Mineral Interactions and Supplementation for Beef Cows

Proper mineral and vitamin nutrition contributes to strong immune systems, reproductive performance, and calf weight gain. Pasture forage is the most significant contributor to the trace mineral nutrition of grazing beef cattle. Mineral supplementation in beef cattle can be divided into two broad categories, macro-minerals and micro-minerals. These categories are based on the amount of mineral required in the cow's diet. As a rule of thumb, micro-minerals are required in amounts less than 1 gram per day compared to macro-minerals, which are often required at levels greater than 1 gram per head per day.

While supplemental energy and protein may not be needed, it is generally recommended to provide supplemental minerals and vitamins. They have less impact than protein and energy on cow/calf performance and economics, but they should not be overlooked. While supplementation is important, over supplementation of minerals should be avoided to prevent possible environmental problems associated with runoff from waste or application of cattle waste to soil (e.g. phosphorus). Certain minerals can actually be toxic if supplemented in excessive amounts.

Mineral Requirements of Beef Cattle.				
	Requirement			
	Growing Cattle	**Pregnant Cows**	**Lactating Cows**	**Maximum Level**
Calcium, %	0.45	0.3	0.45	2
Phosphorus, %	0.3	0.2	0.2-.21	1
Magnesium, %	0.1	0.12	0.2	0.4
Potassium, %	0.6	0.6	0.7	3
Sodium, %	0.08	0.08	0.1	-
Sulfur, %	0.15	0.15	0.15	0.4
Iron, PPM	50	50	50	1000
Manganese, PPM	20	40	40	1000
Zinc, PPM	30	30	40	500
Copper, PPM	10	10	10	100
Iodine, PPM	0.5	0.5	0.5	50
Selenium, PPM	0.2	0.2	0.2	2
Cobalt, PPM	0.1	0.1	0.1	10
Molybdenum, PPM	-	-	-	5

Macro Minerals

Salt

Forages do not contain adequate amounts of salt (sodium). Sodium can be supplemented as sodium chloride or sodium bicarbonate, and both forms are highly available. Iodized salt should always be used to avoid an iodine deficiency. Cattle fed maintenance rations while confined in drylot often consume high levels of mineral mixtures, perhaps from boredom.

Calcium

Calcium is the most abundant mineral in the body. Vitamin D is required for active absorption of calcium. Forages are generally good sources of calcium, and legumes are higher in calcium content than grasses. The National Research Council assumed dietary calcium availability was only 50% when calcium requirements were calculated. For example, alfalfa has relatively high levels of calcium but 20 to 33% is unavailable to the animal.

Calcium can be deficient in mature or weathered forage. Similarly, small grain forage and grains, such as corn, are relatively low in calcium. Grains will contain about 0.03% calcium and about 0.3% phosphorus. Co-product feeds such, distillers grain products, corn gluten feed, and wheat middlings contain 0.5% to over 1% phosphorus.

When dietary phosphorus exceeds dietary calcium, absorption of calcium from the digestive tract is reduced. Animal in these situations will metabolize bone calcium to meet the requirement. However, the calcium in the bone is stored in combination with phosphorus and both will be extracted at the same time, thus both calcium and phosphorus in the bone will be reduced.

Signs of calcium deficiency include problems related to bones and bone growth. When there is an imbalance of calcium and phosphorus, another nutritional disease that can develop in growing male cattle is "water belly" or urinary calculi. Hard masses of mineral salts and tissue cells form in the kidney or bladder and can cause the problem.

The most effective method to prevent urinary calculi is to maintain total dietary calcium to phosphorus ratio of between 1.5:1 and 3:1. Cattle can tolerate calcium to phosphorus ratios of up to about 7:1. However, excessive calcium has been shown to reduce absorption of phosphorus and many of the essential trace minerals. A second method to minimize the risk of this disease is to make certain the cattle have access to salt or the total diet contains 0.5% up to 4% salt. Salt increases water intake, which increases mineral solubility and dilutes the urine.

Grass tetany, related to a calcium deficiency, sometimes occur when pregnant and lactating cows graze lush cool-season forage, such as fescue, and small grains. Cool-season forages are high in phosphorus and low in calcium during immature stages of development. Many people assume grass tetany is solely the result of magnesium deficiency. Symptoms of tetany from deficiencies of magnesium or calcium are indistinguishable without blood tests and the treatment consists of intravenous injections of calcium and magnesium gluconate, which supplies both minerals.

Phosphorus

Forage phosphorus concentration and digestibility declines with advanced maturity and weathering. Drought conditions and increased forage maturity (e.g., stockpiled forage) can result in lower forage-phosphorus concentrations. Therefore, phosphorus supplementation may become more critical in cases of winter grazing than feeding hay. The last table in this manuscript contains mineral concentrations detected in Ohio on 12 farms during one particular during winter months.

