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# Effect of Pasture Trace Mineral Supplementation on Liver Mineral Levels and Feedlot Morbidity and Mortality

**D. M. Grotelueschen,** *DVM, MS, University of Nebraska, Panhandle Research & Extension Center, Scottsbluff, NE 69361*
**A. Wohlers,** *DVM, Pioneer Animal Clinic, Scottsbluff, NE 69361*
**C. Dewey,** *DVM, PhD, University of Nebraska, Great Plains Veterinary Education Center, Clay Center, NE 68933*
**I.G. Rush,** *PhD, University of Nebraska, Panhandle Research & Extension Center, Scottsbluff, NE 69361*
**W. E. Braselton,** *PhD, Michigan State University, College of Veterinary Medicine, E. Lansing, MI 48909-7576*
**D. Hamar,** *PhD, Colorado State University, Fort Collins, CO 80523*
**A. B. Johnson,** *PhD, Zinpro Corporation, Eden Prairie, MN 55344*
**J. H. Pollreisz,** *DVM, Pfizer Animal Health, Exton, PA 19341*

**Abstract**

A study was conducted to determine morbidity and mortality in feedlot calves fed inorganic or organic trace mineral supplements prior to feedlot entry. The specific objectives of this study were to determine if there were differences in trace mineral levels in livers from cows supplemented with one of three mineral mixes during the summer grazing period, and to determine if there were differences in trace mineral levels in livers from calves nursing cows supplemented with and having access to one of three mineral mixtures during the summer grazing period. Three treatments had varied sources of zinc, copper, manganese and cobalt. These included a control mineral (CM) which was a salt/dicalcium phosphate-based mixture with no added copper, manganese, zinc or cobalt; a metal-complex mineral (MCM) which had added metal-complexed copper, manganese, zinc and cobalt; and a sulfate-based mineral (SBM) which was an inorganic mixture with added sulfate-based copper, manganese, zinc and cobalt. The sulfate-based micronutrients were incorporated at twice the level of metal-complexed micronutrients.

The 641 cow/calf pairs were allotted to nine pastures with cattle in each of the pastures receiving one mineral treatment during the grazing season. Intake of supplemented mineral was monitored and mineral content of forage and water was determined. Fall liver biopsy results showed higher liver copper concentrations in cows supplemented with MCM and SBM compared to CM, and higher liver zinc concentrations in MCM cows compared to CM cows. Fall calf liver analyses showed differences in copper, manganese, sulfur and zinc levels between groups. Calves from cows in the MCM and SBM treatment groups had higher liver copper levels than calves from the cows receiving CM.

Trace mineral supplementation appears to enhance response to *Mannheimia (Pasteurella) haemolytica* vaccination as measured by capsular ELISA and whole cell agglutination tests; however, no differences in leukotoxin neutralization test results were detected. No differences in response to viral vaccines were found. While there were no differences in feedlot mortality, feedlot morbidity was influenced by mineral treatment. Sick incident rates, tabulations of first-time treatments, retreats and repulls statistically favored the MCM group, with 49.0% and 56.9% fewer sick incidents than calves from the CM and SBM groups, respectively. Overall, cattle in the MCM group were treated fewer times.

**Résumé**

Une étude a été menée pour déterminer la morbidité et la mortalité de veaux de parcs d'engraissement nourris avec des suppléments oligo-minéraux organiques ou inorganiques avant leur arrivé au parc. Les objectifs plus particuliers de l'étude étaient de voir si des différences existaient dans les niveaux d'oligo-minéraux du foie chez des vaches recevant en supplément l'un de trois mélanges minéraux durant la saison de pâturage estivale et de voir si des différences existaient dans les niveaux d'oligo-minéraux chez les veaux allaités par des vaches recevant l'un des trois mélanges alimentaires supplémentaires pendant la période de pâturage estivale. Les trois mélanges étaient composés de sources variées de zinc, cuivre, manganèse et cobalt. Ces traitements incluaient une source minérale témoin (CM) qui consistait en un mélange à base de sel/ phosphate bicalcique sans addition de cuivre, manganèse, zinc ou cobalt; une source minérale à base de complexe métallique (MCM) avec des complexes métalliques de cuivre, manganèse, zinc et cobalt et enfin une source minérale à base de sulfate (SBM) consistant en un mélange inorganique auquel était ajouté du cuivre à base de sulfate, du manganèse, du zinc et du cobalt. Les micro nutriments à base de sulfate ont été incorporés à un taux deux fois plus élevé que les micro nutriments à base de complexe métallique.

