Mineral Requirements for Beef Cows Grazing Native Rangeland

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Report DREC 01-1033

Introduction

Beef cows grazing native rangeland require seven macrominerals and ten microminerals for normal body functions. Understanding livestock mineral requirements, functions of each mineral, and mineral concentrations that result in deficiencies or toxicities is necessary to maintain beef cows at high levels of production. The quantities of each mineral required vary with cow size, level of milk production, and production period (dry gestation, 3rd trimester, early lactation, and lactation). Animals acquire most of these essential minerals from forages. Forage plant growth can be altered by differential defoliation treatment effects on plant growth processes (Manske 2000). Mineral concentrations in native range herbage are not constant, and the patterns of change during the grazing season differ with management treatment. Supplementation of minerals during periods when concentrations in herbage are below those required by beef cattle is necessary to maintain optimum livestock performance. This report summarizes information on the mineral requirements for beef cows grazing native rangeland of the mixed grass prairie in the Northern Plains.

Beef Cow Macromineral Requirements

The macrominerals required by beef cattle are calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), chlorine (Cl), and sulfur (S). Phosphorus and calcium make up about 70% to 75% of the mineral matter in beef cattle, including over 90% of the mineral matter in the skeleton. Calcium is the most abundant mineral in the cow's body, with 98% of the calcium in the bones and teeth and the remainder in the extracellular fluids and soft tissue (NRC 1996). About 80% of the phosphorus in the cow's body is in the bones and teeth; the remainder occurs in soft tissue, mostly in organic forms. Phosphorus and calcium function together with magnesium in bone formation, and these minerals are required for normal skeletal development and maintenance (NRC 1996). Phosphorus exists in blood serum both in organic forms, as a constituent of lipids, and in inorganic forms. Phosphorus is a component of phospholipids, which are important in lipid transport and metabolism and in cell-membrane structure and cell growth. As a component of AMP, ADP, ATP, and creatine phosphate, phosphorus functions in energy metabolism, utilization, and transfer. Phosphorus is required for protein synthesis as phosphate, a component of RNA and DNA. Calcium exists in blood serum in both organic and inorganic forms. Slight changes in calcium, potassium, magnesium, and sodium concentrations control muscle contractions and the transmission of nerve impulses. Calcium and sulfur are required for normal blood coagulation (Church and Pond 1975, NRC 1996). Phosphorus, calcium, potassium, and magnesium are constituents of several enzyme systems. Phosphorus, calcium, potassium, magnesium, sodium, chlorine, and sulfur function in regulating fluid balance by maintaining osmotic pressure and the acid-base balance of the entire system. The blood contains more sodium and chlorine than other minerals. Sodium and chlorine are electrolytes and function in maintaining osmotic pressure in the body cells. Chlorine is required to form hydrochloric acid in gastric juice (Church and Pond 1975, NRC 1996). Phosphorus and sulfur are required by ruminal microorganisms for their growth and cellular metabolism (NRC 1996).

Relative levels of calcium and phosphorus are important. Dietary calcium to phosphorus ratios between 1:1 and 7:1 result in similar normal animal performance. Dietary phosphorus absorption (NRC 1996) occurs rapidly in the small intestine by passive diffusion across the intestine cell membrane against a concentration gradient in the presence of calcium. Cattle are not known to have an active transport system for phosphorus. About 68% of dietary phosphorus is absorbed. Dietary calcium absorption (NRC 1996) occurs in the first two sections of the small intestine both by passive diffusion and by active transport with a vitamin D-dependent protein carrier. About 50% of dietary calcium is absorbed. Calcium is maintained at a relatively constant concentration in the blood plasma by an elaborate control system that involves calcium deposition in and resorption from the bones, variations in reabsorption rate in the kidneys, and variations in the levels of absorption in the intestines. During periods when blood phosphorus or calcium concentrations are low, the kidney tubules can reabsorb an increased amount of the deficient minerals and the body can thereby conserve them. The skeleton of mature animals provides a large reserve of phosphorus and calcium that can be drawn on during periods of inadequate phosphorus or calcium intake. Skeletal reserves can subsequently be replenished during periods when phosphorus and calcium intake are high relative to requirements (Church and Pond 1975, NRC 1996).

