TRACE MINERAL NUTRITION OF BEEF COWS

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Micro or "trace" minerals differ from macro minerals based strictly on the amount required in the diet. Trace minerals are required at concentrations less than 100 mg/kg of diet (mg/kg = parts per million = ppm) while macro minerals are required at concentrations greater than 100 mg/kg of diet (McDowell, 1992). Fifteen trace minerals are essential, 10 of which are considered essential for beef cattle (NRC, 1996; Table 1). 'Recommended dietary concentrations' are only reported for seven of the 10 trace minerals. Sufficient data is not available to justify a recommended concentration in the diet for chromium (Cr), molybdenum (Mo), or nickel (Ni), although they appear to be essential. Additional trace minerals, including arsenic, boron, lead, silicon, and vanadium, have also been identified as essential in animals; however, evidence of any nutritional importance in beef cattle is lacking (NRC, 1996).

Table 1. Trace mineral requirements and maximum tolerable concentrations for beef cattle[a]

		Requirement (ppm)			
Trace Mineral		Growing and Finishing Cattle	Gestating Cows	Early Lactating Cows	Maximum Tolerable Concentration (ppm)
Chromium	Cr	--	--	--	1,000.0
Cobalt	Co	0.1	0.1	0.1	10.0
Copper	Cu	10.0	10.0	10.0	100.0
Iodine	I	0.5	0.5	0.5	50.0
Iron	Fe	50.0	50.0	50.0	1,000.0
Manganese	Mn	20.0	40.0	40.0	1,000.0
Molybdenum	Mo	--	--	--	5.0
Nickel	Ni	--	--	--	50.0
Selenium	Se	0.1	0.1	0.1	2.0
Zinc	Zn	30.0	30.0	30.0	500.0

[a]Adapted from NRC (1996)

Importance of Trace Minerals

Trace minerals are necessary for normal growth, reproduction, and immune response in beef cattle (McDowell, 1992). In general, macro and micro minerals have four major functions: 1) as a structural component of organs, tissues, molecules, and/or membranes, 2) for maintenance of physiological function for homeostasis, 3) as a catalyst or component of enzyme and hormonal systems, and 4) for regulation of cell replication and differentiation (Underwood and Suttle, 1999). Specifically, trace minerals are necessary for normal tissue growth, homeostasis, enzyme function, and cell regulation, and must be maintained within narrow concentrations in the body (Underwood and Suttle, 1999). If trace mineral homeostasis is unsuccessful, situations of toxicity or deficiency can result (McDowell, 1992), possibly causing depressed productivity, health, and(or) growth and development.

Since trace minerals are poorly absorbed by ruminants (typically less than 5%), deficiencies are more common than in monogastrics (McDowell, 1992). In the Northwestern U.S., copper (Cu), selenium (Se), and zinc (Zn) deficiencies have been reported in beef cattle (Loucks, 1998). However, in most herds, clinical trace mineral deficiencies probably do not exist and do not have a substantial effect on cow or calf performance (Corah, 1995). Although, marginal trace mineral deficiencies likely exist and commonly go unnoticed since only slight reductions in performance occur. In beef cows, trace minerals have been shown to affect reproduction, growth, and immunity:

Reproduction. The effects of trace minerals on beef cow reproduction have been documented (Cu most extensively); however, physiological mechanisms of action are not known. Historically, reproductive symptoms due to a trace mineral deficiency have been vague (Table 2). The actual mechanism(s) by which trace minerals affect female reproduction might be via ovarian activity (Xin et al., 1993), uterine tissue repair after parturition (Manspeaker et al., 1993), enzyme activity causing differences in steroid hormone production (Henkin, 1980) and/or within the hypothalamic-pituitary axis (Kochman et al., 1997; Phillippo et al., 1987).

Growth. Trace mineral supplementation has been shown to increase (Arthington et al., 1995, Mayland et al., 1980), decrease (Baker et al., 2002), and not affect (Muehlenbein et al., 2001; Olson et al., 1999) pre-weaning calf performance, compared with non-supplemented controls. Similarly, the effects of trace minerals on post-weaning (feedlot) performance have been inconsistent (Ward and Spears, 1997; Engle et al., 2000; Engle and Spears, 2000, 2001). It has been documented that lipid metabolism can be affected by trace mineral supplementation (Ward and Spears, 1997; Spears and Kegley, 2002), based on differences in backfat thickness and fatty acid profile.

Table 2. Reproductive symptoms reportedly due to trace mineral deficiency in beef cows[a]

Trace mineral	Deficiency symptom
Copper	• Delayed estrus • Embryonic death • Decreased conception • Delayed puberty • Decreased ovulation
Iodine	• Impaired fertility • Retained placenta
Manganese	• Silent estrus
Selenium	• Retained placenta
Zinc	• Increased dystocia • Abnormal estrus

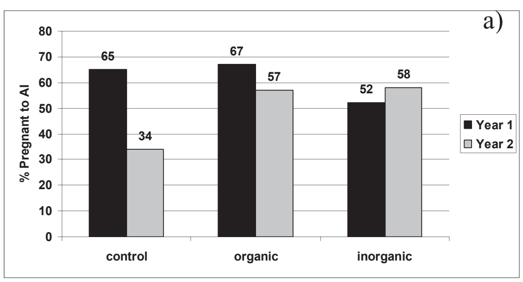
[a]Adapted from Paterson and Engle, 2005; McDowell, 1992; Underwood and Suttle, 1999.