Phosphorus deficient animals will appear malnourished. Reproductive problems are common if phosphorus is deficient. Plasma phosphorus concentrations consistently below 4.5 mg/dL are indicative of a deficiency, but bone phosphorous is a more sensitive measure of phosphorus status.

Since phosphorus is a relatively expensive mineral, varying the phosphorus level during different times of the year is one means of saving money. Forage sampling for mineral content can be a money-saving activity in the long run. An excellent discussion of phosphorus was created by Dr. Francis Fluharty and is located at the OSU Beef Team webpage (http://beef.osu.edu/Neweconomics/ReTkgPhos.doc).

Potassium

Potassium levels of 0.6 to 0.8 percent of ration dry matter are considered adequate for cattle. In general, potassium levels of Ohio forages are adequate to excessive in potassium content. These high levels can be associated with reducing magnesium absorption and thus causing grass tetany problems. Therefore, always check potassium levels before any supplemental additions.

Potassium is soluble in plant tissue and can be depleted in standing forage or hay that is rained on after cutting and before baling. Carbonate forms of potassium appear to be more palatable than the chloride forms but potassium chloride can be an effective source of potassium. If potassium is added for winter feeding, remove it from the mixture when fescue starts growing in the spring. Growing forages are usually high in potassium.

Oilseed meals, such as, soybean meal and cottonseed meal, can be sources of potassium (1.5% K). Alfalfa products contain between 1.5 to 3% potassium. Urea-based supplement feed labels should be checked to see if they contain adequate levels of potassium if this mineral is of concern or is needed.

Magnesium and Grass Tetany

Grass tetany is most common in lactating cows grazing lush spring pastures. The reduction in standing forage magnesium concentration can be substantial during the winter months. During the early spring, climatic and soil conditions are cool and wet; plants will not contain adequate levels of phosphorus or magnesium. Cloudy weather can also increase the incidence of Grass tetany on lush immature spring forages.

While phosphorus and magnesium may be in adequate amounts in the soil, plant uptake is slow due to the cool, wet conditions. Fertilizing pastures with nitrogen and potassium is associated with increased incidence of grass tetany. Cows depend on a frequent supply of magnesium from the feed since mobilization of magnesium from the bone is not very efficient.

Grass tetany can occur more frequently older cows during early lactation than younger cows in the same pasture. Older cows are thought to be less efficient in mobilizing magnesium reserves from bone compared to younger cows.

In one early study the K:(Ca + Mg) ratios of normal and tetanigenic pastures were 1.67 and 2.37, respectively. Another study reported a mean K:(Ca + Mg) ratio of 2.45 in pastures of 19 farms that collectively had a 10% incidence of tetany in beef cattle. Magnesium absorption has been improved by feeding grains and ionophores. Legumes are usually higher in magnesium than are grasses.

Magnesium oxide and magnesium sulfate (epsom salts) are good sources of supplemental magnesium. Including 15-20% magnesium oxide in the mineral mix should reduce the problem. Adding 6-10% molasses or soybean meal will assure intake. In high-risk situations, cows should consume around 1 ounce of magnesium oxide per day. This is difficult because magnesium oxide is very unpalatable to cattle. It is best for the high-magnesium supplements to be provided at least one month ahead of the period of tetany danger. Because tetany can occur when calcium is low, calcium supplementation should also be included.

Fertilization and Grass Tetany

As with all crops, proper pH is the most important factor in crop management. If the soil does need lime, use a dolomitic source if soil-test magnesium levels are less than 50 ppm. If the field has recently received manure, the importance of soil-test information cannot be overstated. At the rate used by some producers, a single manure application may supply several years worth of phosphorus, and sometimes potassium. Do not apply excessive rates of nitrogen early in the spring because high nitrogen levels can reduce magnesium availability in ruminants. Maintain relatively high soil-test phosphorus levels as some research has shown that phosphorus additions can increase tissue magnesium levels and potentially even decrease potassium uptake. Delay potassium application on grasses until late spring as high potassium fertilization decreases magnesium uptake. Consider interseeding clover since legumes are higher in magnesium than grasses.

Sulfur

Sulfur is needed for synthesis of methionine and cystine, which are sulfur-containing amino acids, as well as the B vitamins, thiamin, and biotin. Ruminal microorganisms are capable of synthesizing all organic sulfur containing compounds required by the animal. Therefore, dietary sulfur requirements “might” be higher when diets high in rumen bypass protein are fed because of the limitation of sulfur for optimal ruminal fermentation. However, this is not the case with co-product feeds, such as distillers grains with solubles, that can be quite high in sulfur content but are also know for containing by-pass proteins.

When urea or other nonprotein nitrogen sources are fed, sulfur supplementation may be needed. Mature forage, forages grown in sulfur-deficient soils, corn silage, and sorghum-sudangrass can be low in sulfur. The typical nitrogen to sulfur ratio of a complete diet should be 10:1, nitrogen to sulfur. The sulfur requirement of ruminants grazing sorghum-sudangrass may be increased because of the need for sulfur in the detoxification of cyanogenic glucose found in most sorghum forages. However, there is little likelihood that supplemental sulfur will be needed in most cases.