The concentrations of calcium and phosphorus required by beef cows during lactation are 0.26%-0.27% and 0.18% diet dry matter, respectively (NRC 1996). A deficiency of either calcium or phosphorus can adversely affect the skeletal system. In young growing animals inadequate calcium or phosphorus can cause rickets, which develops when the blood becomes low or deficient in calcium, phosphorus, or both, and normal deposition of calcium and phosphorus in growing bones cannot occur. The bones become soft and weak. In severe cases, bones can become deformed, and with increased severity of the condition, bones can break or fracture readily. A deficiency of calcium or phosphorus in older mature animals can cause osteoporosis, which develops when large amounts of calcium and phosphorus are withdrawn from the bones to meet other systems' needs for these minerals. During prolonged periods of calcium and phosphorus deficiency, the bones become porous and weak, and in severe cases, they can break easily (Church and Pond 1975, NRC 1996).

Pregnancy and lactation produce high demands for calcium and phosphorus. Production of one pound of milk requires 0.020 ounces of calcium and 0.015 ounces of phosphorus (NRC 1996). Most cases of calcium deficiency occur early in lactation, during the period when milk production causes large drains on body calcium reserves. Calcium deficiency during lactation causes milk fever. Severe calcium deficiency produces hypocalcemia (low blood calcium) and interferes with the role calcium plays in normal muscle contractions, including those of the heart, and in normal transmission of nerve impulses; this condition results in tetany, convulsions, and, if not treated early, possibly death (Church and Pond 1975, NRC 1996).

Even when cattle diets are only slightly deficient in calcium or phosphorus, animal performance may suffer. Calcium deficiency causes reduced feed intake, loss of body weight, and failure of cows to come into heat regularly. Calcium deficiency also causes a reduction in the quantity of milk produced: the quality of the milk is not changed, and the mineral content of the milk remains relatively constant; however, reduction in the quantity of milk produced by a cow results in lower calf daily gain (Manske 1998). Phosphorus deficiency in beef cattle results in reduced growth and feed efficiency, decreased feed intake, impaired reproduction, reduced milk production, and weak, fragile bones. Cattle grazing forages low in phosphorus experience lower fertility and lighter calf weaning weights (NRC 1996).

Deficiencies of other macrominerals are also detrimental to beef cattle. Adequate quantities of supplemental minerals should be provided to livestock during periods when forages do not contain sufficient levels.

The concentration of magnesium required by beef cows during lactation is 0.17%-0.20% diet dry matter (NRC 1996). Magnesium deficiency causes grass tetany (hypomagnesemia or low blood magnesium), occurring most commonly in lactating cows grazing lush spring pastures high in protein and potassium. Magnesium deficiency in beef cattle results in nervousness, reduced feed intake, muscular twitching, and staggering gait. In advanced stages of magnesium deficiency, convulsions occur, the animal cannot stand, and death soon follows (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of magnesium has been estimated at 0.40% diet dry matter (NRC 1996).

Intake of proper amounts of potassium, the third most abundant mineral in beef cattle, is important. The concentration of potassium required by beef cows during lactation is 0.70% diet dry matter (NRC 1996). Deficiency of potassium causes decreased feed intake and reduced weight gain. Cattle consuming diets with more than 3% potassium while grazing lush spring pastures experience reduced magnesium absorption and the related magnesium deficiency symptoms (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of potassium has been set at 3.0% diet dry matter because of potassium's antagonistic action to magnesium absorption. High levels of potassium are not known to cause any other adverse effects (NRC 1996).

The concentration of sulfur required by beef cows is 0.15% diet dry matter (NRC 1996). Deficiency of sulfur, a component of some amino acids and some vitamins, causes reduced feed intake and decreased microbial digestion and protein synthesis. Severe sulfur deficiency results in diminished feed intake, major loss of body weight, weak and emaciated condition, excessive salivation, and death (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of dietary sulfur has been estimated at 0.40% diet dry matter, but sulfur toxicity is not a practical problem because absorption of inorganic sulfur is low (Church and Pond 1975, NRC 1996).