Les 641 paires vaches/veaux ont été assignées à neuf champs avec des animaux dans chacun des champs traités avec les minéraux durant la saison du pâturage. La prise du supplément minéral a été suivie et le contenu minéral des aliments et de l'eau a été déterminé. Les résultats de biopsies du foie en automne montraient des niveaux plus élevés de cuivre chez les vaches qui avaient reçu les suppléments MCM et SBM que chez celles qui avaient reçu le supplément CM et des niveaux plus élevés de zinc chez les vaches du traitement MCM que chez celles du traitement CM. L'analyse du foie chez les veaux en automne montraient des différences au niveau du cuivre, du manganèse, du soufre et du zinc entre les groupes. Les veaux des vaches recevant le traitement MCM et SBM avaient des niveaux plus élevés de cuivre dans le foie que ceux des vaches recevant le traitement CM.

L'ajout d'oligo-minéraux semble améliorer la réaction à la vaccination contre *Mannheimia (Pasteurella) haemolytica* comme l'indique le test ELISA capsulaire et le test d'agglutination à cellules entières. Toutefois, des différences au niveau du test de neutralisation de la leucotoxine n'ont pas été détectées. Aucune différence n'a été détectée au niveau de la réaction aux vaccins antiviraux. Bien qu'il n'y avait pas de différence au niveau de la mortalité dans le parc d'engraissement, la morbidité était influencée par le traitement. Les cas de maladies et la compilation du nombre de traitements pour la première fois, du nombre de réadministration de traitements et de retrait, indiquent que les animaux du groupe MCM ont mieux réagi que ceux des groupes CM et SBM. Les animaux du groupe MCM montraient 49.0% et 56.9% moins de cas de maladies que les animaux des groupes CM et SBM, respectivement. Dans l'ensemble, les animaux du groupe MCM étaient traités moins souvent.

## Introduction

Development of healthy, immunocompetent weaned beef calves is important for successful transition to the feedlot. The beef industry as a whole benefits from lower disease incidence. Nutrition can significantly affect the health of feedlot cattle.

Trace minerals are essential for many body functions. Deficiencies are manifested by numerous clinical signs, but are often initially subclinical.[3,7,24] There is evidence that levels of trace minerals required for adequate immune responses may be higher than the current recommended feeding levels, especially during periods of stress.[2,13,15] Trace mineral deficiencies can have negative effects on immune system function and animal health. For example, copper deficiency adversely affects both cell-mediated and humoral immunity.[10,12,17] Zinc supplementation has enhanced antibody titers from vaccination with infectious bovine rhinotracheitis (IBR) virus,[22] while higher IBR and parainfluenza ($PI_3$) virus antibody titers have been reported in calves supplemented with an organic zinc, manganese, copper and cobalt mixture.[6] This study also reported a reduced incidence of respiratory disease in cattle fed organic minerals at levels above those recommended by the National Research Council (NRC).[14] Supplementation with organic minerals has improved humoral and cell-mediated immune function as compared to supplementing with inorganic minerals.[6] Feeding higher levels of zinc and feeding copper lysine has resulted in improved health of newly weaned beef steers.[5] Bioavailability of feed-grade mineral sources is influenced by the source of the micronutrient supplemented.[11]

Cattle may not have adequate trace mineral intake prior to arrival in the feedlot. An analysis of forages from18 states found that only 2.5% of samples had adequate zinc, 36% had adequate copper, 34% had adequate cobalt, 19.7% had adequate selenium and 76% had adequate manganese.[4] Data also indicate that liver samples from cattle arriving at feedlots frequently have marginal or deficient copper levels.[8,18] Supplying proper trace mineral levels prior to feedlot entry could decrease morbidity and mortality caused by bovine respiratory disease (BRD).