Over consumption may be a greater concern than a deficiency. Cattle are sensitive to excessive sulfur intake from water and feed. The maximum tolerable concentration of dietary sulfur is estimated to be 0.4%. Sulphate sulfur in drinking water should not exceed 500 mg/L for young cattle. Diets high in sulfur can cause polioencephalomalicia (PEM). Signs of PEM include restlessness, diarrhea, in coordination, labored breathing, blindness, and death.

Distillers grain products, soybean meal, corn gluten feed, and others, may contain 0.4 to 1% sulfur. Remember, the maximum tolerance for sulfur is around 0.4%. Sulfur analysis becomes more important when wanting to use feeds containing relatively high levels of sulfur at relatively high rates in the diet. High levels of forage sulfur can be increase when using fertilizer sources high in sulfur (e.g. ammonium sulfate). High sulfur containing diets (feed and water) can aggravate copper status of cattle.

Trace Minerals

Selenium

The potential of selenium deficiency has been widely recognized throughout the US. Unlike most other essential trace nutrients, selenium supplementation offers a narrow range between deficiency and toxicity. Selenium inclusion is federally regulated at a maximum inclusion level not to exceed 3 mg/day or about 0.14 mg/lb of total diet (0.3 ppm). This amount is equivalent to only 0.27 gm of total selenium per ton of feed.

Selenium deficiency will cause retained placentas, infertility, and white-muscle disease in calves. The normal cow requirement is 0.1 ppm. Producers should be cautioned against attempting to mix their own formulation with selenium. The toxic level for selenium is only 10 times the requirement (2 ppm) and any math error or mixing mistake can lead to serious consequences.

Selenium is generally supplemented in animal diets as sodium selenite, while seleno-methionine is the predominant form of selenium in most feedstuffs. Selenium from seleno-methionine or a selenium-containing yeast was approximately twice as available as sodium selenite or cobalt selenite in growing heifers. Availability of selenium from sodium selenate is similar to sodium selenite. Vitamin E should be added to the diet along with selenium. Calves should be injected with a selenium-vitamin E solution at birth, where a problem exists. Alternate methods of supplementing selenium include injecting selenium every three to four months or at critical production stages and using boluses retained in the rumen that release selenium over a period of months.

Liver samples are the ideal way to determine a deficiency, with 0.25 to 0.5 ppm considered normal and 0.1 to 0.15 ppm considered deficient. Blood can also be used as an indicator with normal levels being 0.08 to 0.3 ppm with deficiencies considered being 0.002 to 0.025 ppm.

Copper

Copper deficiencies can cause poor reproduction, broken bones, weak calves, and light color hair. Discoloration normally occurs first around the eyes and tips of the ears. Sometimes, changes in hair color are not noted and the effect of a copper deficiency simply occurs as reproductive problems, scours, or calves older than four months ceasing to perform. Simmental and Charolais cows and their calves were more susceptible to copper deficiency than Angus cows fed the same diet in one study.

Copper status in cattle is susceptible to a number of antagonists, including molybdenum, sulfur, iron, and zinc. Forage may contain an adequate levels of copper (approximately 10 ppm), but if the diet contains high levels of molybdenum (2 ppm) and sulfur (0.25), they can work together to tie-up copper, rendering a deficiency. For molybdenum to exert an influence on copper, it is essential that an adequate level of dietary sulfur be available. When total dietary sulfur levels fall below .25%, even high levels of molybdenum may not be a problem with copper absorption. A common rule-of-thumb is if copper: molybdenum ratios are less than 4-5:1 and total dietary sulfur is greater than .25% then a potential Mo induced Cu deficiency is likely. Another way to look at it is for each 1 ppm of Mo in a total ration (DM basis), the amount of Cu available should be discounted by 8 ppm. Thus, if the total ration has 1 ppm of Mo and 20 ppm Cu, available Cu is considered to be 12 ppm . Legumes were blamed for increasing the molybdenum levels on reclaimed strip ground in Montana. Diets that contain greater than 0.35% sulfur and water containing high sulfur concentration have been implicated in initiating copper deficiency in cattle. The dietary copper to molybdenum ratio should be maintained between 4:1 and 10:1 in order to minimize the risk of molybdenum induced copper deficiency.

Copper and zinc are absorbed through similar pathways indicating a competition for absorption sites. Therefore, mineral supplements should be formulated with a copper: zinc ratio of around 1:2 or 1:3.

Forage-based diets containing 250 ppm iron and up can reduce copper status in cattle, iron-induced copper deficiency has resulted in pancreatic damage and impaired neutrophil function, suggesting reduced function of the immune system.

