LIFE CYCLE TRACE MINERAL NEEDS FOR REDUCING STRESS IN BEEF PRODUCTION

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INTRODUCTION

Trace minerals are needed for vitamin synthesis, hormone production, enzyme activity, collagen formation, tissue synthesis, oxygen transport, energy production, and other physiological processes related to growth, reproduction and health. The priority of use for these physiological processes varies. For example, growth, feed intake, and feed efficiency may not be altered during sub-clinical deficient states, although impairment of reproduction or immune-competence may occur. The requirement of trace minerals is often based upon the ability of the animal to maintain desired production performance parameters. Table 1 shows the trace mineral requirements for growing and finishing cattle, and cows (NRC, 1996). These requirements are based upon average cattle consuming average diets. Copper requirements are suggested to be 10 mg/kg of DM intake but can vary depending upon other dietary components.. Because copper utilization can be low in ruminant diets, especially when the antagonists Mo and S are present in moderate to high levels, the NRC recommendations may require adjustment.

Table 1. Trace Mineral Requirements For Growing And Finishing Cattle (NRC, 1996)

	Requirement, mg/kg	
Mineral	Growing and Finishing Cattle	Cows
Cobalt	0.1	0.1
Copper	10	10
Iodine	0.5	0.5
Iron	50	50
Manganese	20	30
Selenium	0.1	0.1
Zinc	30	30

Molybdenum and sulfate form thiomolybdates in the rumen when fed in excess. Thiomolybdate complexes with Cu at both the gastrointestinal and tissue level rendering it unavailable to the animal (Allen and Gawthorne, 1987; Gooneratne et al., 1989; Suttle, 1991). Disorders associated with a simple or induced (high Mo and S) Cu deficiency include anemia, diarrhea, depressed growth, change of hair color, neonatal ataxia, temporary infertility and weak, fragile long bones which break easily (Underwood, 1981). Recently, Herd (1997) indicated that there is concern that trace elements may be limiting production in better-managed herds to a much greater extent than previously recognized. Sub-clinical trace mineral deficiencies in cattle may be a larger problem than an acute deficiency, because specific clinical symptoms are not evident to allow the producer to recognize the deficiency (Wikse, 1992). Animals with a sub-clinical status can continue to reproduce or grow, but at a reduced rate, with decreased feed efficiency, and a depressed immune system (Nockles, 1994). Correcting sub-clinical mineral deficiencies in animals that have been nutritionally stressed may have a positive economic impact on cattle production efficiency. Factors which may contribute to trace mineral requirements when animals experience stress include deficiencies of trace minerals in the forage, antagonistic effects of other minerals found in water or diet, fetal growth of the calf, calving , weaning and even expected level of animal productivity.

ASSESSING TRACE MINERAL STATUS IN BEEF CATTLE

In reviewing the responses to trace mineral supplementation, we have asked the question "Were the responses due to level of intake, form of mineral intake (inorganic vs organic) or a response to overcoming antagonistic effects caused by Mo, S or Fe?" The approach that we have followed with producers is to first test the forages, then the water and finally conduct a liver biopsy to make recommendations. The easiest and least expensive are the first two.

Forage mineral content and bio-availability varies because of factors such as soil mineral level, soil pH, climatic conditions, plant species and even stage of plant maturity (Spears, 1996). When comparing grasses to legumes grown in the same location, legumes have been shown to be higher in Ca, Cu, Zn and Co than grasses (Greene et al. 1998). Distribution of the mineral in the plant, chemical form and mineral interactions can also influence bioavailability.

Table 2 describes average values obtained from grass, grass-legume and legume hay samples collected over the past two years in Montana. The most noticeable and consistent deficiencies were for Cu and Zn.

Table 2. Average Nutrient Concentration of Grasses, Forage-mixes and Legumes for Montana

Forage Type	No. Samples	Crude Protein%	TDN %	Ca %	P %	S %	Cu, ppm	Mo, ppm	Cu:Mo Ratio	Zn, ppm
Grasses	151	9.6	54.9	.62	.16	.14	5.2	1.45	3.6	18.2
Grass-legume	163	13.1	57.9	.85	.21	.19	7.0	.81	8.6	19.2
Legumes	58	17.9	62.7	1.4	.24	.26	8.8	1.15	7.7	21.4

Current NRC dietary recommendations are 10 ppm for Cu and 30 ppm for Zn. Of the forages analyzed, all had average Cu and Zn values much lower than these recommendations, indicating that supplementation would be warranted. Although, fewer samples were analyzed for Mo, concentration in grass hays were high enough to consider antagonistic effects on the utilization of Cu; (Cu:Mo ratio of less than 5:1). These results would be in agreement with those reported by Corah and Dargatz (1996) who reported that 64% of forages analyzed were deficient to marginal in Cu and 97.5% were deficient to marginal in Zn. Similar to MT data, Herd (1997) published trace mineral values for native grasses from Texas and Davis et al. (1999) published results for Arkansas forages (Table 3).