A study was conducted to determine the effect of supplementation with either inorganic or organic trace mineral supplements prior to feedlot entry. The specific objectives of this study were: 1) to determine if there were differences in trace mineral levels in livers from cows supplemented with one of three mineral mixtures during the summer grazing period, and 2) to determine if there were differences in trace mineral levels in livers from calves nursing cows supplemented with and having access to one of three mineral mixtures during the summer grazing period. Rate of gain, serological responses, and feedlot morbidity and mortality were also measured.

## Materials and Methods

Three mineral supplements were formulated with varied sources and levels of zinc, copper, manganese and cobalt. These included a control mineral (CM) which was a salt/dicalcium phosphate-based mixture with no added copper, manganese, zinc or cobalt; a metal-complex mineral (MCM) which had added metal-complexed copper, manganese, zinc and cobalt;[a] and a sulfate-based inorganic mineral (SBM) with added sulfate-based copper, manganese, zinc and cobalt. The SBM micronutrients were incorporated at twice the level of MCM micronutrients (Table 1) because of differences in bioavailability. With the exception of the mineral supplier, all personnel were unaware of the composition of mineral treatments throughout the study.

The mineral treatments were provided in covered mineral feeders placed near sources of water. A maximum of 75 cow/calf pairs was allocated per feeder. Feeder design allowed access by both cows and calves. Four lots of each mineral mix were manufactured during the trial and each was analyzed individually for accuracy of formulation. Mineral was fed and intake was monitored and recorded by one person approximately twice weekly. The three mineral treatments were assigned to three pastures each according to geographical proximity and anticipated carrying capacity of the nine similar pastures located on one western Nebraska ranch.

**Table 1.** Mineral formulation specifications.

| | Control | Metal complex | Sulfate-based |
|---|---|---|---|
| Molasses, % | 5 | 5 | 5 |
| Mineral oil,[1] % | 1 | 1 | 1 |
| Yeast culture, % | 5 | 5 | 5 |
| Salt, % | 30 | 30 | 30 |
| Calcium, % | 9-11 | 9-11 | 9-11 |
| Phosphorus, % | 10 | 10 | 10 |
| Zinc, mg/kg (%) | ≈0 | 4233 (.422) | 8380 (.839) |
| Copper, mg/kg (%) | ≈0 | 1367 (.145) | 2350 (.235) |
| Manganese, mg/kg (%) | ≈0 | 2337 (.233) | 4740 (.474) |
| Cobalt, mg/kg (%) | ≈0 | 298 (.029) | 670 (.067) |
| Potassium, % min | 1.0 | 1.0 | 1.0 |
| Sulfur, % min | .05 | .05 | .05 |
| Magnesium, % min | 3.0 | 3.0 | 3.0 |
| Iodine, mg/kg | 100 | 220 | 220 |
| Selenium, mg/kg | 15 | 33 | 33 |
| Vit. A, min, IU | 100,000 | 100,000 | 100,000 |
| Vit. D, | 23,000 | 23,000 | 23,000 |
| Vit. E, | 100 | 100 | 100 |

[1]As needed for quality - dust control

Forage clippings were collected during early, mid- and late summer grazing dates (June 3, July 13 and September 17, respectively). Forage samples were collected from multiple sites in each pasture, and were individually analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES).[23] The multi-elemental analyses of forage samples were done by simultaneous/sequential ICP-AES, modified by digestion of 1 gm forage samples in triplicate with 5 ml $HNO_3$ each, and diluted to 25 ml. Quality control of forage analysis was done by concurrent analysis of NIST Citrus Leaves SRM 1572.