Generally available copper sources are copper sulfate, copper carbonate, copper proteinate, and organic forms of copper lysine. Injectable forms of copper such as copper glycinate or copper EDTA have been given at three- to six-month intervals to prevent copper deficiency. Although feed-grade copper oxide is largely unavailable, copper oxide needles, which remain in the gastrointestinal tract and slowly release copper over a period of months, have been used as a copper source for cattle.

When formulating mineral supplements for Simmental, Limousin, Charolais, or Maine-Anjou cattle and their crosses, it is important to remember that their requirement for copper is 1.5 times higher than the base requirement (10 ppm). Similarly, Jersey and Brahman cattle are more susceptible to Cu toxicity.

The recommendations here do may not apply to other ruminants. For example, sheep are more sensitive to higher copper levels than cattle..

Iodine

Iodine is critical for the maintenance of proper thyroid function. The iodine requirement is 0.2 to 0.3 ppm in the total diet. Goitrogenic substances in the feed may substantially increase the requirement (two- to four-fold), depending upon the amount and type of goitergens present. Plant sources that can increase the iodine requirement are white clover and some Brassica forage such as kale, turnips, and rape. They impair iodine uptake but can be overcome by increasing dietary iodine.

Ethylenediamine dihydroiodide (EDDI), often provided in trace mineral supplements as a foot rot preventative, provides a quality source of available iodine. As well, the inclusion of iodized salt in the base mineral mix should provide adequate iodine supplementation in most cases. Some signs of iodine deficiency include reduced fertility, enlarged thyroid (goiter), and stillborn, weak, and/or hairless calves.

Zinc

A zinc deficiency can affect reproduction, the skin, and hoof problems and cause swelling of the bone joints or slow healing of wounds. Zinc deficiencies tend to impair sperm production and sperm quality in bulls. Most forages are marginal to low in zinc concentration compared to the suggested requirement. Cows require 30-40 ppm zinc with diets containing 2-10 ppm considered deficient. Legumes are generally higher in zinc than grasses.

Copper and zinc are absorbed through similar pathways indicating a competition for absorption sites. Therefore, mineral supplements should be formulated with a copper: zinc ratio of around 1:2 or 1:3. Zinc sulfate, zinc oxide, and organic forms of zinc are common supplementation sources.

Iron

In general, iron deficiency is unlikely unless parasite infestation or disease exists and causes chronic blood loss. Availability of iron from forage appears to be lower than from most supplemental iron sources. Iron is normally supplemented in the diet as ferrous sulfate, ferrous carbonate, or ferric oxide. However, ferric oxide is basically unavailable and is used simply as a coloring agent.

The antagonistic impact of dietary iron on copper 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 iron. Taken together, additional supplementation of iron to grazing cattle is probably not a concern. Although ferric oxide is commonly used as a coloring agent in mineral supplements and is not readily available to cattle as an iron source, it can exacerbate an already low Cu status in cattle. High iron intake has also been implicated in reducing manganese absorption in cattle.

Manganese
Although dietary manganese absorption and retention in cattle is low (20%), manganese deficiency in grazing cattle is uncommon. Manganese requirements are approximately 40 ppm. A deficiency has sometimes been noted with feeding corn-silage diets. Manganese can cause infertility, light hair color, and calves with weak pasterns. Considering the importance of manganese on cow fertility and young calf development, it is most important to focus on optimal manganese nutrition prior to and following calving. Manganese sulfate is the most available form of manganese, but it is often difficult to find commercially. As an alternative, manganese oxide is an acceptable and widely used source of manganese supplementation. High intake of phosphorous, calcium, and iron results in reduced manganese absorption.

Cobalt
Cobalt is essential to ruminants through its participation in the ruminal synthesis of vitamin B-12. This metabolic process, unique to ruminants, allows us to virtually ignore the dietary supplementation of B-vitamins in cattle. Cobalt is poorly stored in body tissues, thus cobalt status in ruminants is commonly assessed via measurements of blood vitamin B-12 concentrations (200 ng/mL or higher considered adequate). Cobalt affects reproduction, growth, and causes pale skin (anemia). Cobalt supplementation plus an injection of vitamin B-12 should alleviate symptoms. Young rapidly growing cattle seem more susceptible to cobalt deficiency than mature cattle.

Mineral Supplementation

Supplementation of minerals may occur through a variety of means, including free-choice loose mineral mixes, trace mineral blocks, and fortified energy and/or protein supplements. Mineral fertilization of forage is not as efficient as direct supplementation of the animal. Forages should be fertilized to meet the growth characteristics of the plant.

Free-Choice Loose Mineral Supplements
Loose mineral supplements are an effective, cost-efficient means of delivering adequate mineral supplementation in most cases. Although formulations vary greatly, the common base mix should contain approximately 20 to 25% salt. “Average” intake is often targeted at two to four ounces per head per day. Some cattle consume no supplement, while others may consume as much as four or five times the intended daily amount. This variation can be reduced when minerals are incorporated into protein/energy supplements (discussed below).