Immunity. Several trace minerals are necessary for proper immune function. This is especially important in cattle under stressful conditions (e.g. newborn calves, weaned calves, first calf heifers, etc.). Most trace minerals are essential for the activity of enzymes responsible for energy production, protein synthesis, and cell replication. In addition, several trace mineral-dependent enzymes act specifically within the immune system. Copper and Zn are both necessary for the activity of Cu-Zn superoxide dismutase, an enzyme that quenches toxic free radicals, and Mn is necessary for a Mn-dependent form of superoxide dismutase. Selenium is important for glutathione peroxidase, an enzyme that protects cellular membranes from oxidative damage.

Supplementation Effects on Reproductive Performance

In recent years, the effects of trace mineral status and supplementation on cow performance (primarily reproduction) have been evaluated in western beef cows. Reductions in reproductive performance have been reported due to inadequate (Ahola et al., 2004) or excess supplementation (Olson et al., 1999) of trace minerals. Data indicate that trace mineral supplementation can affect the ability of cows to re-breed early in the breeding season (Ahola et al., 2004; Stanton et al., 2000); however, no effect of trace mineral supplementation on reproductive performance (Arthington et al., 1995; Muehlenbein et al., 2001) has also been reported.

A two-year study compared three trace mineral supplementation treatments: control (no supplemental Cu, Zn, or Mn), inorganic (100% inorganic Cu, Zn, and Mn), and organic (50% inorganic Cu, Zn, and Mn + 50% organic Cu, Zn, and Mn; Ahola et al., 2004). No differences were reported for estrous cyclicity or estrus response to synchronization, but pregnancy to a synchronized AI in the first year was greater in organic than inorganic cows (Figure 1). In year two, however, pregnancy rate to AI in the non-supplemented control cows was lower vs. the supplemented cows (receiving either inorganic or organic trace minerals), but not different between organic and inorganic cows. Overall season-long 60-d pregnancy rates tended to be greater in the supplemented cows vs. non-supplemented controls. Data indicate that depressed reproductive performance, especially in response to a synchronized AI, can occur if trace minerals are not supplemented for more than one year.



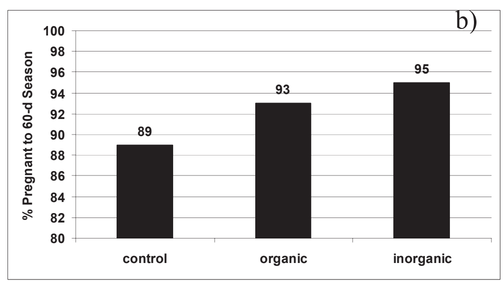


Figure 1. Reproductive performance of beef cows supplemented with different trace mineral treatments: (a) pregnancy rate to a synchronized AI in Years 1 and 2; (b) pregnancy rate throughout a 60-d breeding season for Years 1 and 2 combined (Ahola et al., 2004).

When supplementation of Cu, Zn, and Mn was elevated (two times NRC recommended concentrations), lower 60-d pregnancy rates resulted compared with non-supplemented controls (Olson et al., 1999). When the effect of Cu was evaluated alone, two studies reported no effect of Cu supplementation on 60-d pregnancy rate (Arthington et al., 1995; Muehlenbein et al., 2001). In heifers fed Mo or Fe to cause Cu deficiency, elevated dietary Mo and not low Cu appeared to be the cause of delayed puberty (possibly due to depressed basal LH release, affecting follicular estradiol production), reduced conception rate, and failure to ovulate (Phillippo et al., 1987).

Trace mineral source (organic vs. inorganic) has also been linked to reproductive performance in beef cows. An enhanced pregnancy rate to a synchronized AI was reported in cows receiving supplemental Cu, Zn, and Mn at high concentrations in an organic form compared to an inorganic form; however, overall pregnancy rate at the end of the 60-d breeding season was not affected by trace mineral source (Stanton et al., 2000). It should be noted that, based on reported mean liver Cu concentrations reported by the authors, cows were deficient in Cu (liver Cu < 30 mg Cu/kg; Mills, 1987). In two-year old beef cows, no difference in pregnancy rate was observed among cows supplemented with organic vs. inorganic forms of trace minerals, although cows receiving inorganic trace minerals conceived earlier than cows receiving organic trace minerals in the first year of the two-year experiment (Olson et al., 1999). Other researchers have associated organic trace minerals with reduced postpartum interval to breeding, compared to inorganic trace minerals (Swenson et al., 1998), and an improved pregnancy rate within the first 30 d of the breeding season when Cu was supplied in an organic form compared with non-supplemented controls (Muehlenbein et al., 2001).