Table 3. Variation in Forage Mineral Content for Native Grasses from TX and Mixed Grass Hay from AR and NRC Requirements for Dry and Lactating Beef Cows (adapted from Herd, 1997; Davis et al., 1999)

Mineral	Average	Range of Analyses	Requirements, (NRC,1996) Dry Cow	Lactating Cow
Texas				
(Native Grass)				
Calcium, %	.48	.29-.67	.25	.31
Phosphorus, %	.10	.04-.16	.16	.21
Magnesium, %	.12	.07-.17	.12	.20
Potassium, %	.91	.28-1.54	.60	.70
Sulfur, %	.13	.07-.19	.15	.15
Iron, ppm	205	43-367	50	50
Copper, ppm	5	3-7	10	10
Manganese, ppm	50	25-75	40	40
Zinc, ppm	21	13-29	30	30
Arkansas				
(Mixed Grass Hay)				
Calcium, %	.59	.23-1.35		
Phosphorus,%	.29	.11-.66		
Magnesium,%	.26	.13-.47		
Potassium, %	1.85	.61-5.03		
Sulfur, %	.22	.12-.44		
Iron, ppm	231	56-3982		
Copper, ppm	10.2	1.1-27.6		
Manganese, ppm	197	38-1125		
Zinc, ppm	24.3	15.4-184.5		

The TX data for native grass suggests that P, Mg, Cu, Mn and Zn would all be deficient for a lactating cow. The AR data for mixed grass hay indicates that P, Cu and Zn could also be deficient on certain ranches.

In addition to forage quality, livestock water quality is often considered in making nutritional recommendations. The following figure (Figure 1) shows the variation in sulfate concentration of water for 12 ranches in Montana. The target values above 400 ppm cause us to question the effects on Cu utilization. Independent of Mo, dietary S can also reduce Cu absorption (Suttle, 1974). Our concern has been the interaction that molybdenum and sulfur consumption has on the utilization of Cu. This concept is demonstrated by the work of Arthington et al. (1996) who showed that copper levels in the liver were significantly reduced when molybdenum and sulfur were supplemented to beef cattle (Figure 2).

Figure 1. Analyses of Water Samples for Sulfate Concentration from 12 MT Ranches *(Livermont, 1998, unpublished)*

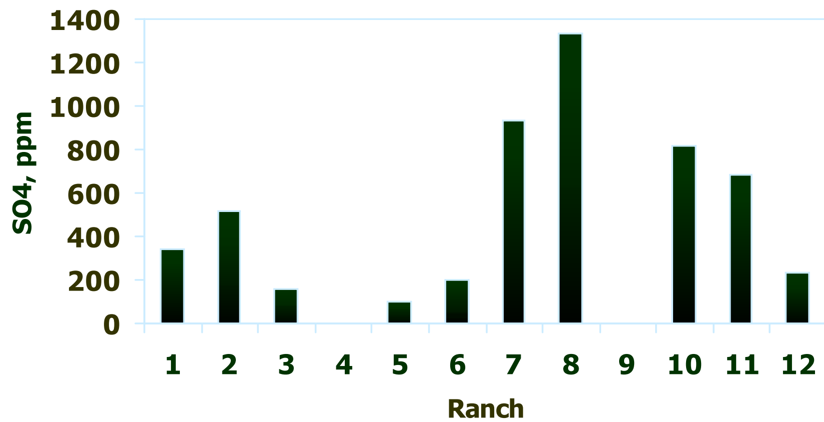
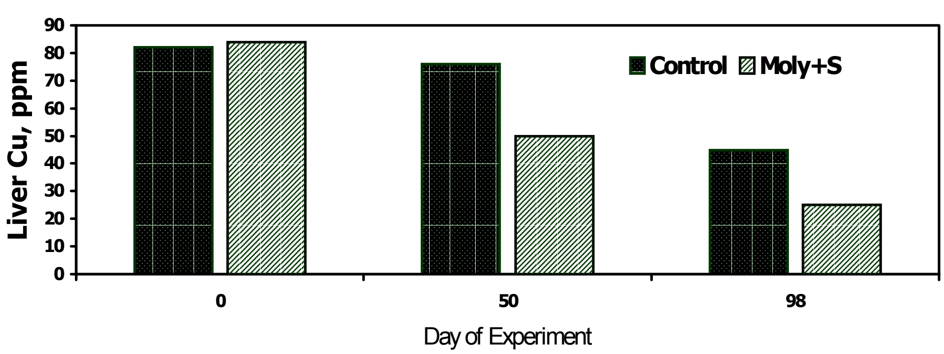


Figure 2. Change in Liver Copper Concentration when Cattle were Supplemented with Mo and S (adapted from Arthington et al., 1996)



These data show that supplementing both S and Mo resulted in a reduction in liver stores of Cu. Ward et al. (1992) also demonstrated that Mo and S supplementation reduced plasma Cu concentrations in steers after 21 days of feeding, and impaired Cu metabolism.