Because of summer drought, supplemental feeding of a beet pulp and ground hay mixture was required in two control pastures from August 4 through weaning. This mixture was fed on the ground at an average daily rate of 24.5 lb of dry matter per cow/calf pair. Analyses were done on the supplemental ration by ICP-AES. Supplemental feeding was not needed in the remaining seven pastures. Water samples from all pumped and surface water sources were taken on June 3 and analyzed by ICP-AES.

The 641 cows used in this study were 10-13 years of age, and had been obtained from one source. The cow/calf pairs were sorted and allotted according to anticipated carrying capacity of each pasture. The three CM pastures had 171 cow/calf pairs (80, 38 and 53 pairs), the three MCM pastures had 240 cow/calf pairs (110, 40 and 90 pairs) and the three SBM pastures had 230 cow/calf pairs (120, 60 and 50 pairs).

A subset group of 90 cow/calf pairs was selected during spring processing of the cow herd. The number of cows going to each pasture was divided by 10, and the quotient was used as the predetermined interval to select cows passing through the processing chute. Ten pairs of the subset group were distributed to each of the nine pastures using this systematic sampling method.[21] Cows and calves to be biopsied were randomly selected from this subset group, using a predetermined order by drawing numbers to identify cows in a group of 10 from each pasture for liver biopsy. Weight gain, serology, morbidity and mortality, and additional liver biopsy data were collected from these animals. Whole blood for selenium analysis and liver biopsies were collected from 39 cows (12 cows from the CM group, 13 cows from the MCM group and 14 cows from the SBM group) on May 9.[9] The number of animals selected was based on statistical power calculations. Trace mineral concentrations in liver biopsies were determined by ICP/AES interfaced with an ultrasonic nebulizer.[1] Blood selenium was determined by atomic absorption spectrophotometry with hydride generation.[16,20]

Branding and castration were done in mid-May. A 7-way clostridial/*Haemophilus somnus* bacterin/toxoid[b] was administered to all calves at that time.

[a]4-Plex, Zinpro Corp., Eden Prairie, MN 55344

[b]Ultrabac 7/Somubac, SmithKline Beecham Animal Health, Exton, PA 19341

**Table 2.** Trace element content of mean forages by treatment group (dried basis; ppm).*

| Element | NRC req.[14] | Control(CM) Grass clippings Early | Mid | Late | Supplemental ration** | Metal complex(MCM) Grass clippings Early | Mid | Late | Sulfate-based(SBM) Grass clippings Early | Mid | Late |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cobalt | 0.10 | <.500 | <.500 | <.500 | <.500 | <.500 | <.500 | <.500 | <.500 | <.500 | <.500 |
| Copper | 10.0 | 4.3 | 3.4 | 3.3 | 5.2 | 3.5 | 3.4 | 2.5 | 3.3 | 3.2 | 3.0 |
| Manganese | 40.0 | 37.5 | 38.7 | 50.8 | 64.4 | 42.5 | 34.2 | 65.5 | 36.2 | 33.1 | 53.9 |
| Molybdenum | - | <1.14 | <1.00 | <1.00 | <1.00 | <1.32 | <1.00 | <1.93 | <1.00 | <1.00 | <1.00 |
| Selenium | 0.10 | <20.0 | <20.0 | <10.0 | <10.0 | <20.0 | <20.0 | <10.0 | <16.7 | <20.0 | <10.0 |
| Zinc | 30.0 | 15.8 | 15.2 | 13.1 | 24.9 | 13.4 | 12.4 | 13.6 | 13.0 | 15.9 | 14.2 |

*Analysis done by ICP/AES.
**Began feeding August 4 in 2 control pastures.

Cow/calf pairs were moved to pasture during the week of May 29, and mineral feeding was initiated on June 4. Fecal samples for flotation were collected at the time of grass sampling on June 3, July 13 and September 17, and examined using the Modified Wisconsin Technique. Results were recorded subjectively using a score of 1-4, with 4 being the heaviest ova concentration. Data pertaining to animal movement, losses and marketings were recorded.