Grazing cattle require supplemental salt (sodium and chlorine) because forages do not contain adequate amounts. The concentration of sodium required by beef cows during lactation is 0.10% diet dry matter (NRC 1996). The concentration of chlorine required by beef cows is not well defined, but the amounts supplied by dietary salt appear to be adequate (Church and Pond 1975, NRC 1996). Severe salt deficiency causes reduced feed intake, rapid loss of body weight, and reduced milk production. In some arid and semi-arid regions of the country, a portion of the required amount of salt is provided by the alkaline water. Supplemental salt can be provided free-choice in loose or block forms. Cattle grazing pastures consume more salt during spring and early summer when the forage is more succulent than later in the season when the forage is drier. High levels of dietary salt reduce feed intake. Cattle occasionally consume greater amounts of salt than required but will generally not consume excessive amounts except after experiencing periods without sufficient quantities (Church and Pond 1975, NRC 1996). The maximum tolerable concentration of dietary salt is estimated at 9.0% diet dry matter. Salt in drinking water is much more toxic; the maximum tolerable concentration of sodium in water is 0.70% (NRC 1996).

Toxicity of magnesium, potassium, sodium, or chlorine is unlikely because amounts in excess of those required are readily excreted by the kidneys. Toxicity problems can develop, however, when drinking water intake is restricted, drinking water contains more than 7,000 mg Na/kg (ppm), or the kidneys malfunction (Church and Pond 1975, NRC 1996).

Beef Cow Micromineral Requirements

The microminerals required by beef cattle are chromium (Cr), cobalt (Co), copper (Cu), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn). Microminerals are primarily components of enzymes and organic compounds or are elements for activation of enzyme systems. The functions of microminerals are determined by the function of the compounds of which the microminerals are a part.

Chromium (Cr) is a cofactor in the action of insulin and is important in glucose utilization and the synthesis of cholesterol and fatty acids. Beef cattle may need supplemental chromium in some situations, but the current data are not sufficient to allow accurate determination of requirements. The maximum tolerable concentration in diet dry matter is estimated to be 1,000 mg Cr/kg (ppm) (Church and Pond 1975, NRC 1996).

Cobalt (Co) functions as a component of vitamin B_{12}. Two vitamin B_{12}-dependent enzymes are known to occur in cattle. Cattle are not dependent on a dietary source of vitamin B_{12} because ruminal microorganisms can synthesize B_{12} from dietary cobalt. The recommended concentration of cobalt in beef cattle diets is approximately 0.10 mg Co/kg (ppm) diet dry matter. Early signs of cobalt deficiency are decreased appetite, reduced milk production, and either failure to grow or moderate weight loss. With severe deficiency, animals exhibit unthriftiness, rapid weight loss, fatty degeneration of the liver, and pale skin and mucous membrane as a result of anemia. Cobalt concentrations in forages are dependent on levels of cobalt in the soil. Availability of cobalt in soil is highly dependent on soil pH, and some soils are deficient in cobalt. Legumes are generally higher in cobalt than grasses. Cobalt can be supplemented in mineral mixtures as cobalt sulfate and cobalt carbonate. Cobalt toxicity is not likely to occur because cattle can tolerate approximately 100 times the dietary requirements. Signs of cobalt toxicity are decreased feed intake, reduced body weight gain, anemia, emaciation, hyperchromia, debility, and increased liver cobalt (Church and Pond 1975, NRC 1996).

Copper (Cu) functions as an essential component of a number of enzymes and is required for normal red blood cell formation, normal bone formation, normal elastin formation in the aorta and cardiovascular system, normal myelination of the brain cells and spinal cord, and normal pigmentation of hair. Copper is important to the functions of the immune system. The recommended concentration of copper in beef cattle diets is 10 mg Cu/kg (ppm) diet dry matter. Copper requirements are affected by dietary molybdenum (Mo) and sulfur (S). Antagonistic action of molybdenum occurs at levels above 2 mg Mo/kg diet, and antagonistic action of sulfur occurs at levels above 0.25% sulfur. Molybdenum and sulfur interact in the rumen to form thiomolybdates, compounds that react with copper to form insoluble complexes that are poorly absorbed. Thiomolybdates also reduce metabolism of copper post absorption. Sulfur can react with copper to form copper sulfide, which also reduces absorption of copper. High concentrations of iron and zinc also reduce copper status. Copper deficiency is a widespread problem in many areas of North America. Signs of copper deficiency are anemia; reduced growth rate; changes in the growth, physical appearance, and pigmentation of hair; cardiac failure; fragile bones that easily fracture; diarrhea; and low reproduction levels resulting from delayed or depressed estrus. Copper concentrations in forages are highly variable, depending on plant species and availability of copper in the soil. Legumes are usually higher in copper than grasses. Copper can be supplemented in mineral mixtures in the sulfate or carbonate forms. Feed-grade copper oxide is largely biologically unavailable but has been used as a source of slow-release copper because it remains in the digestive tract for months. The maximum tolerable concentration of copper for cattle has been estimated at 100 mg Cu/kg (ppm) diet dry matter, but this amount is dependent on the concentrations of molybdenum, sulfur, and iron in the diet. The liver can accumulate large amounts of copper before signs of toxicity are observed (Church and Pond 1975, NRC 1996).