LIVER BIOPSY TO DETERMINE CU, ZN AND MN STATUS

In diagnosing Cu status, serum may not always be a good indicator of status because not all Cu circulating in the blood is available to the animal and can be influenced by Mo, sulfate, infection, trauma and stage of production (Puls, 1990). Serum Cu levels have not been shown to have a high correlation to liver Cu levels (Clark et al., 1993). For example, cattle with low plasma Cu levels had adequate liver Cu levels (Mulryan and Mason, 1992). Stoszek et al. (1986) found that animals with liver Cu levels of 25 ppm had plasma Cu levels between .07 to 1.0 ppm while animals with liver Cu levels between 100 and 400 ppm also had plasma Cu levels close to .9 ppm. Table 4 describes the status levels for Cu, Zn, Mn and Fe in the bovine the liver. For Cu and Zn, approximately 100 ppm (DM basis) is considered to be adequate in the bovine, while 10 ppm is adequate for Mn.

Table 4. Status and Concentration of Cu, Zn, Mn and Fe in Bovine Liver
(ppm on a DM Basis)[a]

Status	Copper	Zinc	Manganese	Iron
Deficient	<25	<40	<3.5	<30
Marginal	30-90	50-90	5-10	40-60
Adequate	100-200	100-300	9-21	75-300
High	300-550	400-800	14-80	400-700

[a]Adapted from numerous sources

To assess trace mineral levels on a regional basis, a nine-state survey was conducted to determine the variation in Cu, Zn, Mn and Mo levels of bovine liver. Twelve hundred and forty three cows were sampled by the use of a liver biopsy technique. States included in the survey were CO, KS, MO, MT, NE, ND, SD and TX. Table 5 presents the number of cows biopsied, and the average, minimum and maximum liver concentrations for these trace elements.

Table 5. Average, Minimum and Maximum Concentrations of Liver Cu, Zn, Mn and Mo of Cattle from Nine States, (ppm on a DM basis)

State	No. Animals Sampled	Cu (Min-Max)	Zn (Min-Max)	Mn (Min-Max)	Mo (Min-Max)
CO	329	73 (5.3-368)	125 (2.9-299)	14.7 (1.9-1222)	5.7 (2.1-16.0)
KS	257	108 (1.3-454)	181 (13-980)	11.5 (2.0-241)	5 (2-8.2)
MO	32	122 (19-237)	109 (89-145)	16.0 (7.5-128)	3.7 (1.5-4.5)
MT	182	102 (29-304)	120 (89-196)	8.3 (5.6-11.9)	3.6 (2.2-6.1)
NE	78	20.4 (4.1-125)	126.6 (4.7-227)	8.5 (5.1-54.5)	3.5 (2.2-5.1)
ND	113	12 (3.9-78)	144 (1.4-640)	8.0 (6.2-10.0)	2.9 (1.8-3.7)
SD	162	39 (3.8-291)	123 (83-237)	8.6 (6.4-11.3)	3.5 (2.4-5.7)
TX	60	121 (6.5-458)	143 (57-759)	11.2 (1.4-60.8)	3.1 (.2-6.8)

Appreciation is expressed to Drs. Brink (NE), Corah (KS), Johnson, Whittier (CO) and Wikse (TX) who contributed data for this survey.

Evaluation of the average liver Cu concentrations suggests that cows from CO, NE, ND and SD would be considered to be deficient to marginal in status. Manganese levels were marginal for MT, NE, ND, and SD. Zinc levels appeared to be adequate based on the recommendations from Table 4. The minimum and maximum values indicate wide variation in liver copper storage. The results were further sorted by state to indicate the percentage of the cattle which were considered to be deficient, marginal or adequate in liver copper (Table 6) based on the recommendations from Table 4.

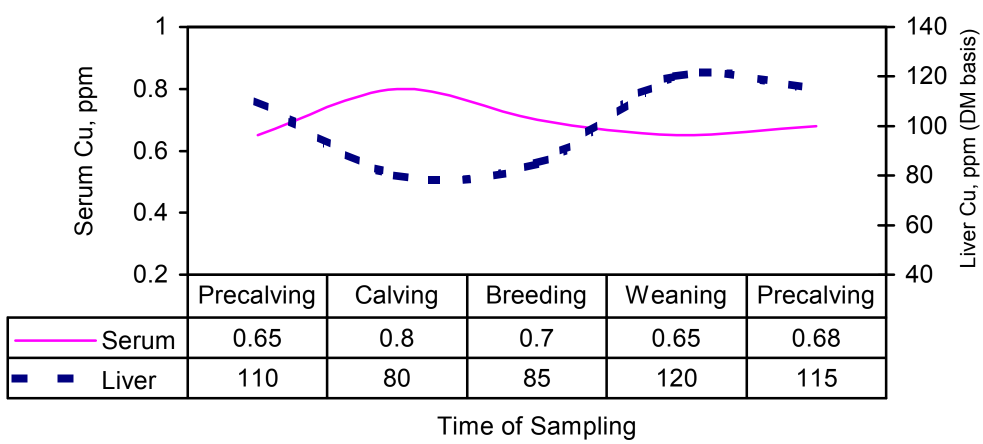
Table 6. Percentage of Cattle Which Were Classified at Deficient, Marginal or Adequate in Liver Cu Concentrations