The challenge when interpreting reproductive data from trace mineral experiments is that few trials have evaluated one trace mineral at a time, confounding the results. Additionally, since most reproductive data is binomial, and relatively limited numbers of animals have been used, detecting an effect of trace mineral treatment on reproductive performance is unlikely. Furthermore, little has been reported concerning likely physiological mechanisms of trace minerals effects on reproductive performance.

Why Closely Manage Supplementation?

The research data discussed above indicate that proper supplementation can optimize reproductive performance in beef cows. Unfortunately, ensuring that the correct amount and kind of trace minerals are available to beef cows can be challenging. The ‘strategic’ supplementation of beef cows requires a commitment to managing trace mineral supplementation in order to address several variables. These variables include: 1) widespread trace mineral deficiencies in forages, 2) presence of mineral antagonists, 3) ineffective supplementation practices, 4) the large number of factors that affect requirements,

5) differences among seasons and among forage species, and 6) variation in intake.

Many Forages are Deficient. Widespread analyses of forages for concentrations of key trace minerals were compiled by the National Animal Health Monitoring Service (NAHMS) of the United States Department of Agriculture (USDA) in 1999. Forage samples were classified as "deficient," "marginal," or "adequate" for each trace mineral based on trace mineral concentration (Table 3; Mortimer et al., 1999).

Table 3. Classification of trace minerals in forage relative to their ability to meet dietary requirements[a]

	Classification			
Trace Mineral[b]	Deficient	Marginal	Adequate	Maximum Tolerable Concentration
Cu, ppm	< 4.0	4.0 - 9.9	≥ 10.0	100.0
Mn, ppm	< 20.0	20.0 - 39.9	≥ 40.0	1,000.0
Se, ppm	< 0.1	0.1 - 0.2	≥ 0.2	2.0
Zn, ppm	< 20.0	20.0 - 29.9	≥ 30.0	500.0

[a]Adapted from Mortimer et al. (1999).
[b]Cu = copper, Mn = manganese, Se = selenium, Zn = zinc.

Table 4. Trace mineral classification of 709 forage samples[a]

	Animal Requirement Level			
Trace Mineral[b]	Deficient (%)	Marginal (%)	Adequate (%)	> Maximum Tolerable Conc. (%)
Cu	0.71	66.01	33.29	0.00
Mn	0.56	14.10	85.33	0.00
Se	43.44	26.09	30.18	0.28
Zn	33.29	43.72	22.99	0.00

[a]Adapted from Mortimer et al. (1999).
[b]Cu = copper, Mn = manganese, Se = selenium, Zn = zinc.

Results of 709 forage samples analyzed for trace mineral concentration (and classified according to Table 3) indicate that many forage diets for cow/calf operations across the U.S. are not adequate in Zn, Se, or Cu (Mortimer et al., 1999). As seen in Table 4, Mn was adequate in 85% of forage samples. However, Cu was adequate in only 33% of samples, Se was adequate in only 30%

of samples, and Zn was adequate in only 23% of samples. Selenium and Zn were the most commonly deficient trace minerals in harvested feeds on cow/calf operations – 43.4% of samples were deficient in Se (< 0.1 ppm) and 33.3% of samples were deficient in Zn (< 20 ppm).

Mineral Antagonists. Cattle can become deficient in Cu due to: 1) inadequate Cu in the diet (primary deficiency), and/or 2) due to elevated concentrations of Cu antagonists in the diet (secondary deficiency). Antagonists to Cu – such as iron (Fe), molybdenum (Mo), or sulfur (S) – can hinder the absorption and metabolism of Cu, and ultimately reduce the availability of Cu in ruminants. Therefore, the USDA-NAHMS report (Mortimer et al., 1999) also evaluated forage samples for concentrations of these antagonists. Forages were classified as "deficient" or "ideal" (relative to ability to meet an animal's needs), and as "marginal" or "high" (based on ability to be antagonistic to Cu; Table 5).

Table 5. Classification of trace elements in forage relative to their ability to meet dietary requirements or cause an antagonistic problem with Cu[a]

	Animal Requirement Level		Cu Antagonistic Level[c]		
Cu antagonist[b]	Deficient	Ideal	Marginal	High	> Maximum Tolerable Concentration
Fe, ppm	< 50.0	50-200	>200-400	> 400	1,000.0
Mo, ppm	--	< 1.0	1.0-3.0	> 3.0	5.0
S, ppm	< 0.1	0.15-0.2	>0.2-0.3	> 0.3	0.4

[a]Adapted from Mortimer et al. (1999).
[b]Fe = iron, Mo = molybdenum, S = sulfur.
[c]Concentrations above these can adversely affect copper availability.

Based on these classifications, 8.2% of samples were high in Mo, 8.0% of samples were high in Fe, and 12.8% of samples were high in S (Table 6; Mortimer et al., 1999). From these data, it appears that many Cu deficiency situations could be caused by elevated concentrations of Cu antagonists in beef cattle diets.

