only low in Mg, but they contain high concentrations of K, a potent Mg antagonist. Mature and/or heavy milking cattle are the most susceptible to grass tetany. Signs of grass tetany include nervousness, twitching around the face and ears, incoordination, collapse, and convulsions. Grass tetany is easily prevented by providing ½ to 1 oz Mg oxide per head per day or 1 to 2 oz Mg oxide per head per day when current clinical cases are present. Supplementation should begin 2 weeks prior to the cattle being turned out on the pasture; however, initiating supplementation 30 days prior to turn out would allow more time to insure the cattle are consuming the supplemental mineral at the proper rate.

Toxicity
Magnesium toxicity is not likely under practical circumstances. Signs of toxicity include severe diarrhea, sluggish appearance, and reduced intake.

Potassium (K)
Functions
Potassium is the third most abundant mineral in the body. It is primarily found in the intracellular fluid where it is involved in acid-base balance, osmotic pressure regulation, muscle contraction, nerve impulse transmission, oxygen and CO_2 transport in the blood, and enzyme reactions.

Requirements

Potassium requirements for various classes of beef cattle are presented in Table 7. Lactating cows require slightly more K than do growing and finishing or gestating cattle because of the relatively large amount of K secreted in milk. Potassium is well absorbed and is not subject to any significant antagonism. Grazing cattle rarely need supplementation; however, K concentrations will be significantly lower in mature, stockpiled forages, leading to the need to supply K from other sources. As many of these forages need supplementation with other nutrients, such as protein, adequate K is often supplied when correcting other nutrient imbalances. Grains are typically low in K and consequently growing and finishing diets may require supplemental K to meet the needs of the cattle. An exception would be when corn co-products are being used in significant quantities. They tend to contain higher amounts of K and can supply a significant proportion of the dietary needs.

Sources

Forages, particularly lush, rapidly growing forages, are generally high in K. Oilseed meals and corn co-products are good sources of K. Supplemental K is often provided by K chloride or K bicarbonate.

Deficiency

Signs of a K deficiency include muscle weakness, anorexia, cardiac arrhythmias, glucose intolerance, and renal dysfunction. Marginal deficiencies may result in reduced feed intake, growth, and milk yield. Potassium deficiency may be caused by low K intake, vomiting, diarrhea, or use of diuretics. Young calves with scours are particularly vulnerable to K deficiency.

Toxicity

Potassium toxicity is rare in cattle, but may result in renal dysfunction and hyper excitability.

Sodium (Na) and Chloride (Cl)

Functions

Sodium and chloride are each found primarily in the extracellular fluid where they are involved in acid-base balance, osmotic pressure regulation, muscle contraction, nerve impulse transmission, and absorption of glucose and amino acids. Chloride is also necessary for acid production in the stomach and aids in respiratory gas exchange.

Requirements

Although there is a published Na requirement for beef cattle (Table 7), beef cattle diets are rarely formulated for Na independent of chloride. Cattle have an appetite for Na and will generally consume enough to meet their needs when Na is provided free choice. Because cattle have an appetite for Na, white salt is commonly utilized as an intake modifier. Small amounts of white salt often stimulate intake, whereas high concentrations will reduce intake.

Sources

Most feeds used in beef cattle production are low in Na. As such, white salt is commonly included in the diet, either as a component of a supplement or free choice. Sodium bicarbonate might also be used as a Na source.

Deficiency

Chloride deficiency is unlikely under practical conditions. Signs of Na deficiency include reduced growth, feed efficiency, and fluid volume. Sodium deficiency might also be accompanied by losses of Cl, K, and water.

Toxicity

Dietary salt is well tolerated by cattle provided there is adequate water available, but when salt is present in drinking water, the risk of toxicity increases. Toxicity signs include anorexia, reduced weight gain, lower water intake, and collapse. This can become particularly problematic for beef producers with poor-quality water. In most cases, the most dangerous component of poor-quality water is sulfate. However, high sulfate concentrations are frequently accompanied by high Na concentrations. When this occurs, cattle are less likely to consume mineral supplements containing white salt and will generally lose weight as a result of the reduced feed intake. Otherwise unexplained loss of body condition score in beef cows may be a result of high salt concentrations in the water.

Sulfur (S)

Functions

Sulfur is a two-edged sword for many beef producers. On one hand, S is an essential building block of certain amino acids and B-vitamins. It is also a key component in detoxification reactions and is required by ruminal microbes. However, high sulfur concentrations can result in S-induced polioencephalomalacia (PEM) and reduce copper (Cu) absorption and status in cattle.

Requirements

Beef cattle require 0.15% S in their diets, a concentration easily obtainable with common dietary ingredients. Sulfur supplementation may be necessary when cattle are fed a large percentage of their dietary protein via non-protein nitrogen sources such as urea. However, in most instances, there is enough S present from other feed ingredients and the water to meet the needs.