Iodine (I) is an essential component of thyroid hormones, which regulate the rate of energy metabolism. Iodine requirements of beef cattle have not been determined with certainty, but 0.5 mg I/kg (ppm) diet dry matter should be adequate. Signs of iodine deficiency are enlargement of the thyroid, calves born weak or dead, and reduced reproduction that results from irregular cycling, low conception rate, and retained placenta in cows and from decreased libido and semen quality in bulls. Iodine concentrations in forage depend on the availability of iodine in the soil, and many of the soils in central North America are deficient in iodine. Iodine can be supplemented in iodized salt or in mineral mixtures as calcium iodate or an organic form of iodine. Cattle tolerate maximum iodine levels of 50 mg I/kg (ppm) diet dry matter. Signs of iodine toxicity are coughing, excessive nasal discharge, reduced feed intake, and reduced weight gain (Church and Pond 1975, NRC 1996).

Iron (Fe) is a component of hemoglobin in red blood cells, myoglobin in muscles, and other proteins involved in transport of oxygen to tissues or utilization of oxygen. Iron is also a constituent of several enzymes associated with the mechanisms of electron transport, and iron is a component of several metalloenzymes. Iron is important to the functions of the immune system. The iron requirement of beef cattle is approximately 50 mg Fe/kg (ppm) diet dry matter. Iron requirements of older cattle are not well defined but are probably lower than those of young calves, in which blood volume is increasing. Iron deficiency is unlikely in cattle because adequate levels of iron are available from numerous sources. Iron concentration in forages is highly variable, but most forages are high in iron, containing from 70 to 500 mg Fe/kg. Water and ingested soil can be significant sources of iron for beef cattle. When iron needs to be supplemented, it can be added to mineral mixtures as ferrous sulfate or ferrous carbonate. Ferric oxide is basically biologically unavailable. Dietary iron concentrations as low as 250 to 500 mg/kg have caused copper depletion in cattle. In areas where drinking water or forages are high in iron, dietary copper may need to be increased to prevent copper deficiency. The maximum tolerable concentration of iron for cattle has been estimated at 1,000 mg Fe/kg (ppm) diet dry matter. Signs of iron toxicity are diarrhea, metabolic acidosis, hypothermia, reduced feed intake, and reduced weight gain (Church and Pond 1975, NRC 1996).

Manganese (Mn) is a component of a few metalloenzymes that function in carbohydrate metabolism and lipid metabolism. Manganese also stimulates and activates a number of other enzymes. Manganese is important in cattle reproduction because it is required for normal estrus and ovulation in cows and for normal libido and spermatogenesis in bulls. Manganese is essential for normal bone formation and growth. Manganese is important to the functions of the immune system. The recommended concentration of manganese for breeding cattle is 40 mg Mn/kg (ppm) diet dry matter. Signs of manganese deficiency are skeletal abnormalities in young animals and, in older animals, low reproductive performance resulting from depressed or irregular estrus, low conception rate, abortion, stillbirths, and low birth weights. Manganese concentrations in forage are generally adequate but are variable, depending on the availability of manganese because of soil pH and soil drainage. Manganese can be supplemented in mineral mixtures as manganese sulfate, manganese oxide, or various organic forms. Manganese oxide is less readily available biologically than manganese sulfate. Maximum tolerable concentration of manganese is set at 1,000 mg Mn/kg (ppm) diet dry matter (Church and Pond 1975, NRC 1996).