		---------------- % of cattle ---------------------		
State	No Cattle	Deficient <30 ppm	Marginal < 60 ppm	Adequate >90 ppm
CO	329	30	49	30
KS	257	16	39	51
MO	32	6	13	63
MT	182	.2	12	61
NE	78	55	77	12
ND	113	92	96	0
SD	162	65	69	27
TX	60	10	23	62

Cows from CO, KS, NE, ND and SD had high percentages of cows that were considered to be of marginal status. Three questions arise from this survey; "When should a liver biopsy be conducted, how does liver copper concentrations change throughout the year and does a high level of Mo in the liver influence availability of copper to the animal?"

Swenson, (1998) repeatedly biopsied sixty spring-calving cows starting 30 days precalving, at calving, at breeding, at weaning and again just before calving the next year. These results are presented in Figure 3.

Figure 3. Changes in Liver and Serum Copper Concentrations For Beef Cows (Swenson, 1998)



Results from this experiment indicated that the cows had adequate liver Cu stores pre-calving (110 ppm) but became marginal by the time of parturition (80 ppm). We interpreted these results to indicate a maternal transfer of Cu to the fetus during the last trimester of pregnancy. Copper reserves were increased during the summer and fall and did not appear to decline until just before calving the next year. Serum Cu changes were not indicative of liver copper changes.

EFFECT OF FORM OF SUPPLEMENTAL MINERALS

Traditionally, supplemental trace minerals have been supplied to livestock in the form of inorganic salts, sulfates, oxides and chlorides. The use of organic trace minerals has increased due to reports of improved feed efficiency, growth, reproduction and immune response (Manspeaker et al., 1987; Chirase et al., 1991; Swenson, 1998).

Power et al., (1994) showed bio-availability of zinc proteinate to be 159% of the bio-availability of zinc sulfate in rats while Lovell (1994) reported that zinc methionine had 300-400% the potency of zinc sulfate in young channel catfish. Spears et al. (1991) reviewed the beneficial effects of feeding zinc methionine to cattle, which resulted in improved performance, carcass quality and immune response. The following table (Greene et al., 1998) compares the bio-availability of several trace elements from different sources (Table 7).

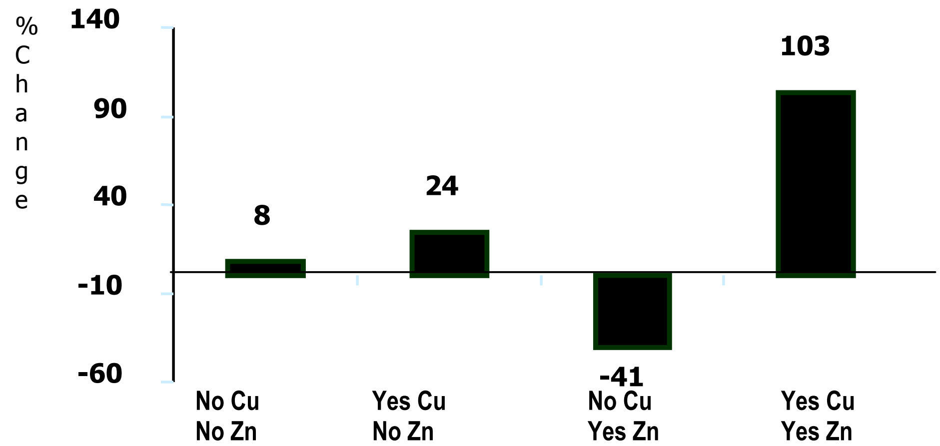
Table 7. Relative bioavailability of trace minerals from different sources (adapted from Greene et al., 1998)

Mineral	Sulfate	Oxide	Carbonate	Chloride	Organic
Co	100	31[a]	110[a]	-	85[g]
Cu	100	0[b]	-	105[c]	130[h]
Fe	100	0[d]	0-75[d]	-	-
Mn	100	58[e]	28[e]	-	176[i]
Zn	100	-	60[f]	40[f]	159[j]-206[k]

[a]Henry (1995)
[b]Kegley and Spears (1994)
[c]Ivan et al. (1990)
[d]Spears (1996)
[e]Wong-Valle et al. (1989)
[f]Kincaid (1979)
[g]Kawashima et al. (1986)
[h]Kincaid et al. (1986)
[i]Fly et al. (1989)
[j]Power et al. (1994)
[k]Wedekind et al. (1992)

Other work has suggested that the bioavailability of Cu-lysine was similar to $CuSO_4$ in chicks (Baker et al., 1990) and steers (Ward et al., 1992). But, Du et al., (1996) showed that the utilization of Cu from either Cu-proteinate or Cu-lysine was higher than Cu-sulfate based on rat liver Cu content. Interestingly, these data also revealed that high dietary Zn decreased the utilization of Cu, but this effect could be overcome by increasing Cu in the diet. Wellington et al. (1998) came to a similar conclusion with beef heifers (Figure 4). In this study, heifer calves were fed 5 ppm Mo and supplemented with either Cu-amino acid complex (15 ppm in the diet) or Zn-amino acid complex (90 ppm in the diet) to determine the effects on liver Cu changes over 90 days. Data indicate that Cu-supplementation alone increased liver Cu by 24% while Zn supplementation alone decreased liver Cu levels by 41%. But, supplementing both Cu and Zn increased liver Cu by 103%.