Sources

Sulfur is found in most feeds as a component of protein. Although highly variable, water can contain appreciable concentrations of S. Corn co-products also generally contain high concentrations of S due to the use of sulfuric acid in the ethanol production process. Some ethanol plants have recognized this as a problem and have discontinued the use of sulfuric acid. Potential S supplements include Na sulfate, ammonium sulfate, Ca sulfate, and Mg sulfate.

Deficiency

Sulfur deficiency results in anorexia, weight loss, weakness, excessive salivation, and can be fatal. Marginal deficiencies may result in reduced feed intake and growth and reduced microbial activity in the rumen.

Toxicity

Sulfur toxicity is a tremendous problem for beef producers. Moderate excess S consumption can lead to a thiamin deficiency resulting in traditional PEM. Cattle affected by traditional PEM may respond to injections of thiamin and an anti-inflammatory and/or oral thiamin supplementation. However, cattle are far more likely to be affected by S toxicity (a.k.a. hydrogen sulfide toxicity or S-induced PEM). Generally, S toxicity results from overconsumption of S from water or corn co-products. Sulfur toxicity rarely responds to either thiamin therapy or oral thiamin supplementation. Unfortunately, the signs of both traditional PEM and sulfur toxicity are similar. Star-gazing and head pressing are commonly associated with both conditions. Sulfur toxicity is more prevalent with low ruminal pH and consequently observed more frequently in growing and finishing cattle. As such, the NRC (2005) recommends a maximum of 0.3% S for cattle consuming 85% concentrate diets or more and 0.5% S for cattle consuming at least 40% forage. In concert with iron (Fe) and molybdenum (Mo), S can also reduce Cu absorption and status in cattle. This will be discussed in greater detail in a subsequent section.

Cobalt (Co)

Functions

Cobalt itself is not required by beef cattle. However, Co is utilized by ruminal microbes to synthesize vitamin B_{12} and is thus included in the dietary requirements. Vitamin B_{12} is a component in several enzyme systems and metabolic processes.

Requirements

Beef cattle require 0.10 ppm Co in their diets. Because ruminal microbes utilize the dietary Co, it is not susceptible to many of the antagonisms commonly associated with other trace minerals.

Sources

Cobalt concentrations of forages are highly variable. Generally legumes contain higher concentrations than grasses; however, soil pH has a major effect on Co availability. Forage Co concentrations tend to be lower in rapidly growing forages and forages grow in alkaline soils. Cobalt supplementation is frequently necessary. Common supplemental Co is available from both inorganic (Co carbonate and Co sulfate) and organic (Co glucoheptonate) sources.

Deficiency

Cobalt deficiency is more common in young cattle than in mature cattle. Signs include reduced appetite and growth. Severe deficiency may result in severe unthriftiness, weight loss, liver atrophy, and anemia. Compromised immune function and reduced ruminal propionate production are also possible.

Toxicity

Cobalt is essentially non-toxic under practical conditions. Gross formulation error may result in toxicity. Signs would include reduced feed intake and weight gain, anemia, and abnormally high hemoglobin content of red blood cells.

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Copper (Cu)

Function

Copper is present in and essential for the activity of numerous enzymes, cofactors, and reactive proteins. Physiological functions relevant to beef production that depend on Cu include growth, immune function, reproduction, and collagen formation.

Requirements

Beef cattle require 10 ppm Cu in their diets, but that requirement is extremely fluid. Sulfur, Fe, and Mo are potent Cu antagonists and present significant challenges when formulating diets. The combination of S and Mo in the rumen results in the formation of thiomolybdates which form insoluble complexes with Cu and reduce its absorption. A percentage of the thiomolybdates is absorbed by the animal and can reduce the existing stores of Cu in the system. Given the relatively high concentrations of Mo in feeds and forages and the amount of high-sulfate water and feeds (e.g. distillers co-products), Cu deficiency is arguably one of the most common mineral concerns in the upper Great Plains. Zinc (Zn) has also been reported to antagonize Cu absorption; however, the dietary Zn concentrations necessary to antagonize Cu are significantly above those found in practical applications. Supplementation to overcome these antagonisms requires formulation of supplements with increased levels of Cu or utilization of organic Cu sources.

Some evidence suggests that breed may influence the Cu requirements of beef cattle. Researchers have determined that Simmental and Charolais cattle may require as much as 25% to 50% more Cu than Angus cattle.