Preweaning vaccinations, including a 7-way clostridial/*Haemophilus somnus* bacterin-toxoid,[b] a combination chemically altered infectious bovine rhinotracheitis (IBR), killed bovine viral diarrhea (BVD), chemically altered parainfluenza-3 ($PI_3$), modified-live bovine respiratory syncytial virus (BRSV) vaccine[c] and a *Mannheimia (Pasteurella) haemolytica*[d] bacterin-toxoid, were administered when calves in each pasture were processed between September 1 and September 7. Prevaccination serum samples were collected for serology from the subset of 90 calves at that time.

Weaning was done September 19-25 in the same pasture order as for preweaning vaccinations. At that time, a second liver biopsy and whole blood sample for selenium analysis were collected from the same cows (12 cows per treatment group) initially sampled in the spring, however three of the original 39 cows had lost ear tags and could not be identified. Liver biopsies were performed on 41 calves at weaning, which included calves from biopsied cows and additional calves from the subset of 90 calves; 12 from the CM group, 15 from the MCM group and 14 from the SBM group. A combination modified-live virus (MLV) IBR, BVD, $PI_3$ and BRSV[e] vaccine was given intramuscularly at weaning. Serum from calves for serology and whole blood from calves for selenium analysis were collected at that time. Individual weaning weights for the subset of 90 calves and group weaning weights for all calves were also recorded.

Calves (618) were placed into three commercial feedlot pens located on the ranch premises immediately after weaning. The number of calves placed in the feedlot was less than placed on pasture due to marketing of animals, straying from pastures and death loss. Each feedlot pen received calves from three pastures; one each from CM, MCM and SBM pastures as calves were weaned. The same receiving and finishing ration was fed to all pens of calves. The finishing ration was composed of corn, corn silage, beet pulp and alfalfa hay.

Individual weights of the subset of 90 calves were taken and recorded on October 26 (31 to 37 days postweaning) when calves were administered injectable ivermectin[f] and an implant. Serum samples were collected at the same time.

All sera, including those obtained at preweaning, weaning and postweaning, were harvested, frozen and stored following collection. All sera were subsequently submitted to the respective laboratories as a batch for analysis.

Health records were maintained during the entire feeding period. Calves were checked daily for signs of sickness by trained feedlot personnel. Calves were removed from the pen and treated (first-time treatment) if they showed clinical signs of illness, including coughing, de-

[c]Cattlemaster 4, SmithKline Beecham Animal Health, Exton, PA 19341
[d]One Shot, SmithKline Beecham Animal Health, Exton, PA 19341
[e]Bovishield 4, SmithKline Beecham Animal Health, Exton, PA 19341
[f]Ivomec, 1% Injection, Merial Limited, Iselin, NJ 08830

pression, anorexia, gauntness and fever. Those which required a second treatment more than three days after initial treatment and remaining in the recovery pen, or if returned to the home pen and removed for treatment in less than 14 days, were classified as retreats. Cattle which had received a first-time treatment, retreatment, and then needing another treatment 14 days or more after having been returned to the home pen were classified as a repull.

### Statistical Analysis

All analyses were done using PC/SAS.[19] The overall and within treatment group mean, standard deviation and minimum and maximum levels of the following parameters were described: mineral levels in the livers of calves and cows; blood selenium levels of calves and cows; mineral levels in the pastures and water; consumption of trace minerals per cow/calf pair; weaning weights for individual subsets of calves and group weights for all calves in the study; serological titers for IBR, BVD, BRSV and *M. haemolytica;* and postweaning morbidity and mortality rates by treatment group. Student's T-tests were used to determine differences in liver biopsy values between groups and to detect differences in average daily gain between mineral treatment groups. Chi-square tests were used for detecting differences in morbidity and mortality between mineral treatment groups and to detect differences in the efficacy between long-acting oxytetracycline[g] and tilmicosin[h] used to treat cattle with BRD. Analysis of variance (ANOVA) was used to detect differences in titers against IBR virus, BVD virus, BRSV and *M. haemolytica* between mineral treatment groups within samples. Paired T-tests were used to detect differences between samples within mineral treatment groups for IBR virus, BVD virus, BRSV and *M. haemolytica* titers. These tests also were used to detect any mineral level differences in cow livers that may have occurred between spring and fall.