Figure 4. Effect of Supplementing Cu, Zn or Cu+ Zn on Change in Liver Cu Concentrations in Beef Heifers After 90 days (Wellington et al., 1998)



Herd (1997) hypothesized that the usage of organic forms of trace minerals may be of greater value when an animal is under nutritional, disease or production stress. Ward et al (1992) demonstrated that source of trace minerals may result in differences with result to ADG and feed intake. Their data showed improved performance for incoming feedlot calves during the first two weeks compared to feeding the sulfate form of trace minerals (Table 8).

Table 8. Effect of Form of Mineral on Performance of Calves (adapted from Ward et al. 1992)

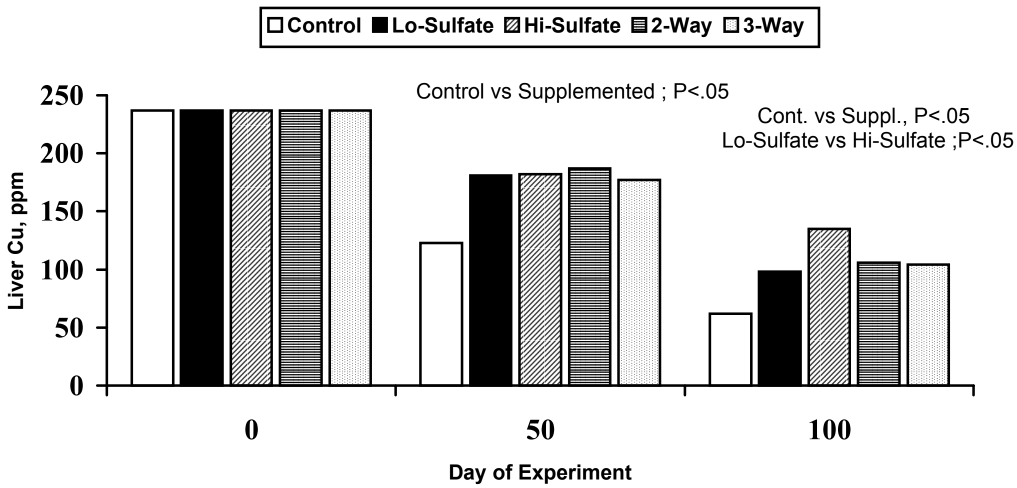
Parameter	Control	Oxide	Sulfate	Complex	SE
Number of animals	31	31	31	31	
Initial weight (lbs)	454	454	456	452	6.3
Daily gain, lb/d					
Day 0-14	2.93[ab]	2.76[ab]	2.69[b]	3.44[a]	0.29
Day 0-28	2.00	1.76	1.74	2.09	0.18
DM Intake, lb/d					
Day 0 – 14	7.3[ab]	7.1[ab]	6.7[b]	7.4[a]	0.24
Day 0 – 28	9.9	10.1	10.0	10.4	0.35

[a,b] Values within a row with different superscripts differ ($P<0.01$)

Nockles et al. (1993) showed that Cu from Cu-Lysine was better retained than from $CuSO_4$ and that significant changes occurred in both Cu and Zn balance due to supplementation and stress. Eckert et al., (1999) conducted a study with crossbred ewes comparing copper sulfate to copper- proteinate fed at three levels (10, 20 or 30 ppm of diet). Although no observable Cu toxicity was measured, feeding Cu-proteinate resulted in greater ceruloplasmin activity than $CuSO_4$, but liver Cu was greater when $CuSO_4$ was fed.