Sources

Copper is found in numerous feeds used in beef cattle production, but concentrations are highly variable and absorption is dependent upon the concentrations of the antagonists mentioned above. Supplemental Cu may be provided by inorganic (Cu sulfate and tri-basic Cu chloride) or organic sources (Cu amino acid complex, Cu lysine, Cu polysaccharide, Cu proteinate). Copper oxide is also available as a supplement; however, its bioavailability depends on the form. Powdered or granular Cu oxide included in supplemental feeds is essentially unavailable to cattle. In contrast, when Cu oxide needles are included in bolus form, they work extremely well. Copper is also available in an injectable multi-element product.

Numerous research experiments have been conducted to evaluate Cu sources and dietary levels. Organic Cu sources appear to be the most beneficial for cattle under high-stress situations (e.g., weaning time and calving time) and to overcome antagonists. Supplementing Cu above the requirement will also help overcome antagonists. There is little evidence that use of organic Cu sources or elevated dietary concentrations will be beneficial under circumstances outside of those described above.

Deficiency

Copper deficiency is a common problem for beef producers. Deficiency signs include anemia, reduced growth, compromised immune function, impaired reproduction, heart failure, changes in hair growth and appearance, and depigmentation. Depigmentation is a classical deficiency sign; however, caution must be exercised when evaluating cattle with depigmentation. Black hided cattle will often appear to have a reddish tinge, particularly when they have a winter coat, but this is not always associated with a Cu deficiency. Depigmentation associated with a Cu deficiency tends to be more prevalent around the eyes and muzzle with black cattle commonly turning red and red cattle turning a cream color. Severe deficiency will result in more uniform depigmentation. Copper deficiency is easily corrected with supplementation.

Toxicity

Copper toxicity is not as problematic in cattle as it is in sheep. Cattle can easily tolerate up to 40 ppm dietary Cu, but that level could be significantly higher in the presence of high concentrations of antagonists. Toxicity signs include liver damage, elevated methemoglobin, impaired oxygen transport, jaundice, and finally death.

Iodine (I)

Function

Iodine has only one known, but vital function as a constituent of thyroid hormones. Some research has attributed infertility, sterility, and poor conception rates due to delayed or depressed estrus to thyroid dysfunction in response to increased

I losses during peak lactation. In goats, iodine-deprivation has resulted in decreased libido and deterioration of semen quality. Although there is conflicting evidence, some research also suggests that supplementing I in the form of ethylenediamine dihydroiodide (EDDI) may help treat and/or prevent foot rot. However, the dietary concentration necessary to achieve this response is above the maximum level allowed by FDA (50 ppm).

Requirement

All cattle require 0.50 ppm I in their diets. Under certain circumstances, supplementation above the requirement may be necessary. Use of brassicas as cover crops for fall grazing has become increasingly popular. These crops can provide excellent quality feed for ruminants; however, many of them contain compounds called goitrogens that can interfere with thyroid hormone production. Generally, these goitrogens are largely destroyed by ruminal microorganisms, but if consuming large amounts, the microorganisms may not be able to detoxify them adequately.

Sources

Forages and feeds grown in many areas of the upper Great Plains are deficient in I and livestock need to be supplemented. This is generally accomplished with the use of iodized white salt. Other supplemental sources include Ca iodate (inorganic) and EDDI (organic). Potassium and Na iodides are not recommended because of their instability.

Deficiency

The classic sign of an I deficiency, regardless of species, is goiter. In addition to goiter, I deficiency may result in impaired brain development, birth of dead, weak, or hairless young, irregular estrus, embryonic death, skin abnormalities, reduced growth, and reduced milk production.

Toxicity

Iodine toxicity may result from single dose or repeated exposure. Signs include nasal and lachrymal discharge, conjunctivitis, coughing, hair loss, and dermatitis. Cattle can tolerate 50 ppm.

Iron (Fe)

Function

Approximately half of the Fe in the body is associated with hemoglobin and myoglobin. Iron is also an essential component of several cytochromes and Fe-S proteins involved in the electron transport chain and is an activator of several other enzymes.

Requirement

Although Fe absorption is affected by Fe status, age, chemical form, and the Fe concentration of the diet, the published requirement for all classes of cattle is 50 ppm Fe. In ruminant diets, Fe is relatively unaffected by antagonists. Some evidence suggests that the Fe requirement of young cattle may be slightly higher than that of mature cattle.

Sources

Most common feeds and water contain appreciable amounts of Fe. However, the Fe concentrations of forages can be highly variable. Soil ingestion is another route by which cattle can meet their Fe requirements. As a result, in the Upper Great Plains, Fe is rarely included in free choice mineral supplements for grazing cattle. It may occasionally be added to growing and finishing diets. Supplemental sources may be inorganic (Fe carbonate and Fe sulfate) or organic (Fe amino acid complex). Iron oxide may appear on an ingredient label, but it is essentially unavailable to the animal and is only added as a coloring agent. In some instances, water may be a significant source of dietary iron, but its bioavailability is not well documented.