Seasonal Variation in Consumption.

Body mineral reserves can be mobilized in time of need and deficiencies can take long periods of time to develop. During the summer months, cattle may readily consume salt-based mineral supplements. In winter months free-choice intake may be reduced by 15% or more. To avoid over consumption in the summer, offer mineral every 10 to 14 days at a level slightly exceeding the target intake. It is acceptable for the feeder to remain empty for a few days prior to the next scheduled day of mineral offered. In the winter and warranted, you could blend your mineral with your winter supplement (See energy-protein supplements below).

Trace Mineral Blocks

Salt blocks may not provide sufficient trace mineral intake in marginal or deficient situations due to the block being so hard it may be difficult for ruminants to consume enough to meet requirements. When cattle producers 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.

Energy-Protein Supplements

If consumption of adequate levels of minerals are a problem, a solution may be incorporating your free-choice trace mineral supplement with a protein-energy supplement.

Palatability (the desire to consume/taste)

Monitor and record average daily intake of free-choice supplements so that the supplement formula can be adjusted if necessary to increase or reduce intake. Cattle do not have the natural desire to consume trace minerals. Cattle only possess the desire 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. While adequate levels of trace mineral are needed, consuming beyond that nutritionally required by the animal is excreted in urine and feces.

If cattle are over-consuming mineral, consider adding plain white salt directly into the trace mineral mixture. Once mineral intake has normalized, remove the additional salt. Phosphorus and magnesium sources are unpalatable and may reduce mineral supplement consumption. Do not provide plain white salt and trace mineral supplement separately.

A rule of thumb is the more acidic types (sour taste) are more palatable than the alkaline (bitter taste). Excessive ph on either side and reduce the potency of drugs, vitamins and additives. The alkaline (high pH) ingredients can cause a gaseous ammonia release from some ammonium-based ingredients (Limestone + Ammonium Sulfate).

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. The first step in identifying trace mineral deficiencies is to attempt to rule out other contributing factors. For instance, if average cow body condition score is less than 4-4.5, chances are decreases in reproductive performance and/or immune function are a result of energy/protein deficiency versus trace mineral deficiency.

Other things to evaluate are: Is the mineral supplement in an easily accessible location? 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?

Forage Mineral Concentrations

Grazing cattle selectively consume forage with higher quality (Na, P, Zn, and Co) than hand-clippings of the same pasture. Intensive, rotational grazing may reduce these differences. Even with this variation, hand-clipped forage samples are still a useful tool in evaluation of mineral status. Although availability of forage mineral varies with the specific mineral, soil mineral concentrations, and forage maturity and weathering, most data indicate that minerals of forage origin are between 50 and 90% available to the ruminant animal. The exception to these higher absorption values is manganese, which may be considerably lower. However, there is a general lack of data available to predict the biological availability of minerals from forages.

Collect pasture forage samples where cattle are observed grazing during the evening and morning over a period of several days. Be careful to not contaminate your sample with weeds or dirt. Samples should be composited and placed in a clean container and chilled until mineral analyses can be conducted. Prior to collection, find a laboratory that will test forage for the minerals you wish to consider. Commercial laboratories offer an analysis package containing a group of minerals for $15 to $30 per sample. The laboratory can provide directions for collection, handling, and shipping. From the discussion above, suggested "trace" minerals to test for are copper, zinc, selenium, cobalt, and manganese. Three commonly antagonistic minerals in forages are molybdenum, iron, and sulfur.

Animal Mineral Status

In some instances there may be a need to examine animal blood and/or liver mineral status. Directly measuring animal mineral status can be costly and time consuming. Therefore this tactic may be used if animal performance is below what is expected and no other explanations for the problem are apparent. Liver concentrations of copper, manganese, selenium, and zinc provide the best indication of trace mineral status. Liver iodine and iron concentration are not indicative of nutritional status. Liver biopsies should be done by a veterinarian. Ideally, biopsy samples are taken before and after treatments to gauge the efficacy of treatment.

Mineral status in cattle using liver mineral concentrations					
	Deficient	Marginal	Adequate	High	Toxic
Cobalt	<0.005		0.020-0.085	0.085-8.70	5.0-300
Copper	<33	33-125	125-300	600-1250	>1250
Iodine	<0.094		0.094-2.0		>0.781
Iron	<40		45-300	53-700	
Magnesium	<40-200		100-250		
Manganese	<5	5-10	10-15	15-25	
Phosphorus	6-14		6-14		
Potassium					
Selenium	<0.5	0.6-1.25	1.25-2.50	>2.5	
Zinc	<20	20-40	25-200	300-600	>1000
Source: Puls (1988) and Kincaid (1999)					

Blood samples can be an unreliable approach for measurement of mineral levels unless the cattle are severely deficient. Blood or blood components can be used as a preliminary screening tool for mineral deficiency. Blood analysis is sometimes used for copper, iodine, iron, selenium, and zinc.