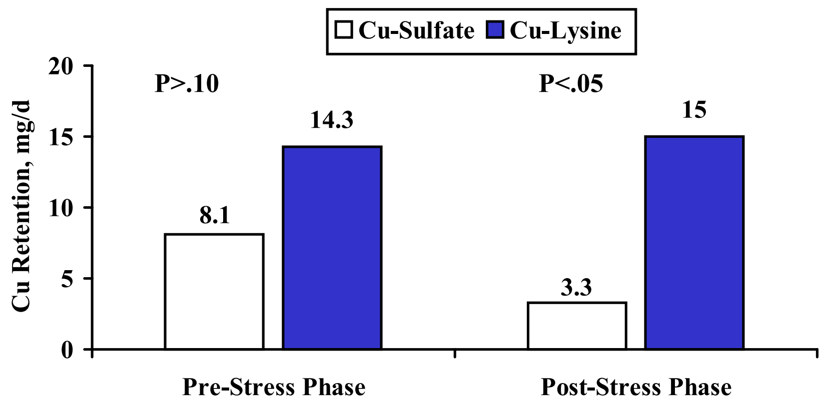
In the presence of high dietary antagonists, we have hypothesized that feeding a higher amount of Cu/day may overcome these effects. However, we also hypothesized that a combination of inorganic and amino acid complexed forms of Cu fed at a lower level may give a similar response as feeding a high level of Cu in the sulfate form. Bailey et al. (1999) conducted an experiment with growing heifers (average initial weight of 643 lbs) to determine if form and(or) level of supplemental Cu and Zn in the presence of the antagonists Mo, S and Fe influenced liver Cu level. This work was conducted to determine if increasing the level of supplemental Cu, or if a combination of inorganic and amino acid complexed-Cu sources would result in similar changes in liver Cu when animals were consuming diets high in the antagonists Mo, S and Fe. Supplemental trace mineral treatments were: 1) basal supplement with no additional Cu or Zn (Control), 2) 250 mg/d Cu and 500 mg/d Zn in sulfate form (Lo-Sulfate), 3) same as treatment 2 but 50% of the Cu and Zn were provided from amino acid complex form and 50% was from the sulfate form (2-Way), 4) same as treatment 2 but the ratios of Cu and Zn were 50% amino acid complex form, 25% sulfate-form and 25% from the oxide form (3-Way) and 5) 500 mg/day Cu and 1000 mg/day Zn in sulfate form (Hi-Sulfate).

Figure 5. Effect of Cu Supplementation Level and Form on Changes in Liver Cu When Heifers Were Fed the Mineral Antagonists Mo, S and Fe (Bailey et al., 1999)



All animals were individually fed the antagonists Mo (10 ppm), S (3,500 ppm) and Fe (450 ppm) of the daily DM intake. The diets were formulated so that the Cu:Mo ratios were .8:1 for the Control; 5:1 for the Hi-sulfate and 2.5:1 for all other diets. The basal diet was composed of chopped hay and a barley-based concentrate formulated to achieve 1.5 lb/day gain. Liver biopsies were taken on days 0, 50 and 100 and analyzed for trace minerals. Copper loss from the liver over the 100 day trial was slower ($P<.05$; Figure 5) for Cu-supplemented heifers compared to Control heifers. The rate of Cu loss was not different between the Hi-sulfate supplement vs the supplements with half the amount of supplemental Cu for the first 50-d of the experiment. But, by day 100, heifers fed the high Cu-sulfate supplement, did retain slightly more ($P<.05$) liver Cu than heifers fed the lower levels. Daily gains were not different among the treatments. In retrospect, all heifers started the experiment with more than adequate liver Cu (236 ppm). A different response may have been observed if heifers had been deficient (<60 ppm) at trial initiation. Over the 100 d study, there were no differences in liver Cu retention for the treatments in which the heifers were fed 250 mg/d supplemental Cu. Other work has shown that when animals were in a negative Cu balance due to stress, retention was significantly greater when Cu-lysine was supplemented compared with $CuSO_4$ following a repletion phase (Nockles et al., 1993; Figure 6). This work implies that Cu from Cu-lysine was metabolized differently than copper from copper sulfate. It ican be speculated whether the differences in copper retention between the Bailey et al. (1999) and the Nockles et al. (1993) studies may be a result of differences in degree of stress on the animals and(or) simply a result of differences in antagonist consumption. Nockles et al, did not feed the same high level of antagonists as did Bailey et al.

Figure 6. Influence of copper source on copper retention in calves; pre- vs post-Stress (Nockles et al., 1993)



EFFECTS OF TRACE MINERALS ON REPRODUCTION AND IMMUNITY

Reproduction. Table 9 describes effects of Cu, Zn and Mn deficiencies on the fertility of cattle. Copper, Zn and Mn have all been shown to have negative effects on reproductive efficiency. As an example of this, Doyle et al. (1988) conducted a study in which Zn, Cu and Mn supplementation were compared to no additional Cu, Zn or Mn. The average length of time from the beginning of the breeding season to conception was 22 days for trace mineral supplement treatment vs. 42 days for non-supplemented cows. Manspeaker (1987) compared no supplementation to supplementation with Cu, Zn, Mn, Fe and Mg (chelated forms) for dairy heifers. Results of this experiment are presented in Table 10.

Table 9. Review of the influence of Cu, Zn and Mn on fertility of beef cattle

Mineral	Female	Male	References
Cu	Delayed estrus Embryonic death Decreased conception Delayed puberty Decreased ovulation	Decreased libido Decreased spermatogenesis	Corah and Ives, 1991 Herd, 1994 Hidiroglou (1979) Ingraham et al., 1987 Kappel et al., 1984 Phillippo et al. 1987
Zn	Increased dystocia Abnormal estrus	Impaired growth Delayed puberty Decreased testicular size Decreased libido	Duffy et al., 1977 Mass, 1987 Apgar, 1985 Pitts et al., 1966 Puls, 1990
Mn	Increased anestrus Increased abortion Decreased ovarian activity Decreased conception rates	Increase in abnormal Sperm	Brown and Casillas, 1986 Corah and Ives, 1991 Pugh, 1985

Table 10. Influence of mineral supplementation on heifer post-partum fertility (adapted from Manspeaker, 1987).