Deficiency

Iron deficiency results in anemia, lethargy, reduced feed intake and weight gain, pale mucous membranes, and impaired immune function. Deficiency is unlikely for most beef cattle; however, calves raised in confinement on milk diets are more prone to deficiency.

Toxicity

Iron toxicity is rare under practical conditions. Toxicity signs may include diarrhea, acidosis, hypothermia, and reduced feed intake and weight gain. Although not toxic, high dietary concentrations of Fe may reduce Cu absorption and status in cattle.

Manganese (Mn)

Function

Manganese (Mn) is among the least well-researched trace minerals. It is an integral component of many enzyme systems including those involved in energy metabolism, immune function, skeletal development and reproductive function. Manganese has been linked to the function of the corpus luteum and the synthesis of cholesterol and sex hormones, although perhaps not as significant as once thought. Pregnant heifers fed diets deficient enough in Mn to result in deformed calves, did not have any alterations of plasma cholesterol concentrations or conception rates. Manganese deprivation has also been shown to restrict testicular growth in rams, but has not been investigated in cattle.

Requirement

The Mn requirements for various classes of cattle are presented in Table 7. In general, reproductive females require twice as much dietary Mn as growing and finishing cattle. This is due to the association of Mn with reproductive function. The Mn requirement of bull calves has not been established. High dietary Ca and P may reduce Mn absorption and high Fe concentrations may also antagonize Mn by competing for absorption sites. Neither of these antagonisms has been well researched in beef cattle.

Sources

Feed and forage Mn can be highly variable. However, forages generally contain enough Mn to meet the requirements. Supplemental sources may be inorganic (Mn oxide and Mn sulfate) or organic (Mn amino acid complex, Mn methionine, Mn polysaccharide, Mn proteinate). Supplemental Mn is also available as a component of an injectable multi-element product.

Deficiency

Although Mn deficiency is relatively uncommon, signs include skeletal abnormalities, depressed or irregular estrus, poor conception rates, abortion, still birth, and light birth weights.

Toxicity

Manganese is essentially non-toxic to domestic animals.

Selenium (Se)

Function

Selenium (Se) can be a challenging mineral to deal with on many beef cattle operations. In certain locations across the Midwest and Upper Great Plains, Se is deficient in the soil and hence the feeds and forages grown there. Yet in other locations, the Se concentrations found in feeds may exceed levels considered to be toxic. As with many other trace minerals, Se is a component of several enzyme systems. Many of these systems function as antioxidants, but there are numerous biologically active selenoenzymes. Production responses to Se supplementation of deficient animals have included improved fertility, reproductive function, and immune function.

Requirements

Beef cattle require 0.10 ppm Se in their diets. Selenium is commonly associated with vitamin E; both function in antioxidant roles in the body. From a nutritional perspective, they do have a sparing effect on each other (i.e., one can partially offset a deficiency in the other), but cannot completely cover deficiencies. Selenium absorption is also dependent to some degree on dietary Ca and S. Research suggests that some dietary Ca must be present in order for maximal Se absorption, but that too much Ca may actually reduce Se absorption. High dietary S concentrations may also reduce Se absorption.

Selenium supplementation should be based on the amount of Se in the basal dietary ingredients. In some areas, supplementation will result in beneficial responses, in others, it may be the straw that breaks the camel's back relative to toxicity. Given the narrow window between the requirement and toxicity, feed analysis and careful formulation is as essential for Se nutrition as for any other mineral.

Sources

The Se content of feeds will be dependent upon the Se content of the soil in which they were grown. Selenium in feeds is generally highly available to animals and should be considered when formulating diets. Supplemental Se is available in inorganic forms (Na selenate and Na selenite) and organic forms (high-Se yeast). Selenium is also available as a component of a multi-element injectable product. Selenium supplementation is regulated to a maximum of 0.3 ppm by the FDA. Up to 120 ppm can be included in a free choice mixture.

Deficiency

Selenium deficiency is most commonly associated with white muscle disease or nutritional muscular dystrophy in cattle. Cattle may also experience compromised immune function and reproductive disorders including retained placenta.

Toxicity

Selenium toxicity is one of the most likely toxicities faced by cattle in South Dakota and the Upper Great Plains. The maximum tolerable Se concentration for ruminants is 5 ppm. In many locations across South Dakota, forages may contain at least that much, if not more. That is not including Se accumulator plants that could potentially contain one hundred times as much Se. Acute Se toxicity (i.e., consumption of a Se accumulator plant) leads to abnormal movement, garlic breath, vomiting, labored breathing, and generally results in death. Subacute toxicity results in blind staggers, abdominal pain, excessive salivation, teeth grating, paralysis, respiratory failure, lameness, and death. The most likely situation faced by ranchers, is chronic Se toxicity (a.k.a. alkali disease). This condition results in cracked hooves, hoof deformation, sloughing of hooves and tails, lameness, and loss of tail.