Molybdenum (Mo) is a component of a metalloenzyme and other enzymes. The requirements for molybdenum have not been established. No evidence that molybdenum deficiency occurs in cattle under practical conditions has been found. Metabolism of molybdenum is affected by copper and sulfur, which are antagonistic. Sulfide and molybdate interact in the rumen to form thiomolybdates, compounds that cause decreased absorption and reduced post absorption metabolism of molybdenum and increased urinary excretion of molybdate. Molybdenum concentrations in forages are generally adequate but vary greatly, depending on soil type and soil pH. Neutral or alkaline soils coupled with high moisture and organic matter favor molybdenum uptake by forages. High concentrations of molybdenum can cause toxicity. The maximum tolerable concentration of molybdenum for cattle has been estimated to be 10 mg Mo/kg (ppm) diet dry matter. Signs of molybdenum toxicity are diarrhea, anorexia, loss of weight, stiffness, and changes in hair color. Supplementation of large quantities of copper will overcome molybdenosis (Church and Pond 1975, NRC 1996).

Nickel (Ni) is an essential component of urease in rumen bacteria. Nickel deficiency in animals can be produced experimentally, but the function of nickel in mammalian metabolism is unknown. Research data are not sufficient to determine nickel requirements of beef cattle. Nickel can be supplemented in mineral mixtures as nickel chloride. The maximum tolerable concentration of nickel is estimated to be 50 mg Ni/kg (ppm) diet dry matter (Church and Pond 1975, NRC 1996).

Selenium (Se) is part of at least two metalloenzymes, and its functions are interrelated with vitamin E. Failure of functions involving selenium can result in nutritional muscular dystrophy. Selenium is also a component of an enzyme that has a role in maintaining integrity of cellular membranes. Selenium is required for normal pancreatic morphology and is involved in normal absorption of lipids and tocophenols. Selenium is important to the functions of the immune system. The factors that affect selenium requirements are not well defined, but beef cattle requirements can be met by 0.1-0.2 mg Se/kg (ppm) diet dry matter. Selenium deficiency results in degeneration of muscle tissue (white muscle disease) in young animals. Signs of deficiency are stiffness, lameness, and possible cardiac failure. Signs of selenium deficiency in older animals are unthriftiness, weight loss, diarrhea, anemia, and reduced immune responses. Selenium concentrations in forages vary greatly and depend primarily on the selenium content of the soil. Soils developed from Cretaceous or Eocene shales contain high levels of selenium. Some species of milkvetch (*Astragalus spp.*) absorb selenium more readily than other native plants. Cattle grazing plants high in selenium can consume toxic amounts. The maximum tolerable concentration of selenium has been estimated to be 2 mg Se/kg (ppm) diet dry matter. Signs of selenium toxicity are lameness, anorexia, emaciation, loss of vitality, liver cirrhosis, inflamed kidneys, loss of hair from the tail, and cracked, deformed, and elongated hoofs. Signs of acute selenium toxicity are labored breathing, diarrhea, loss of coordination, abnormal posture, and death from respiratory failure (Church and Pond 1975, NRC 1996).

Zinc (Zn) is a constituent of many enzymes and many metalloenzyme systems, and zinc is effective in activation of a large number of other enzymes. Zinc is required for normal protein synthesis and metabolism. A component of insulin, zinc functions in carbohydrate metabolism. Zinc is important for normal development and functioning of the immune system. The recommended requirement of zinc in beef cattle diets is 30 mg Zn/kg (ppm) diet dry matter, although zinc requirements of beef cattle fed forage-based diets and requirements for reproduction and milk production are not well defined. Dietary factors that affect zinc requirements in ruminants are not understood. Subclinical deficiencies of zinc cause decreased weight gain, reduced milk production, and reduced reproductive performance. Signs of severe zinc deficiency are listlessness, excessive salivation, reduced testicular growth, swollen feet, loss of hair, failure of wounds to heal, reduced growth, reduced feed intake, reduced feed efficiency, and lesions with horny growths on legs, neck, and head and around the nostrils. The zinc content of forages is affected by a number of factors, including plant species, plant maturity, and soil zinc. Legumes are generally higher in zinc than grasses. A relatively large portion of the zinc in forages is associated with the plant cell wall, but it is not known whether zinc's association with fiber reduces absorption. Zinc can be supplemented in mineral mixtures with feed-grade sources of bioavailable zinc in the form of zinc oxide, zinc sulfate, zinc methionine, and zinc proteinate. The maximum tolerable concentration of zinc is 500 mg Zn/kg (ppm) diet dry matter, a much greater amount than required. Signs of zinc toxicity are reduced feed intake, reduced feed efficiency, and decreased weight gain (Church and Pond 1975, NRC 1996).