Item	Supplemented	No Supplement
Infections Bacteria isolated from cervix & uterus, %	5	25
Ovarian activity Mature follicles 30-80 d post-partum, %	35	20
Embryonic mortality Palpated embryonic depression 35-55 d post-Insemination, %	0	20
Incidence of endometrial scarring, %	10	58
Post-partum involution and tone of pregnant horn compared to nonpregnant horn	Indistinguishable 30-35 d	Distinguishable 50-55 d

Supplementation reduced the percentage of infections, embryonic mortality, endometrial scarring and improved post-partum involution and tone of the pregnant horn. Swenson (1998) supplemented Cu, Zn, Co and Mn in either the inorganic-sulfate form or in an amino acid complex form to first calf heifers. Results from these researchers showed that even though significant structures and the percentage of cows exhibiting estrus by day 45 was lower when complexed minerals were supplemented, the percentage of cows bred by AI was improved (Table 11). In another study (Swenson, 1998), days to conception were reduced by 10 days in first calf heifers supplemented with amino acid complex forms of Cu, Zn, Mn and Co compared to sulfate forms and controls with no additional trace minerals.

Table 11. Influence of trace mineral supplementation[a] on reproduction parameters in first-calf beef heifers (Swenson, 1998)

Reproduction parameters	Control	Sulfate	Complex
Significant structures[b] by 45 d,%	86.7^{x}	88.9^{x}	50.0^{w}
Exhibited estrus[c] by 45 d,%	46.7^{xw}	66.7^{x}	27.8^{w}
Bred AI,%	46.7^{yz}	33.3^{y}	61.1^{z}

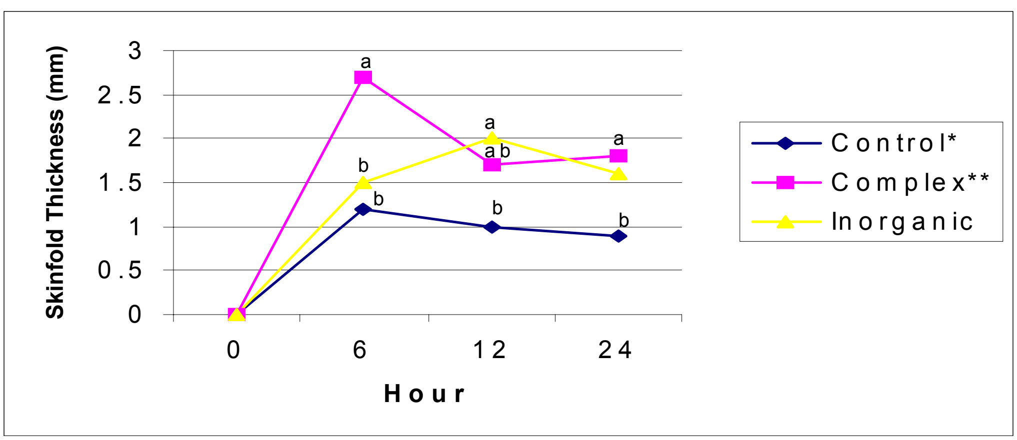
[a]Complex contained Zn methionine, Cu lysine, Co glucoheptonate and Mn methionine; Sulfate provided Zn, Cu, Co and Mn sulfate forms; and Control had no additional Zn, Cu, Co, or Mn added to supplement.
[b]Significant structures include follicles greater than 12mm and/or corpra lutea as determined by rectal palpation.
[c]The presence of a corpra lutea indicated that a heifer had exhibited estrus.
^{xw}Means in the same row with uncommon superscripts differ ($P<.05$).
^{yz}Means in the same row with uncommon superscripts differ ($P=.09$).

Ansotegui et al. (1999) utilized the same heifers (avg wt. of 700 lbs) of Bailey et al. (1999) to determine the influence of Cu and Zn supplementation on estrus, ovulation rate and fertility. Supplemental trace mineral treatments were: 1) basal supplement with no additional trace minerals; 2) basal supplement plus 250 mg/d of Cu and 500 mg of Zn/d in the sulfate form and 3) basal supplement plus an additional 250 mg/d of Cu and 500 mg/d of Zn in which 50% were in the sulfate form and 50% were amino acid complexes. The number of heifers responding to estrous synchronization and ovulating at least one ova did not differ ($P>.10$) among treatments. Heifers supplemented with the blended forms of Cu and Zn (Treatment 3) produced more ova than the control heifers, and heifers supplemented with the blended supplement or the control supplement produced more ova than the heifers fed the supplement containing Cu and Zn in the sulfate form (Treatment 2). Numbers of embryos did not differ ($P>.10$) between the control and blended supplement treatments, but were higher ($P<.05$) than for the sulfate-only supplemented heifers.