Unfortunately, other than providing the livestock with low-Se feeds, very little can be done to address Se toxicity.

Zinc (Zn)

Function

Zinc is among the most ubiquitous of the trace minerals. It is an integral component of over 300 enzymes and is associated with numerous biological processes. Among the biological processes dependent upon Zn are enzyme activation, gene expression, immune function, reproductive function, and collagen formation. Supplementation of deficient cattle has improved growth, immune function, fertility, and hoof health. However, supplementation above the requirement is generally not beneficial.

Requirement

All classes of beef cattle require 30 ppm Zn. In ruminant diets, Zn is relatively unaffected by antagonists.

Sources

Zinc concentrations in feeds and forages are highly variable and depend on a number of factors. With that said, legumes tend to contain higher concentrations than grasses and plant protein sources tend to contain higher concentrations than cereal grains. Supplemental Zn is available in inorganic (Zn oxide and Zn sulfate) and organic (Zn amino acid complex, Zn methionine, Zn polysaccharide, Zn proteinate forms). Zinc is also available as a component of a multi-element injectable product.

Deficiency

Since Zn has very few antagonists, Zn deficiency most commonly results from inadequate dietary concentrations. Signs include reduced feed intake and growth, impaired reproduction, impaired immune function, scaly lesions on feet, slow wound healing and hair loss.

Toxicity

Zinc is essentially non-toxic. Cattle easily tolerate concentrations substantially above the requirement. Although extremely rare, signs of toxicity include reduced intake, weight gain, and feed efficiency.

Forage Minerals

Minerals are important components of plant growth and development. Some mineral differences among feeds are somewhat predictable based on plant sources. However, forage mineral concentrations are affected by soil type, growing conditions, fertilization, and plant type and species. In addition, the bioavailability of minerals can also be affected by some of these factors.

Table 9 presents information on how forages may differ in mineral levels and how forages may compare to grains. These relationships are general and are best considered for crops grown in the same region. Differences in mineral levels due to climate and soils across regions may have more influence on mineral concentrations than differences between species or due to maturity within a region. It is also important to evaluate a range of nutrients within a forage to identify minerals that interact with one another. Changes with plant maturity are affected by both the amount of 'green versus brown' (tissue age) and by changes in the proportion of leaf and stem. At times, these two factors can be having different effects on total forage minerals.

Mineral Supplementation

For most producers, the place to begin development of a mineral program is simply identifying the animals' requirements. It is important to recognize that, while published requirements are based on years of published research, our understanding of mineral nutrition in beef cattle is cursory at best. A growing body of research suggests that mineral requirements can vary significantly by breed, production, and the presence of antagonists. Producers should work with their nutritionist or Extension personnel to adjust their mineral program accordingly to account for these factors.

Mineral status can have an impact on the response to supplementation. If an animal's mineral stores are adequate, it is unlikely that supplementation will result in a biologically or economically significant response. However, if an animal is in a deficient state, and production has been compromised, the response to supplementation can be dramatic.

The first step in determining mineral status of the cowherd is to objectively analyze various performance and production measures. If there appears to be a reduction in a particular measure, be sure to rule out other potential causative factors. It is also essential to evaluate the current mineral program. Is it well balanced? What percentage of the cow's requirements does it meet? And, perhaps most importantly, are the cows consuming enough? The solution to the problem may be as simple as including a small amount of molasses to the mineral supplement to increase consumption.

The second step in determining mineral status is to determine how much of each mineral is supplied by the diet. Because of the inherent variability in the mineral content of the feeds and the potential error associated in predicting feed intake, this estimation can be challenging. Water also contributes a significant amount to the mineral nutrition of a beef cow. However, because of the extreme variability in mineral content and intake, most producers should only consider water as a source of potentially detrimental minerals (e.g., S and Fe).

The third and final means of assessing mineral status is to directly sample the animal. Mineral status can be evaluated by sampling and analyzing blood and/or tissue. For most minerals, a liver sample is the most reliable means of determining mineral status, especially for trace minerals. Mineral concentrations in blood are generally not good indicators of mineral status unless an animal is severely deficient. Liver samples can be obtained either post-mortem or from a live animal via liver biopsy. The liver biopsy procedure is simple and inflicts very little stress upon the animal. Consult your veterinarian or Extension personnel to find out more information on collecting liver biopsies.