### Results

Mineral content of the forages is shown in Table 2. Forage mineral content from each pasture taken at different times during the grazing season was comparable. The analyses showed copper and zinc concentrations to be consistently lower than levels recommended by the NRC.[14] Additionally, manganese levels tended to be low at times. Molybdenum levels occasionally rose above the minimum detectable level of 1.00 ppm. Results of water analyses are presented in Table 3.

Mean mineral consumption was 153 gm/unit/day in the CM group, 114 gm/unit/day in the MCM group and 113 gm/unit/day in the SBM group. A unit was defined as a cow/calf pair or bull. The daily consumption of cobalt, copper, manganese and zinc from mineral was lower in the MCM group than in the SBM group (Table 4).

Analysis of initial liver biopsies revealed no statistical differences in liver mineral content between groups, except for higher manganese levels found in the SBM group (Table 5). Significant differences were found, however, in the analysis of liver biopsies done in the fall. Fall liver copper concentrations were higher in the MCM and SBM groups of cows as compared to the CM group. In addition, MCM cows had higher fall liver zinc concentrations than CM cows. There were no differences, however, between treatment groups for liver manganese levels in the fall. Blood selenium analyses showed that cows in the CM group had higher blood selenium levels

**Table 3.** Mean trace element content of water (ppm).*

| Element | Control group | Metal complex | Sulfate-based |
|---|---|---|---|
| Cobalt | <0.010 | <0.010 | <0.010 |
| Copper | <0.005 | <0.005 | <0.011 |
| Iron | 0.053 | <0.055 | <0.075 |
| Manganese | <0.005 | <0.005 | <0.009 |
| Molybdenum | <0.020 | <0.020 | <0.020 |
| Selenium | <0.100 | <0.100 | <0.100 |
| Sulfur | 8.06 | 10.20 | 8.59 |
| Zinc | <.011 | 0.023 | <0.106 |

* Analysis done by ICP/AES.

**Table 4.** Mean daily unit* intake of trace elements by treatment groups.

| | Control | Metal complex | Sulfate-based |
|---|---|---|---|
| Salt, mg | 45,850 | 34,250 | 33,875 |
| Calcium, min, mg | 13,755 | 10,275 | 10,163 |
| Phosphorus, mg | 15,283 | 11,417 | 11,292 |
| Zinc, mg | ≈0 | 482 | 947 |
| Copper, mg | ≈0 | 166 | 265 |
| Manganese, mg | ≈0 | 266 | 535 |
| Cobalt, mg | ≈0 | 33 | 76 |
| Potassium, min, mg | 1,528 | 1,142 | 1,129 |
| Sulfur, min, mg | 76 | 57 | 56 |
| Magnesium, min, mg | 4,585 | 3,425 | 3,388 |
| Iodine, mg | 34 | 25 | 25 |
| Selenium, mg | 5 | 4 | 4 |
| Vit. A, min, IU | 33,694 | 25,169 | 24,894 |
| Vit. D, IU | 7,750 | 5,789 | 5,726 |
| Vit. E, IU | 34 | 25 | 25 |

*Unit is defined as a cow/calf pair or bull.