Daily Mineral Requirements

Understanding mineral requirements for beef cows is necessary for effective nutritional management of livestock grazing native rangeland. Beef cow daily nutritional requirements (NRC 1996) change with cow size, level of milk production, and production period. Requirements for some macrominerals change with cow production period. Fetal development requires increased amounts of dietary calcium, phosphorus, and magnesium. Lactation requires increased amounts of dietary calcium, phosphorus, magnesium, potassium, and sodium. Milk production increases the demand for iodine and zinc, but dietary requirements do not increase because the demands are likely met by increases in absorption (NRC 1996). Daily macromineral and micromineral requirements for 1000-, 1200-, and 1400-pound cows with average milk production are shown in tables 1-6. Lactating cows grazing native rangeland require diet dry matter containing 0.26-0.27% calcium, 0.18% phosphorus, 0.17-0.20% magnesium, 0.70% potassium, 0.10% sodium, and 0.15% sulfur. Lactating cows require diet dry matter containing the following micromineral concentrations: 0.10 ppm cobalt, 10.0 ppm copper, 0.50 ppm iodine, 50.0 ppm iron, 40.0 ppm manganese, 0.10 ppm selenium, and 30.0 ppm zinc. The amounts of chlorine, chromium, molybdenum, and nickel lactating cows require from diet dry matter are not known.

Acknowledgment

I am grateful to Amy M. Kraus for assistance in preparation of this manuscript. I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Table 1. Daily macromineral requirements in pounds per day and percent diet dry matter for 1000-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Macrominerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	21	21	24	24
Calcium	%	0.15	0.24	0.30	0.27
	lbs/day	0.03	0.05	0.07	0.06
Phosphorus	%	0.11	0.15	0.20	0.18
	lbs/day	0.02	0.03	0.05	0.04
Magnesium	%	0.12		0.17-0.20	
	lbs/day	0.03		0.04-0.05	
Potassium	%	0.60		0.70	
	lbs/day	0.13		0.17	
Sodium	%	0.06-0.08		0.10	
	lbs/day	0.01-0.02		0.02	
Chlorine	%	requirements are not well defined but a deficiency does not seem likely in practical conditions			
	lbs/day				
Sulfur	%	0.15		0.15	
	lbs/day	0.03		0.04	

Table 2. Daily macromineral requirements in pounds per day and percent diet dry matter for 1200-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Macrominerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	24	24	27	27
Calcium	%	0.15	0.25	0.29	0.26
	lbs/day	0.04	0.06	0.08	0.07
Phosphorus	%	0.12	0.16	0.19	0.18
	lbs/day	0.03	0.04	0.05	0.05
Magnesium	%	0.12		0.17-0.20	
	lbs/day	0.03		0.045-0.05	
Potassium	%	0.60		0.70	
	lbs/day	0.14		0.19	
Sodium	%	0.06-0.08		0.10	
	lbs/day	0.01-0.02		0.03	
Chlorine	%	requirements are not well defined but a deficiency does not seem likely in practical conditions			
	lbs/day				
Sulfur	%	0.15		0.15	
	lbs/day	0.04		0.04	

Table 3. Daily macromineral requirements in pounds per day and percent diet dry matter for 1400-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Macrominerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	27	27	30	30
Calcium	%	0.16	0.26	0.28	0.26
	lbs/day	0.04	0.07	0.08	0.08
Phosphorus	%	0.12	0.17	0.19	0.18
	lbs/day	0.03	0.05	0.06	0.05
Magnesium	%	0.12	0.17-0.20		
	lbs/day	0.03	0.05-0.06		
Potassium	%	0.60	0.70		
	lbs/day	0.16	0.21		
Sodium	%	0.06-0.08	0.10		
	lbs/day	0.016-0.022	0.03		
Chlorine	%	requirements are not well defined but a deficiency does not seem likely in practical conditions			
	lbs/day				
Sulfur	%	0.15	0.15		
	lbs/day	0.04	0.05		