Many Supplementation Methods are Ineffective. Only 8% of beef cattle operations complete a laboratory analysis on purchased, grazed, or harvested feed (USDA, 1996a), indicating that supplementation practices may not be effective at preventing trace mineral deficiencies. Therefore, the USDA evaluated trace mineral supplementation practices employed by beef cow/calf producers and the trace mineral status of beef cattle (based on concentrations in serum) across the U.S. (Cu – USDA, 2000a; Zn – USDA, 2000b; Se – USDA, 1996b).

Table 6. Trace mineral classification of 709 forage samples – mineral antagonists[a]

	Animal Requirement Level		Cu Antagonistic Level		
Cu antagonist[b]	Deficient (%)	Ideal (%)	Marginal (%)	High (%)	> Maximum Tolerable Conc. (%)
Fe	2.82	70.52	18.62	8.04	1.69
Mo	--	51.48	40.34	8.18	2.68
S	6.06	25.53	33.57	12.83	1.97

[a]Adapted from Mortimer et al. (1999).
[b]Fe = iron, Mo = molybdenum, S = sulfur.

Supplementation of trace minerals is fairly common on beef cow/calf operations. Copper supplementation occurred on 64% of operations (91.6% as a mineral mix, 0.8% bolus, 0.4% fertilizer, and 0.0% injected; USDA, 2000a). However, of operations that supplemented Cu, 38.0% were still moderately deficient (compared to 43.2% of operations where Cu was not supplemented), as shown in Figure 2. This relatively high rate of moderate Cu deficiency, even when Cu was supplemented, indicates that supplementation practices currently used by cow/calf producers are not very effective at avoiding a deficiency situation. This relatively high rate of Cu deficiency, even with Cu supplementation, may have been due to inadequate Cu bioavailability and/or concentration in the supplement, and/or inadequate duration of supplementation or elevated concentrations of antagonists in the forage or water.

Compared to Cu, the incidence of Zn deficiency was similar. Among operations surveyed for Zn status, nearly 63% supplemented Zn to their cows (93.8% as free choice mineral; USDA, 2000b). On operations where Zn was supplemented, 62.8% of operations were moderately deficient and 0.4% were severely deficient in Zn (Figure 3). On operations that did not supplement Zn, 68.6% of operations were moderately deficient, and 2% were severely deficient.

Selenium (evaluated as whole blood Se) was severely deficient (0-0.05 ppm) in 7.8% of the cattle (Figure 4) and on 2.0% of the operations sampled (USDA, 1996b). In addition, 10.4% of cattle were marginally deficient (0.051-0.080 ppm). Survey data indicate that 49% of operations supplemented Se (98% added Se to a mineral supplement and 4% gave injections). However, of operations in the western U.S., only 19% supplemented Se. In general, most cattle were adequate in Se, and most operations (85%) did not have any cattle considered severely deficient in Se.

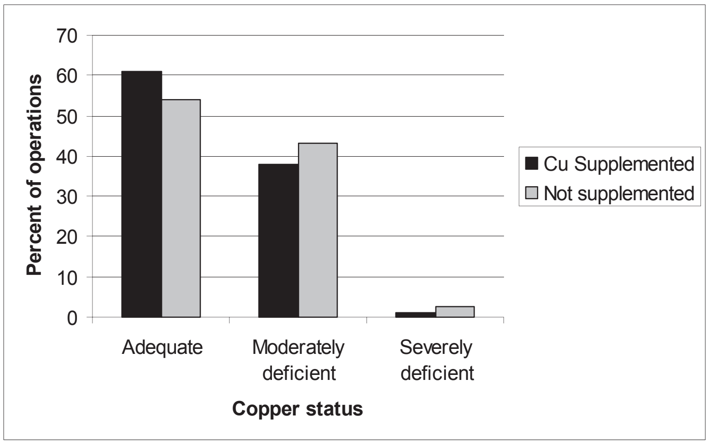


Figure 2. Percent of operations by serum Cu concentration level and by Cu supplementation (n = 411 operations). Adequate: ≥ 0.65 ppm (n = 240); Moderately Deficient: 0.25 to 0.65 ppm (n = 164); Severely Deficient: < 0.25 ppm (n = 7); USDA (2000a).

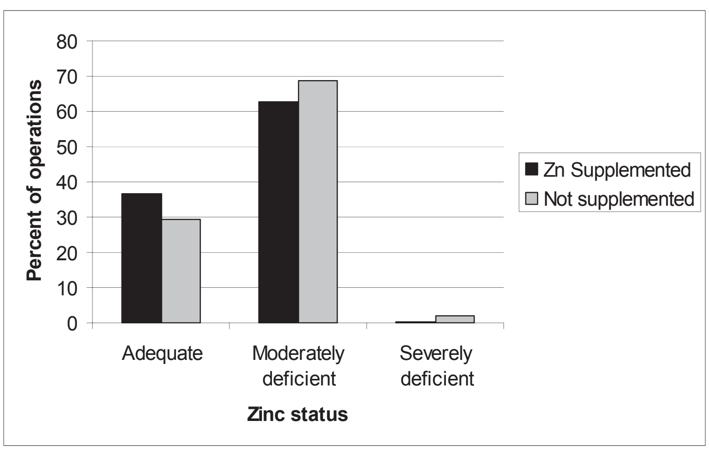


Figure 3. Percent of operations by serum Zn concentration level and by Zn supplementation (n = 411 operations). Adequate: ≥ 1.0 ppm (n = 140); Moderately Deficient: 0.7 to 1.0 ppm (n = 267); Severely Deficient: < 0.7 ppm (n = 4); USDA (2000b).