Trace mineral status in cattle using blood, plasma, or serum concentrations					
	Deficient	Marginal	Adequate	High	Toxic
Copper, plasma, microgram/mL	<0.5	0.5-0.7	0.7-0.9	0.9-1.1	>1.2
Iodine, serum, microgram/100 mL	<5		10-40	70-300	
Iron, serum, microgram/100 mL	<120		130-150	400-600	
Manganese, whole blood, ng/mL	<20	20-60	70-200		
Manganese, serum, ng/ML	<5	5-6			
Selenium, whole blood, ng/mL	<60	60-200	210-1200	>1200	
Zinc, plasma, microgram/mL	<0.4	0.5-0.8	0.8-1.4	2-5	3-15
Source: Puls (1988) and Kincaid (1999)					

Blood enzymes and metabolites are also used as indicators of mineral status in cattle. Glutathione peroxidase is an indicator of selenium status, alkaline phosphatase, superoxide dismutase, and metallothionein are indicators of zinc status. Ceruloplasmin, superoxide dismutase, and metallothionein are indicators of copper status. Vitamin B12 and methylmalonic acid are indicators of cobalt status.

Analyses of minerals in milk and urine are seldom useful in mineral assessment. However, molybdenum and iodine in milk are exceptions and reflect dietary intake. selenium and iodine levels in milk and urine could have a role in indicating excess intakes if reference values were ever established. Mineral content of hair, wool, and hoofs lack reference standards, are too slowly responsive to intakes, and can be easily contaminated.

How many animals need to be tested? An example might be copper. To estimate the average concentration of plasma Cu in a herd of 200 cows, with 95% confidence and within a 0.5 standard deviation of the mean, approximately 8% of the cattle must be tested. To determine the proportion of a population that might be Cu-deficient, and if the proportion is suspected to be less than 25%, 60% might have to be sampled.

Vitamins

Vitamins are classified as either fat-soluble (A, D, E, and K) or water-soluble (B, thiamin, niacin, and choline) based upon their structure and function. Fat-soluble vitamins contain only carbon, hydrogen, and oxygen, whereas the water-soluble B-vitamins contain these elements and either nitrogen, sulfur, or cobalt. Fat-soluble vitamins may occur in plant tissues as a pro-vitamin (a precursor to the vitamin). A good example is carotene in forages, which is converted to vitamin A by ruminant animals. No pro-vitamins are known to exist for the water soluble vitamins. However, rumen microorganisms have the ability to synthesize water-soluble vitamins. Therefore, the supplementation of water-soluble vitamins is generally not necessary in ruminants.

Vitamin A

Vitamin A is considered by many to be the most important vitamin regarding the need for supplementation. Vitamin A is necessary for proper bone formation, growth, vision, skin and hoof tissue maintenance, and energy metabolism (glucose synthesis).

Green leafy forage, green hay, silages, dehydrated alfalfa meal, yellow corn, and whole milk are good sources of carotene. In cattle, 1 mg of beta-carotene is converted to the equivalent of about 400 international units (IU) of vitamin A. Carotene can be destroyed as the plant matures and with exposure to sunlight, air, and high temperatures.

The liver does store vitamin A. It is generally thought that vitamin A stores can last only 2 to 4 months if a severe dietary deficiency exists. Situations where cattle are susceptible to vitamin A deficiency are when they are consuming high concentrate diets or winter pasture, crop residues, or hay grown during drought conditions or hay that has been stored for a long time. Vitamin A can be destroyed over time by other minerals in a mineral mix.

Thiamin

A thiamin deficiency results in central nervous system disorders, because thiamin is an important component of the biochemical reactions that break down the glucose supplying energy to the brain. Other signs of thiamin deficiency include weakness, retracted head, and cardiac arrhythmia. As with other water-soluble vitamins, deficiencies can result in slowed growth, anorexia, and diarrhea.

Vitamin B-12
B-vitamins are abundant in milk and other feeds. B-vitamin deficiency is limited to situations where an antagonist is present or the rumen lacks the precursors to make the vitamin. Cobalt content of the diet is the limiting factor for ruminal microorganism synthesis of vitamin B-12. A vitamin B-12 deficiency is difficult to distinguish from a cobalt deficiency.

Vitamin D
Vitamin D is essential for bone growth and maintenance because it is directly involved in calcium absorption as well as phosphorus absorption. Sun-cured hay contain high concentrations of vitamin D. However, because vitamin D is synthesized by beef cattle when exposed either to sunlight or fed suncured forages, they rarely require vitamin D supplementation.

Examples of situations conducive to moderate vitamin D deficiency would include cattle housed indoors for long periods of time and fed a high concentrate ration (little or no sun-cured forage), and cattle consuming extremely low quality forage during long periods with little or no sunlight. Severe vitamin D deficiency results in a disease referred to as rickets and other bone abnormalities.