[g]Liquamycin LA-200, Pfizer Animal Health, Exton, PA 19341
[h]Micotil 300, Elanco Animal Health, Indianapolis, IN 46285

**Table 5.** Trace element content of liver biopsies* and blood selenium levels** from cows and calves sampled at various times.

| Elements (ppm dry wt) | Control Mean | Control Range | Control Std dev | Metal complex Mean | Metal complex Range | Metal complex Std dev | Sulfate-based Mean | Sulfate-based Range | Sulfate-based Std dev |
|---|---|---|---|---|---|---|---|---|---|
| **Copper** | | | | | | | | | |
| Spring cow | 38.7[a] | 14.1-82.0 | 21.15 | 45.0[a] | 5.7-134.0 | 35.57 | 28.1[a] | 5.7-70.5 | 15.13 |
| Fall cow | 88.4[a] | 31.3-145.0 | 39.98 | 187.0[b] | 91.1-392.0 | 96.00 | 176.0[b] | 134.0-253.0 | 39.54 |
| Fall calf | 60.6[a] | 23.3-125.0 | 32.10 | 216[b] | 34.4-578.0 | 153.86 | 106[c] | 37.1-189.0 | 43.48 |
| **Manganese** | | | | | | | | | |
| Spring cow | 11.5[a] | 9.1-14.1 | 1.42 | 11.3[a] | 8.0-13.6 | 1.99 | 13.0[b] | 10.9-17.6 | 1.68 |
| Fall cow | 8.1[a] | 6.4-18.3 | 1.11 | 9.1[a] | 7.1-10.9 | 1.44 | 8.6[a] | 7.1-10.8 | 0.95 |
| Fall calf | 7.5[a] | 6.3-9.4 | 0.90 | 8.7[b] | 6.4-11.5 | 1.29 | 8.5[b] | 7.0-10.0 | 0.94 |
| **Molybdenum** | | | | | | | | | |
| Spring cow | 2.7[a] | 2.1-3.4 | 0.42 | 2.8[a] | 1.6-3.4 | 0.52 | 2.7[a] | 1.9-3.8 | 0.52 |
| Fall cow | 3.2[a,b] | 1.2-3.7 | 0.45 | 3.1[a] | 2.5-3.7 | 0.40 | 3.5[b] | 3.0-4.2 | 0.37 |
| Fall calf | 2.9[a] | 2.0-3.7 | 0.50 | 3.2[a] | 2.4-3.7 | 0.39 | 3.1[a] | 2.3-4.0 | 0.50 |
| **Sulfur** | | | | | | | | | |
| Spring cow | 7831[a] | 6740-8570 | 545.55 | 7679[a] | 6730-8400 | 553.90 | 7854[a] | 6980-8190 | 348.66 |
| Fall cow | 8158[a] | 7530-8710 | 364.00 | 8089[a] | 7520-8860 | 383.25 | 8432[b] | 7820-9150 | 354.01 |
| Fall calf | 7932[a] | 7550-8240 | 251.46 | 8243[b] | 7730-9030 | 406.19 | 8301[b] | 7180-8780 | 386.07 |
| **Zinc** | | | | | | | | | |
| Spring cow | 179[a] | 78-193 | 243.45 | 114[a] | 94-158 | 18.08 | 110[a] | 84-206 | 30.97 |
| Fall cow | 292[a] | 198-432 | 56.65 | 375[b] | 244-532 | 77.10 | 327[a,b] | 233-511 | 86.61 |
| Fall calf | 268[a] | 221-360 | 44.88 | 405[b] | 308-534 | 62.38 | 294[a] | 193-541 | 92.57 |
| **Selenium** (blood) | | | | | | | | | |
| Spring cow | 0.31[a] | 0.24-0.39 | 0.04 | 0.31[a] | 0.23-0.38 | 0.04 | 0.31[a] | 0.25-0.42 | 0.05 |
| Fall cow | 0.26[a] | 0.17-0.39 | 0.07 | 0.18[b] | 0.09-0.28 | 0.07 | 0.20[b] | 0.14-0.28 | 0.05 |
| Fall calf | 0.24[a] | 0.15-0.31 | 0.06 | 0.21[a] | 0.16-0.31 | 0.05 | 0.20[a] | 0.16-0.23 | 0.02 |

*Michigan State University, by ICP-AES
**Colorado State University
[a,b,c]Within a row, mean values with different superscripts differ significantly ($p<0.05$).

than the other treatment groups. Cows in the SBM group had higher liver molybdenum levels than those in the MCM group.