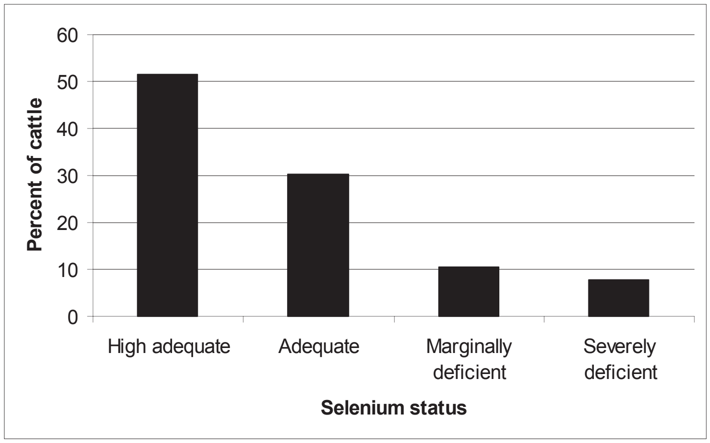


Figure 4. Percent individual cattle blood Se concentrations (n = 2,216 cows and heifers). High Adequate: ≥ 0.161 ppm; Adequate: 0.081 to 0.160 ppm; Marginally Deficient: 0.051 to 0.080 ppm; Severely Deficient: ≤ 0.050 ppm; USDA (1996b).

Many Factors Affect Requirements. Ruminants are unable to absorb most of the trace minerals they consume. The efficiency of Cu absorption from normal feeds ranges from approximately 1 to 15% across all species, but appears to be higher in non- and young ruminants compared to adult ruminants (Hemken et al., 1993). Several factors can affect the efficiency of trace mineral absorption. In addition to the effect of species on trace mineral requirements, the true requirement for a trace mineral can be impacted by other factors including age, physiological status, breed, mineral interactions in the gastrointestinal tract, environment, trace mineral source and availability, concentration, stress, and duration of supplementation. To briefly, but fairly, address this topic, only the well-documented factors will be discussed:

1. Age. Age can substantially affect the rate of absorption of particular trace minerals. During early life, calf growth and mineral deposition can be intensive (Annenkov, 1981). The rate of Zn absorption decreases with age (McDowell, 1992), partially due to a slowing of growth and protein deposition (Stake et al., 1973), a primary function of Zn. In addition to a change from growth to maintenance associated with age, trace mineral requirements can also be affected by changes in the gastrointestinal tract. Absorption rates of Zn decreased with age (Suttle, 1979), possibly due to development of the rumen. Liver Mn concentrations are very non-responsive to Mn supplementation (McDowell, 1992); however, in calves liver Mn concentrations responded substantially to increased Mn intake (Howes and Dyer, 1971), suggesting that the metabolism of Mn in a newborn calf differs from that in an older animal.

2. Breed. In beef cattle, several experiments have reported differences in absorption rates of trace minerals between breeds, with Cu in particular. In an experiment using nine breeds of beef cattle that compared liver Cu, Zn, and Fe and serum Cu, Zn, calcium, and magnesium concentrations across breeds, Cu metabolism was affected by breed based on greater liver Cu concentrations in Limousin cattle compared to all other breeds except Angus. The authors concluded that Limousin cattle may be more able to maintain liver Cu concentrations on a reduced intake of Cu (Littledike et al., 1995). Another breed effect was noted in beef cattle when Cu excretion via bile was evaluated, and biliary excretion of Cu was greater in Simmental vs. Angus cattle (Gooneratne et al., 1994).