Vitamin E
Vitamin E occurs naturally in feedstuffs as alpha tocopherol. Vitamin E is not stored in the body in large concentrations. This vitamin serves several functions including a role as an antioxidant. Vitamin E is important in muscle growth and structure.

The vitamin E requirement for cattle has not been firmly established. For young growing cattle, the requirement is estimated to be between 7 and 27 IU/lb of feed dry matter. However, 50 to 100 IU per head per day has been suggested for older growing and finishing cattle.

Vitamin E deficiencies can be initiated by the intake of unsaturated fats. Examples of common sources of unsaturated fats include whole soybeans and cottonseeds.

Signs of deficiencies in young calves are characteristic of white-muscle disease including general muscular dystrophy, weak leg muscles, crossover walking, impaired suckling ability caused by dystrophy of tongue muscles, heart failure, paralysis, and hepatic necrosis.

Co-Product Feed Focus

Co-product feeds and be economically competitive sources of protein and energy compared with traditional sources such as corn and soybean meal. However, co-product feeds may not have mineral profiles similar to corn and soybean meal. Production of co-product feeds can remove some nutrients while concentrating others. Wheat middlings, corn gluten feed, and distiller's grains products have calcium to phosphorus ratios substantially less than the 1.2:1. Calcium to phosphorus ratios greater than 18:1 may need to be designed to be fed in conjunction with these byproducts.

Corn gluten feeds and distiller's grains products can have high concentrations of sulfur. As indicated earlier, sulfur is a potential antagonist of copper. Sulfur toxicity can also be a concern if feeding relatively high levels of these feeds. Moderate to high dietary sulfur intake has the potential to cause polioencephalomalacia (PEM) in ruminants. Clinical and pathological signs are similar to thiamine deficiency and PEM is often accompanied by thiamine deficiency. In many cases thiamine activity is was not altered in the presence of high sulfur intake, even though PEM symptoms were present. Therefore, sulfur can cause PEM directly. Rumen microbes normally produce hydrogen sulfide. Under conditions of high dietary sulfur intake, the capacity for microbial production of hydrogen sulfide increases. Hydrogen sulfide is highly toxic and when present in rumen gas that is eructated and inhaled, may cause brain lesions resulting in PEM symptoms. Therefore, sulfur levels should be checked when feeding feeds like corn gluten feed and distiller' grain products to not exceed the maximum tolerable concentration of sulfur in the complete diet.

Soybean hulls, wheat middlings, corn gluten feed, rice bran, and distiller's grains are typically high in trace minerals relative to most forages (for example:, Cu, Se, Fe, and Zn). Trace mineral intakes require careful balancing when diets contain high proportions of these byproducts.

Bioavailability

Total content of a mineral element has little significant unless it is qualified by bioavailability. Before a nutrient is utilized, it must be consumed, digested, absorbed and transported where needed in the body.

Cost is an important factor but the cheapest product per ton is not always the cheapest product per desired nutrient(s).

For example:

Source	$/lb of Ingredient	Nutrient Content	Divide ÷	Cost/lb Nutrient	Bioavailability (BA)	Divide ÷	Cost.lb of Avail. Nutrient
Product X	15¢	21%	$/lb of Ingredient by Nutrient Content	71.42¢	95%	Cost/lb Nutrient by BA	75.18¢
Product Y	13¢	18.5%		70.27¢	93%		75.56¢
Product Z	13¢	18.0%		72.22¢	85%		84.97¢
Conclusion: Product Z is the most expensive							

Perhaps more important to feed companies than livestock producers is particle size. Larger, more course particles flow easier and reduce the amount of dust and potential for dust-caused employees health problems. However. In ruminant diets, smaller particle magnesium oxide is more soluble in the rumen.

Producers (and researchers) are often interested in differences of performance in response to various sources of minerals (organic vs inorganic). Organic mineral sources have improved growth and reproductive performance in some studies where high levels of performance (embryo transfer or response to estrous synchronization and artificial insemination) were expected.