When formulating mineral supplements, the source of each mineral can have an impact on the effectiveness of the supplementation program. In general, inorganic sources are the most cost-effective means of supplying minerals to a beef cow. However, all inorganic mineral sources are not created equal. Research suggests that sulfate and chloride forms of various minerals are the most bioavailable, followed by carbonates, with oxides being the least bioavailable. One exception to this rule of thumb is Cu oxide. When the powdered or granular form of Cu oxide is included in a mineral supplement, it is a very poor Cu source. However, research indicates that Cu oxide needles, administered as a bolus, can be an extremely effective means of delivering Cu to cattle on forage-based diets.

Organic mineral sources represent another option for producers to supply minerals to their cowherds. Research suggests that some organic mineral sources are indeed more bioavailable; however, production responses to supplementation have been variable. Positive responses to organic mineral supplementation are most likely during stressful periods in the production cycle (i.e., calving and weaning), or when mineral antagonists (e.g., S, Mo, Fe, and Al) are present in large amounts. In these situations, producers should objectively weigh any expected benefit to animal performance against the added cost of including organic minerals in their supplementation program.

Table 8 includes the relative bioavailability of numerous mineral sources.

When evaluating a mineral supplement, it is extremely important to read the feed tag carefully to determine the guaranteed amount and source of each mineral. In some cases, a mineral source may be listed as an ingredient on the tag without a guaranteed analysis. In this situation, producers should err on the side of caution and assume that there is essentially none of that mineral in the supplement. It is also important to look at the expected consumption rate shown on the tag. Generally, the difference between a 6% and 12% P mineral is that the first assumes a consumption of 4 oz per day and the second assumes 2 oz per day. Monitor mineral intake of cows to determine the appropriate mix to use based on typical consumption by your cows.

Summary

In developing the most cost effective mineral program, no single mineral formula is applicable to every farm and ranch around the country. Producers should carefully evaluate their production system, its resources, level of production, and production constraints, to develop the most cost-effective program for their operation. Keep in mind that more expensive mineral supplements do not always correlate with increased production or performance. Any cost associated with change in a mineral program must be accompanied by a corresponding increase in production or performance (i.e., weaning rate, weaning weight, etc.) to offset the added expense.

Table 1: Calcium and phosphorus requirements of beef cows (1000 lb mature weight). *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

Mineral	**Months since calving**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
% of diet DM												
10 lb peak milk production												
Ca	0.24	0.24	0.23	0.22	0.20	0.19	0.15	0.15	0.15	0.24	0.24	0.24
P	0.17	0.17	0.16	0.15	0.14	0.14	0.11	0.11	0.11	0.15	0.15	0.15
20 lb peak milk production												
Ca	0.30	0.32	0.30	0.27	0.24	0.22	0.15	0.15	0.15	0.24	0.24	0.24
P	0.20	0.21	0.19	0.18	0.17	0.15	0.11	0.11	0.11	0.15	0.15	0.15
30 lb peak milk production												
Ca	0.35	0.38	0.35	0.32	0.28	0.25	0.15	0.15	0.15	0.24	0.24	0.24
P	0.22	0.24	0.22	0.21	0.19	0.17	0.11	0.11	0.11	0.15	0.15	0.15

Table 2: Calcium and phosphorus requirements of beef cows (1200 lb mature weight). *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

Mineral	**Months since calving**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
% of diet DM												
10 lb peak milk production												
Ca	0.24	0.25	0.23	0.21	0.20	0.19	0.15	0.15	0.15	0.26	0.25	0.25
P	0.17	0.17	0.16	0.15	0.14	0.14	0.12	0.12	0.12	0.16	0.16	0.16
20 lb peak milk production												
Ca	0.29	0.31	0.29	0.26	0.24	0.22	0.15	0.15	0.15	0.26	0.25	0.25
P	0.19	0.21	0.19	0.18	0.17	0.15	0.12	0.12	0.12	0.16	0.16	0.16
30 lb peak milk production												
Ca	0.34	0.36	0.34	0.31	0.27	0.25	0.15	0.15	0.15	0.26	0.25	0.25
P	0.22	0.23	0.22	0.20	0.18	0.17	0.12	0.12	0.12	0.16	0.16	0.16

Table 3: Calcium and phosphorus requirements of beef cows (1400 lb mature weight). *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

Mineral	Months since calving											
	1	2	3	4	5	6	7	8	9	10	11	12
% of diet DM												
10 lb peak milk production												
Ca	0.23	0.25	0.23	0.21	0.20	0.19	0.16	0.16	0.16	0.27	0.26	0.26
P	0.17	0.17	0.16	0.15	0.15	0.14	0.12	0.12	0.12	0.17	0.17	0.17
20 lb peak milk production												
Ca	0.28	0.30	0.28	0.26	0.24	0.22	0.16	0.16	0.16	0.27	0.26	0.26
P	0.19	0.20	0.19	0.18	0.17	0.16	0.12	0.12	0.12	0.17	0.17	0.17
30 lb peak milk production												
Ca	0.33	0.35	0.32	0.30	0.27	0.24	0.16	0.16	0.16	0.27	0.26	0.26
P	0.22	0.23	0.21	0.20	0.18	0.17	0.12	0.12	0.12	0.17	0.17	0.17