Table 4. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1000-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Microminerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	21	21	24	24
Chromium	mg/kg (ppm)	current information is not sufficient to determine requirements			
	g/day				
Cobalt	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0010	0.0010	0.0011	0.0011
Copper	mg/kg (ppm)	10.0	10.0	10.0	10.0
	g/day	0.0953	0.0953	0.1089	0.1089
Iodine	mg/kg (ppm)	0.50	0.50	0.50	0.50
	g/day	0.0048	0.0048	0.0054	0.0054
Iron	mg/kg (ppm)	50.0	50.0	50.0	50.0
	g/day	0.4763	0.4763	0.5443	0.5443
Manganese	mg/kg (ppm)	40.0	40.0	40.0	40.0
	g/day	0.3810	0.3810	0.4355	0.4355
Molybdenum	mg/kg (ppm)	requirements are not established but there is no evidence that deficiency occurs			
	g/day				
Nickel	mg/kg (ppm)	research data are not sufficient to determine requirements			
	g/day				
Selenium	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0010	0.0010	0.0011	0.0011
Zinc	mg/kg (ppm)	30.0	30.0	30.0	30.0
	g/day	0.2858	0.2858	0.3266	0.3266

Table 5. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1200-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Microminerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	24	24	27	27
Chromium	mg/kg (ppm)	current information is not sufficient to determine requirements			
	g/day				
Cobalt	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0011	0.0011	0.0012	0.0012
Copper	mg/kg (ppm)	10.0	10.0	10.0	10.0
	g/day	0.1089	0.1089	0.1225	0.1225
Iodine	mg/kg (ppm)	0.50	0.50	0.50	0.50
	g/day	0.0054	0.0054	0.0061	0.0061
Iron	mg/kg (ppm)	50.0	50.0	50.0	50.0
	g/day	0.5443	0.5443	0.6124	0.6124
Manganese	mg/kg (ppm)	40.0	40.0	40.0	40.0
	g/day	0.4355	0.4355	0.4899	0.4899
Molybdenum	mg/kg (ppm)	requirements are not established but there is no evidence that deficiency occurs			
	g/day				
Nickel	mg/kg (ppm)	research data are not sufficient to determine requirements			
	g/day				
Selenium	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0011	0.0011	0.0012	0.0012
Zinc	mg/kg (ppm)	30.0	30.0	30.0	30.0
	g/day	0.3266	0.3266	0.3674	0.3674

Table 6. Daily micromineral requirements in grams per day and mg/kg (ppm) of diet dry matter for 1400-pound beef cows with average milk production during four production periods (data from NRC 1996).

		Production Periods			
Microminerals		Dry Gestation	3rd Trimester	Early Lactation	Lactation
Dry matter	lbs	27	27	30	30
Chromium	mg/kg (ppm)	current information is not sufficient to determine requirements			
	g/day				
Cobalt	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0012	0.0012	0.0014	0.0014
Copper	mg/kg (ppm)	10.0	10.0	10.0	10.0
	g/day	0.1225	0.1225	0.1361	0.1361
Iodine	mg/kg (ppm)	0.50	0.50	0.50	0.50
	g/day	0.0061	0.0061	0.0068	0.0068
Iron	mg/kg (ppm)	50.0	50.0	50.0	50.0
	g/day	0.6124	0.6124	0.6804	0.6804
Manganese	mg/kg (ppm)	40.0	40.0	40.0	40.0
	g/day	0.4899	0.4899	0.5443	0.5443
Molybdenum	mg/kg (ppm)	requirements are not established but there is no evidence that deficiency occurs			
	g/day				
Nickel	mg/kg (ppm)	research data are not sufficient to determine requirements			
	g/day				
Selenium	mg/kg (ppm)	0.10	0.10	0.10	0.10
	g/day	0.0012	0.0012	0.0014	0.0014
Zinc	mg/kg (ppm)	30.0	30.0	30.0	30.0
	g/day	0.3674	0.3674	0.4082	0.4082

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