BIOAVAILABILITY			
Inorganic Calcium Sources	Approximate Bioabvailability		
	Calcium (CA) %	Iron (Fe) %	
Calcium carbonate	95-100	50	
Ground limestone	90-95	50	
Magnesian limestone	80	50	
Dolomitic/magnesium limestone	52	34	
Marble dust	95-100		
Oystershell flour	95-100		
Aragonite	95-100		
Calcium sulfate	99		
Fishmeal – Organic	95		
Bone meal, Steamed – Organic	95		
Meat and bone meal – Organic	95		
Calcium phosphates (moncal, dical, deflour)			
Calcium choride	100		
Inorganic Phosphorus Sources	Approximate Bioabvailability		
	Phosphorus (P) %	Iron (Fe) %	Sodium (Na) %
Phosphoric acid	100		
Ammonium polyphosphate solution	95-100		
Monocalcium phosphate	95-98	60	80
Dicalcium phosphate	93-95	50	80
Deflourinated phosphate	78-90	40	80
Bone meal, steamed – Organic	80-92		
Rock phosphate – soft	25-35		
Rock phosphate – low fluorine	50-60		
Monosodium phosphate	95-100		
Monammonium phosphate	95-100		
Sodium tripolyphosphate	95-100		
Diammonium phosphate	95-100		
Potassium Sources	Approximate Bioabvailability		
	Potassium (K) %		
Potassium chloride	100		
Double sulfate of potassium & magnesium	100		
Potassium sulfate	100		
Sulfur Sources	Approximate Bioabvailability		
	Sulfur (S) %		
Calcium sulfate	94		
Ammonium sulfate	93		
Double sulfate of potassium & magnesium	90-95		
Magnesium sulfate	90-95		
Sodium sulfate	90		
Potassium sulfate	90-95		
Sulfur	36		

Sodium and Chloride Sources	Approximate Bioabvailability		
	Sodium (Na) %	Chloride (CL) %	
Salt	100	100	
Sodium bicarbonate	100		
Sodium sesquicarbonate	100		
Potassium chloride		100	
Calcium chloride		100	
Ammonium chloride		95-100	
Magnessium chloride		95-100	
Magnesium Sources	Approximate Bioabvailability		
	Magnesium (Mg) %		
Magnesium oxide	100		
Magnesium sulfate	90-95		
Double sulfate of potassium & magnesium	90-95		
Dolomitic limestone	28		
Magnesium chloride	95-100		
Source: D. Axe and G. Morris. Guide to macrominerals. Iowa Limestone Company			

Forage mineral values for winter grazing demonstration project.[1]										
Specie	Ca[2]	P	K	Mg	S	Mn	Fe	Cu	Zn	Na
	(%)					(ppm)				
Fescue	0.47	0.24	1.6	0.22	0.2	66	117	3	22	38
Fes-RC-A	0.62	0.18	1.4	0.29	0.2	57	106	4	20	58
Fes-RC-OG	0.54	0.18	1.6	0.24	0.2	83	74	3	22	24
Fes-OG	0.29	0.26	2.4	0.19	0.2	147	73	5	29	15
RC-Fes	0.44	0.28	2.2	0.33	0.2	86	55	4	23	21
RC-OG	0.77	0.30	2.3	0.28	0.2	102	170	8	42	230
OG-BG	0.54	0.19	1.4	0.21	0.2	122	385	6	32	87
BG	0.48	0.24	1.7	0.22	0.2	184	101	6	29	9
OG	0.60	0.22	1.4	0.18	0.2	104	198	5	33	4
Std. Dev.[3]	0.163	0.064	0.45	0.073	. . .	6.9	119	1.7	9.2	76.6
P[4]	0.11	0.44	0.09	0.36	. . .	0.04	0.09	0.01	0.05	0.02

[1] Fes = Fescue, RC = Red clover, A = Alfalfa, OG = Orchardgrass, BG = Bluegrass.
[2] Ca = calcium, P = phosphorus, K = potassium, Mg = magnesium, S = sulfur, Mn = manganese, Fe = iron, Cu = copper, Zn = zinc, Na = sodium.
[3] Standard deviation of least square means.
[4] Probability level.
Source: Boyles et al. 1996.

Sources:

Axe, D. E and G. P. Morris. Guide to Macrominerals. Iowa Limestone Company. Des moines, IA.

Boyles, S. L., H. M. Bartholomew, and R. M. Sulc. 1996. Sustainable winter grazing and dormant forage quality. Reseach and Reviews. OSU Dept. Anim. Sci. OARDC Special Circular No. 156. pp. 37-44.

Boyles, S., E. Vollborn, C. Penrose, H. Bartholomew, and R.L. Hendershot. 1998. Maximizing fall and winter grazing of beef cows and stocker cattle. OSU Extension. Bulletin 872.

Hale, C. and K.C. Olson. 2001. Mineral supplements forbeef cattle. Univ. MO Ext. G2081

Kincaid, R.L. (1999) Assessment of trace mineral status of ruminants: a review. Proc. Am. Soc. Anim. Sci., http://www.asas.org/jas/symposia/proceedings/ 0930.pdf. Viewed 3/17/08/

Lalman, D. 2004. Vitamin and mineral nutrition for grazing cattle. Oklahoma State Unviv. E-861

Olson, K.C. Cost-Effective Mineral Supplementation Programs for Beef Cattle http://www.extension.iastate.edu/feci/4StBeef/Olson.pdf Viewed 3/16/08

Puls, R. (1988) Mineral levels in animal health. Sherpa International. Clearbrook, B.C., Canada.

Compiled by: S. L. Boyles, OSU Extension Beef Specialist, boyles.4@osu.edu