3. Presence of Antagonists. Interactions among minerals and between minerals and other dietary compounds (e.g. fiber) can affect trace mineral absorption and therefore requirements. Common mineral interactions have been summarized (Puls, 1994), but possibly the best example of an interaction that reduces availability is the interaction of Cu with molybdate and sulfide in the rumen. When S is consumed as either sulfate (SO_4^{2-}) or via an S-containing amino acid, it is converted to sulfide (S^{2-}) in the rumen (Ward, 1978). Rumen microorganisms use sulfide as a source of S for bacterial synthesis of S-containing amino acids; however, sulfide readily combines with Mo to form a thiomolybdate (MoS_4^{-2}), which binds Cu and forms $CuMoS_4$ (Suttle, 1991). The Cu-Mo-S complex is almost completely unabsorbable and unavailable to ruminants (Ward, 1978). According to Ward (1978), most Cu deficiencies in ruminants are primarily caused by one of four types of feed: 1) High Mo (over 100 mg Mo/kg diet), 2) low Cu:Mo ratio (2:1 or less), 3) inadequate Cu (less than 5 mg Cu/kg diet), and/or 4) high sulfur within the diet and/or from water. Elevated concentrations of dietary Fe have also caused Cu deficiency in young calves (Phillippo et al., 1987) and elevated dietary Zn depressed Cu absorption in cattle (Davis and Mertz, 1987). These interactions typically reduce or prevent absorption of the mineral, since the trace mineral becomes part of a large and insoluble complex. Absorption of thiomolybdates has been detected, but since they most likely bind albumin in the blood, the Cu component is unavailable and unusable to the body (Gooneratne et al., 1989). Ward (1978) predicted that problems with marginal mineral deficiencies and interactions will continue to increase in prevalence as the trend for intensified animal agriculture and forage production continues.

4. Physiological Status. Physiological status of an animal (i.e. growing, gestating, lactating, etc.) can have a major effect on trace mineral requirements

(Annenkov, 1981). This can clearly be seen by the two-fold increase in Mn that is recommended in beef cattle diets from feedlot cattle (20 mg Mn/kg diet) to gestating and early lactating cattle (40 mg Mn/kg diet) by the NRC (1996). This increase is based on research indicating that reproductive performance requires more Mn than simply growth and development (Rojas et al., 1965). During late pregnancy, fetal weight and mineralization of tissue occurs, in addition to maternal mineral deposition for use in early lactation (Annenkov, 1981). When the apparent absorption and retention of Cu and Zn from an alfalfa-based diet were evaluated in pregnant (third trimester) and non-pregnant Angus cows and Suffolk ewes, in the absence of supplemental Cu, apparent absorption and apparent retention of Cu and Zn were greater in pregnant than non-pregnant cows, while apparent absorption and retention of Zn was greater in pregnant vs. non-pregnant ewes (Vierboom, 2002). These data indicate that pregnancy can affect absorption of Cu and Zn, likely due to increased physiological need. In an experiment where maternal and fetal liver Cu concentrations were measured at the same time, and classified based on stage of gestation, Cu concentration in the fetal liver increased and maternal liver decreased during gestation, particularly during the third trimester (Gooneratne and Christensen, 1985).

5. Stress. Stress in cattle (caused by weaning, parturition, disease, environment, etc.) can affect absorption and requirements of trace minerals. When adrenocorticotropic hormone was administered to beef calves every 8 h over a 3 d period at the same time as feed and water restriction in order to simulate stressful conditions, urinary excretion of Cu and Zn decreased and affected the rate of trace mineral retention (Nockels et al., 1993).

Concentrations Differ by Season and Forage Species. Trace mineral concentrations can vary substantially by species of plant and season of year. These changes are rarely accounted for in trace mineral supplementation strategies, and few producers modify the composition of their trace mineral mix based on these factors. The USDA-NAHMS survey reported concentrations of Cu, Zn, Se, and Mn for over 10 species of forages (Figure 5; Mortimer et al., 1999).

In addition to variation among forage species, trace mineral concentrations can change substantially during the growing season. Repeated forage sampling over two years at five sites in Arizona was evaluated for trace mineral concentration change (Sprinkle et al., 2000). As seen in Figure 6, concentrations of Cu and Zn increased with increased winter and summer moisture. More importantly, the forage samples did not consistently contain adequate concentrations of Cu, Zn, and Se for grazing beef cattle during the two-year period. Copper was the only trace mineral with an adequate concentration, which was only present at one time point.