Table 4: Calcium and phosphorus requirements of pregnant replacement heifers. *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

Mineral	Months since conception								
	1	2	3	4	5	6	7	8	9
% of diet DM									
1000 lb mature weight									
Ca	0.22	0.22	0.22	0.21	0.21	0.20	0.32	0.31	0.31
P	0.17	0.17	0.17	0.17	0.17	0.16	0.23	0.23	0.22
1100 lb mature weight									
Ca	0.23	0.22	0.22	0.22	0.21	0.21	0.32	0.31	0.30
P	0.18	0.17	0.17	0.17	0.17	0.17	0.23	0.22	0.22
1200 lb mature weight									
Ca	0.23	0.23	0.22	0.22	0.22	0.21	0.31	0.31	0.30
P	0.18	0.18	0.18	0.17	0.17	0.17	0.23	0.22	0.22
1300 lb mature weight									
Ca	0.24	0.23	0.23	0.22	0.22	0.22	0.31	0.30	0.30
P	0.18	0.18	0.18	0.18	0.18	0.17	0.23	0.22	0.22
1400 lb mature weight									
Ca	0.24	0.24	0.23	0.23	0.22	0.22	0.31	0.30	0.30
P	0.18	0.18	0.18	0.18	0.18	0.18	0.23	0.22	0.22

Table 5: Calcium and phosphorus requirements of growing and finishing cattle. *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

1200 lb at finishing or maturity[a]				1300 lb at finishing or maturity				1400 lb at finishing or maturity			
Wt. lb	**ADG lb/d**	**Ca, % of diet DM**	**P, % of diet DM**	**Wt. lb**	**ADG lb/d**	**Ca, % of diet DM**	**P, % of diet DM**	**Wt. lb**	**ADG lb/d**	**Ca, % of diet DM**	**P, % of diet DM**
660	0.72	0.22	0.13	715	0.76	0.22	0.13	770	0.80	0.22	0.13
	2.00	0.36	0.19		2.11	0.36	0.19		2.22	0.36	0.19
	3.04	0.49	0.24		3.21	0.49	0.24		3.38	0.49	0.24
	3.78	0.61	0.29		3.99	0.61	0.29		4.20	0.61	0.29
	4.25	0.72	0.34		4.48	0.72	0.34		4.72	0.72	0.34
720	0.72	0.21	0.13	780	0.76	0.21	0.13	840	0.80	0.21	0.13
	2.00	0.34	0.18		2.11	0.34	0.18		2.22	0.34	0.18
	3.04	0.45	0.23		3.21	0.45	0.23		3.38	0.45	0.23
	3.78	0.56	0.27		3.99	0.56	0.27		4.20	0.56	0.27
	4.25	0.66	0.32		4.48	0.66	0.32		4.72	0.65	0.32
780	0.72	0.20	0.13	845	0.76	0.21	0.13	910	0.80	0.21	0.13
	2.00	0.32	0.17		2.11	0.32	0.17		2.22	0.32	0.17
	3.04	0.42	0.21		3.21	0.42	0.22		3.38	0.42	0.22
	3.78	0.52	0.26		3.99	0.51	0.26		4.20	0.51	0.26
	4.25	0.61	0.30		4.48	0.60	0.30		4.72	0.60	0.30
840	0.72	0.20	0.13	910	0.76	0.20	0.13	980	0.80	0.20	0.13
	2.00	0.30	0.16		2.11	0.30	0.17		2.22	0.30	0.17
	3.04	0.39	0.20		3.21	0.39	0.20		3.38	0.39	0.20
	3.78	0.48	0.24		3.99	0.48	0.24		4.20	0.47	0.24
	4.25	0.56	0.28		4.48	0.56	0.28		4.72	0.56	0.28
900	0.72	0.19	0.12	975	0.76	0.20	0.13	1050	0.80	0.20	0.13
	2.00	0.28	0.16		2.11	0.28	0.16		2.22	0.28	0.16
	3.04	0.37	0.19		3.21	0.37	0.19		3.38	0.37	0.20
	3.78	0.44	0.23		3.99	0.44	0.23		4.20	0.44	0.23
	4.25	0.52	0.26		4.48	0.52	0.26		4.72	0.51	0.26
960	0.72	0.19	0.12	1040	0.76	0.19	0.13	1120	0.80	0.19	0.13
	2.00	0.27	0.15		2.11	0.27	0.15		2.22	0.27	0.16
	3.04	0.34	0.19		3.21	0.34	0.19		3.38	0.34	0.19
	3.78	0.41	0.22		3.99	0.41	0.22		4.20	0.41	0.22
	4.25	0.48	0.25		4.48	0.48	0.25		4.72	0.48	0.25

[a] Finishing for feedlot cattle and maturity for replacement heifers.