Phillipo et al. (1987) conducted two heifer studies with barley grain- straw based diets containing 4 ppm Cu and 5 ppm Mo (.80:1 Cu:Mo ratio). Molybdenum supplementation resulted in the delayed onset of puberty, decreased conception rate and caused anestrus in cattle without accompanying changes in Cu status or in live-weight gain. It was proposed that the effects of Mo were associated with a decreased release of luteinizing hormone that might be due to an altered ovarian steroid secretion. Earlier work by Case et al. (1973) found that cattle grazing pasture on soil with an elevated Mo content had reduced fertility while Peterson and Waldern (1977) described a negative association between the Cu:Mo ratio of silage and fertility in dairy herds in Canada.

Immunity. Trace mineral requirements are determined largely by animal growth or reproductive response and not by the ability of the immune system to respond to a challenge. There is increasing evidence that the concentrations of trace elements required for healthy animals are often below what is required for animals experiencing an immunological challenge (Berger, 1997; Beisel, 1982.). Research (Stabel et al., 1993) has indicated that Cu deficiency affects various physiological characteristics that may be important in immunological defense to pathogenic challenge. Woolliams et al. (1986) showed that Cu supplementation affected the resistance of sheep to bacterial infections. Genglebach and Spears (1998) showed that when Mo was supplemented to a diet containing adequate Cu, no differences were apparent in plasma or liver Cu. However, calves fed Mo had a more severe Cu deficiency based on depressed humoral-immune response and super-oxide dismutase activity. In another study, Ward and Spears (1999) concluded that Cu deficiency and 5 ppm Mo in the diet did not dramatically alter the specific immunity of stressed cattle. Genglebach et al. (1997) showed that when diets were marginally deficient in Cu with supplemental Fe, Mo added, body temperature and feed intake responses to disease were affected. Ward et al. (1997) concluded that Cu deficiency and Cu deficiency coupled with high dietary Mo or Fe intake produced inconsistent immune function responses, indicating at Cu deficiency may not affect specific immune function in calves. Ansotegui et al (1994; Figure 7) found that cell mediated immune response was faster and significantly higher when complexed-forms of Cu, Zn, Co and Mn were fed compared to sulfate forms of the same minerals or to cows which were not supplemented. This study was conducted with out additional antagonists added to the diet. Subsequent responses have been much more variable when antagonists have been provided.

Figure 7. Effects of Mineral Supplementation on Skinfold Thickness at 6, 12 and 24 hr Post Injection with PHA-P (Ansotegui et al., 1994).



Zinc methionine, manganese methionine, copper lysine and cobalt glucoheptonate
**Sulfate forms fed in equal amounts to organic treatment
[a,b] (P<0.01)

Zinc has been shown to have a positive impact on immunity in stocker and feedlot cattle with limited research in beef cows. Weaned calves normally experience stress due to transportation, changes in feed and handling, which increase susceptibility to infectious diseases. During this period of stress, providing adequate dietary Zn may be critical, because stress has been shown to have a negative impact on Zn retention (Nockels et al., 1994). Infection can also have a detrimental effect on Zn status in cattle. Infecting cattle with a bovine rhinotracheitis challenge increased urinary Zn excretion which caused a negative balance (Orr et al., 1990). Feed intake is often depressed when feeder cattle are stressed and the reduction in intake results in a decrease of trace minerals ingested. Supplying Zn to steer calves which had undergone stress (weaning, transportation, exposure to new cattle and vaccination) was shown to increase feed intake (Spears and Kegley, 1991) while Chirase et al., (1991) showed that dietary Zn enhanced the recovery rate of IBR-stressed cattle.

SUMMARY

Data from MT, TX and AR indicate that copper and zinc can be deficient in many of the forages cattle consume. Coupled with the antagonistic effects of Mo and S, this may require additional supplementation with copper because it would also appear that there are a fairly large number of cows who are deficient to marginal in liver Cu and Mn stores. Experimental results do suggest that single trace element supplementation can be antagonistic (e.g. excessive Zn depressing liver Cu stores) or symbiotic (Cu and Zn both supplemented). Supplemental trace minerals have been shown to have positive effects on reproduction, immune status, disease resistance and feed intake of incoming feeder cattle. Although the data is somewhat variable among experiments, it has been shown that complexed minerals are more available than inorganic minerals and have application in the presence of dietary antagonists, and(or) when the animal is under stress. Our present field recommendations have been to use a blend of inorganic-organic minerals in front of an expected stress (calving to breeding and pre-weaning) and then use an inorganic based trace mineral supplement the rest of the year. This approach is only part of a program to provide balanced nutrition with emphasis on supplying adequate protein, energy and trace minerals to prevent loss of beef cattle productivity. It is our opinion that providing adequate nutrition prior to expected stress can result in reduced morbidity of beef cattle; trace mineral supplementation is an important part of this management approach.

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