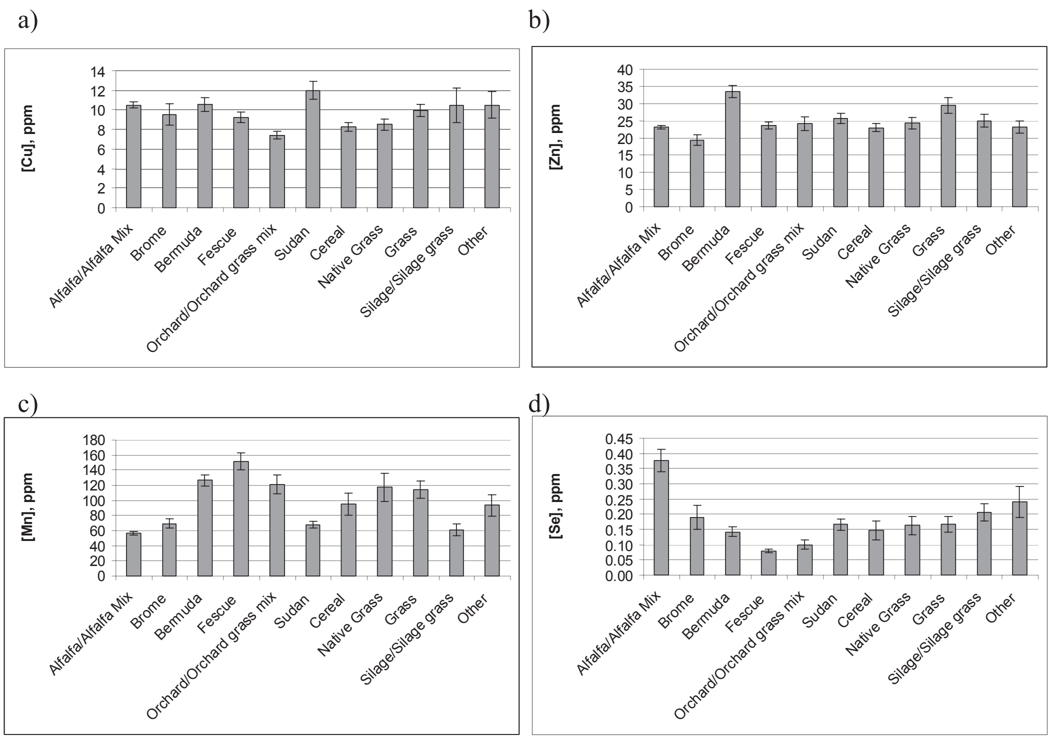
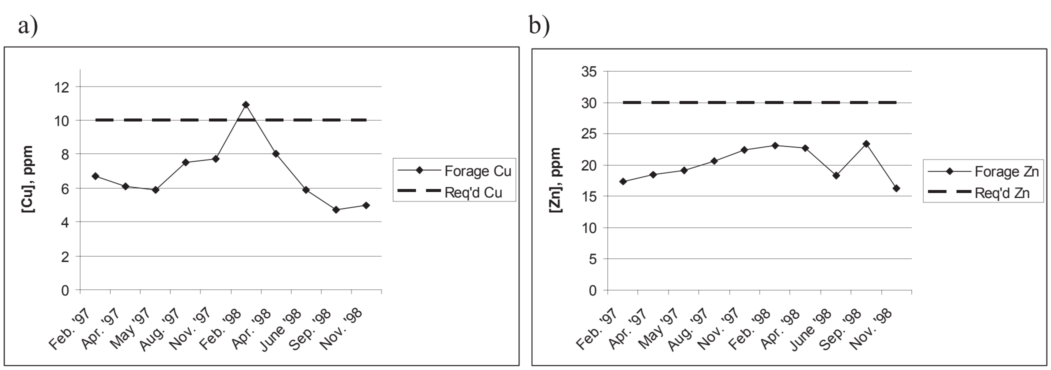


Figure 5. Mean Cu (a), Zn (b), Mn (c), and Se (d) concentrations for alfalfa (n = 196), brome (n = 20), bermuda (n = 112), fescue (n = 73), orchard grass (n = 34), sudan (n = 61), cereals (n = 46), native grass (n = 38), grass (n = 70), silage (n = 31), and other (n = 28) forage samples; adapted from Mortimer et al. (1999).



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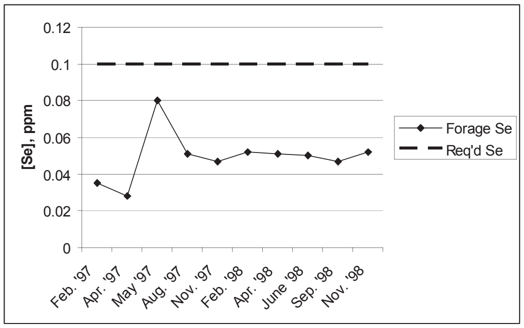

Figure 6. Concentrations of Cu (a), Zn (b), and Se (c) in range forage samples collected over a two-year period in Arizona, compared to the amount of Cu, Zn, and Se required for grazing beef cattle (as recommended by the NRC, 1996); adapted from Sprinkle et al. (2000).

Intake Variability. Intake of a free-choice mineral mix by beef cattle is generally targeted at two to four ounces per cow per day. This amount provides the basis for calculating the amounts of trace minerals to include in a mix. Unfortunately, limited literature is available regarding consumption patterns of trace mineral mixes by beef cattle in the western U.S. It is generally agreed that the variation in intake among cows is substantial, and that some cows will consume much greater quantities than the target, while others will consume little or no mineral. Research in Florida indicates that beef cows consume more of a salt-based mineral supplement during the wetter months (summer) and less during the dryer months (winter; Arthington, 2003). In that study, during the winter months, cows consistently refused over 75% of the mineral that was provided (2 oz./head/day), compared to 0% refusal during each of the summer months. The author indicated that this variation in intake was probably caused by changes in the moisture content of pasture forages and the presence of winter supplement.

Strategy Development

Concentrations of trace minerals that should be included in beef cow diets for optimum performance have been reported (NRC, 1996). However, many trace mineral supplementation strategies are poorly planned, excessive, and may negatively affect the environment (McDowell, 1992). Unfortunately, the economic advantages or disadvantages of supplementing trace minerals to beef cattle and potential environmental problems that may result from the over-supplementation of trace minerals have not been well addressed in the literature.