Table 6: Percent phosphorus contributed to diet by feedstuffs fed at various levels.[a] *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

Feedstuffs	% P in feedstuff	lb fed per day		
		2	4	6
		% P contributed to diet		
Canola meal	1.20	0.09	0.18	0.27
Corn gluten feed	0.95	0.07	0.14	0.21
Cottonseed meal	0.76	0.06	0.11	0.17
Dried brewers grains	0.70	0.05	0.11	0.16
Dried distillers grains	0.83	0.06	0.12	0.19
Soybean meal	0.71	0.05	0.11	0.16
Sunflower meal	1.02	0.08	0.15	0.23
Wheat middlings	1.00	0.08	0.15	0.23
[a] Calculations are based on a 1200 lb cow consuming dry matter at 2% of body weight.				

Table 7: Mineral requirements of beef cattle. *Adapted from Nutrient Requirements of Beef Cattle, National Research Council, 2000*

Mineral	Unit	Growing and Finishing	Gestation	Early lactation
Cobalt	ppm (mg/kg)	0.10	0.10	0.10
Copper	ppm (mg/kg)	10	10	10
Iodine	ppm (mg/kg)	0.50	0.50	0.50
Iron	ppm (mg/kg)	50	50	50
Magnesium	%	0.10	0.12	0.20
Manganese	ppm (mg/kg)	20	40	40
Potassium	%	0.60	0.60	0.70
Selenium	ppm (mg/kg)	0.10	0.10	0.10
Sodium	%	0.06-0.08	0.06-0.08	0.10
Sulfur	%	0.15	0.15	0.15
Zinc	ppm (mg/kg)	30	30	30

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Table 8: Mineral concentrations and relative bioavailabilities of common mineral sources. *Adapted from Hale and Olson, 2000*

Supplement	Mineral concentration (%)	Relative bioavailability[a]
Calcium		
Calcium carbonate	38	100
Calcium chloride	31	125
Dicalcium phosphate	20	110
Limestone	36	90
Monocalcium phosphate	17	130
Cobalt		
Cobaltous sulfate	21	100
Cobaltic oxide	73	20
Cobaltous carbonate	47	110
Cobaltous oxide	70	55
Copper		
Cupric sulfate	25	100
Cupric chloride (tri-basic)	58	115
Cupric oxide	75	15
Iodine		
Potassium iodate	69	100
Calcium iodate	64	95
Ethylenediamine dihydriodine (EDDI)	80	105
Magnesium		
Magnesium sulfate	20	100
Magnesium oxide	55	100
Manganese		
Manganese sulfate	30	100
Manganese carbonate	46	30
Phosphorus		
Defluorinated phosphate	12	80
Dicalcium phosphate	18	85
Selenium		
Sodium selenite	45	100
Sodium		
Sodium chloride	40	100
Sodium bicarbonate	27	95
Zinc		
Zinc sulfate	36	100
Zinc carbonate	56	60
Zinc oxide	72	100
[a] Relative bioavailability is expressed relative to the source listed first (italicized) for each mineral.		

Table 9: Forage species and maturity effects on mineral composition.

Mineral	Legume versus Grass	Cool versus Warm-Season Forage	Leaf versus Stem	Green versus Brown Forage Tissue	Grains versus Forages	Interactions with other minerals
Major elements						
Calcium	+	+	+	--	-	P
Magnesium	+	-	- or ND	+	ND	Na, K
Phosphorus	+	+	-	+	+	Ca
Potassium	+	+	UK	+	-	
Trace elements						
Cobalt	+	UK	+ or ND at low levels	IC	-	
Copper	+ (temperate only)	IC	IC	ND or IC	-	Mo, Fe, S, Zn
Iodine	IC	IC	UK	-	-	
Manganese	ND OR – at >60 ppm	UK	IC	IC	IC	Ca, P, Fe
Selenium	ND or -	UK	UK	UK	IC	
Sodium	+	+	ND	-	-	
Zinc	+	- (small)	+	-	-	Ca

+ = mineral is generally found in greater concentrations in the first source than second (i.e., for legume versus grass, a + indicates that the mineral is generally found in greater concentrations in legumes than grass species)
- = mineral is generally found in lesser concentrations in the first source than second (i.e., for cool versus warmseason forages, a - indicates that the mineral is generally found in lesser concentrations in cool-season than warm-season forages)
IC = inconsistent (may be related to differences in climate or soil type)
ND = No difference
UK = relationship is not known or is unclear

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