These factors have contributed to the rate of trace mineral deficiencies that have been reported by USDA.

To avoid purchasing and supplying trace minerals unnecessarily, producers should determine the specific trace minerals that need to be supplemented, and at what concentration they should be included in the mineral mix. This can be determined by comparing the results of a laboratory analysis of feedstuffs (ideally across several times of the year), with the recommended concentrations that trace minerals should be included in the diet, based on the physiological needs of different classes of cattle. Producers should realize that trace mineral antagonists can affect the amount of trace mineral supplemented.

Analyze Feed and Water for Trace Mineral Content. To begin the development of a supplementation program, feed and pasture samples should be collected and sent to a laboratory for analysis of trace mineral concentration. A major challenge with sample collection is making sure that samples collected are representative of the forages actually consumed by grazing cattle. Plants not typically selected by grazing cattle should not be included in the sample. Water samples should not be overlooked as a source of trace minerals or Cu antagonists. Sulfate, an antagonist of Cu, has been reported to be elevated (> 300 ppm) in water sources for livestock (Figure 7; Gould et al., 2002; USDA, 2000c).

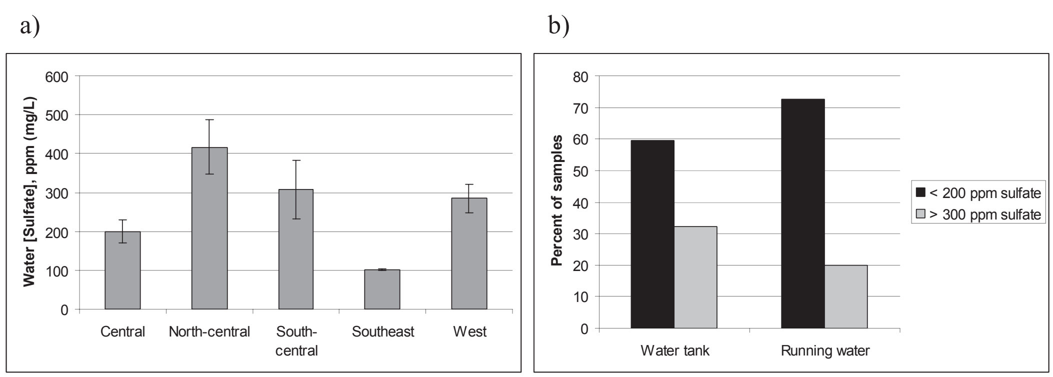

Figure 7. Sulfate in livestock water: a) mean sulfate concentration of water samples from beef cow/calf operations by region of the U.S., Gould et al. (2002); and b) percent of water samples from water tanks or other running water sources below 200 ppm sulfate (considered safe) or above 300 ppm sulfate (could lead to weight loss due to decreased feed and water intake), USDA (2000c).

Determine Animal Requirements. Recommendations for concentrations of trace minerals that should be included in diets based on estimated endogenous losses and availability are reported and updated regularly (NRC, 1996). These recommendations for the seven trace minerals in beef cattle diets are listed in Table 7. The estimated amount of trace minerals consumed by cattle (based on laboratory analysis of feeds and estimated dry matter intake) should be compared with these recommendations. Ideally, a trace mineral mix should be developed to provide supplemental trace minerals to meet the physiological needs of an animal if an adequate amount is not available from the forage. The suggested composition of a mineral mix has also been included in Table 7 (Bohnert and Ganskopp, 2004); however, these suggested values do not account for trace minerals consumed via feed and water sources.

Table 7. Trace mineral requirements and suggested mineral mix composition

	Cow Requirement (ppm)[a]		Suggested Mineral Mix Composition[b]
Mineral	Gestating	Early Lactating	(ppm)
Co	0.1	0.1	30.0
Cu	10.0	10.0	1,200 - 2,000
I	0.5	0.5	100.0
Fe	50.0	50.0	--
Mn	40.0	40.0	4,000.0
Se	0.1	0.1	60.0
Zn	30.0	30.0	3,000.0

[a]Adapted from the NRC (1996)
[b]Based on estimated average consumption of 2 oz (56 g) per head per day (adapted from Bohnert and Ganskopp, 2004).

Implications

Proper management of trace mineral supplementation practices and status – through the use of a well-designed trace mineral supplementation strategy – can help to optimize reproductive performance in beef cows. Unfortunately, supplementation strategies used by many cow/calf producers are not effective at avoiding marginal Cu, Zn, and Se deficiencies. Strategic supplementation should account for variables that affect the ability of a cow/calf producer to properly supplement trace minerals to beef cows. The widespread deficient concentrations of Cu, Zn, and Se in forages consumed by beef cattle and elevated concentrations of Cu antagonists, including Mo, Fe, and S, should be accounted for. Ideally, producers should determine the trace mineral concentrations in feed and water sources and utilize current National Research Council recommendations to properly formulate a trace mineral mix and enable their cows to maintain a trace mineral status within an acceptable range.

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