Spring to fall changes in liver element concentrations occurred within each treatment group (Table 5). In the CM group, there was significant ($p<0.05$) spring to fall changes in copper, manganese and blood selenium. In the MCM group, significant ($p<0.05$) changes occurred in copper, zinc and blood selenium levels. Significant ($p<0.05$) changes in copper, manganese, zinc and blood selenium concentrations occurred in the SBM group.

Spring to fall changes in liver element concentrations and blood selenium also occurred between treatment groups of cows. Cows in both the MCM and SBM groups had greater changes ($p<0.05$) in liver copper concentration than those in the CM group. Cows in the MCM group had less of a decrease ($p<0.05$) in liver manganese levels than those in the SBM group. The MCM group showed a larger decrease ($p<0.05$) in blood selenium than the CM group.

Analysis of fall calf liver biopsies showed differences in copper, manganese, sulfur or zinc concentrations between groups (Table 5). Calves in the MCM group had higher ($p<0.05$) liver copper levels than those in the SBM and the CM groups, and the SBM group had higher levels of liver copper than the CM group ($p<0.05$). Copper levels in the MCM group were more than three times greater than those of the CM group, while levels in the SBM group were nearly twice those of the CM group. Standard deviations within groups were quite high. Calves in both the MCM and SBM groups had higher ($p<0.05$) liver manganese than the CM group. Zinc concentrations in livers of calves in the MCM group were significantly higher than those in the CM and the SBM group ($p<0.05$).

The average weaning weight of all calves was 422 lb (191.8 kg), 400.8 lb (182.2 kg) and 438.9 lb (199.5 kg) for the CM, MCM and SBM treatment groups, respectively. However, follow-up weights for all calves were not collected due to logistical difficulties. Instead, average daily gain of the subset of 90 calves was determined for the five-week postweaning period. Calves in the CM group gained an average of 1.86 lb (0.845 kg) per day, which was significantly higher than gain of calves in both the MCM group 1.27 lb (0.577 kg; p=0.0198) and the SBM group 1.18 lb (0.536 kg; p=0.0031).

Results of *M. haemolytica* serological tests, including leukotoxin neutralization, capsular ELISA and whole cell agglutination, are shown in Table 6. Leukotoxin neutralization assays revealed no differences in titers between treatment groups, however, within groups there were mean titer increases during preweaning to weaning, preweaning to postweaning and weaning to postweaning periods ($p<0.05$).

Capsular ELISA titers were higher in the SBM group as compared to those in the CM and MCM groups at preweaning (Table 6). Calves in the SBM group also had higher titers than those in the CM group at weaning. There were increases in capsular ELISA titers for all groups during all periods, but no differences between any groups at postweaning.

Whole cell agglutination test results between groups differed at preweaning and weaning, where calves in both the MCM and SBM treatment groups had higher titers than calves supplemented with the CM. There were no differences between groups postweaning. Within-mineral treatment comparisons showed increases in titers in all groups for all time periods (Table 6).

Preweaning viral serum neutralizing antibody titers showed that a high percentage of calves were serologically naive. Of calves tested preweaning, 70.8, 24.7 and 85.4% of calves were negative to IBR virus, BVDV and BRSV, respectively. Seronegative animals were defined as those having titers of 1:2 or less. Seroconversion was defined as an increase in an initial titer of 1:2 or less to 1:4 or greater, or a fourfold or greater increase when two samples from the same calf were compared. For example, a calf with an initial titer of 1:2 and a subsequent titer of 1:4 was considered to have seroconverted. There were no group differences in the percentage of calves seroconverting during the preweaning to weaning (19 days), preweaning to postweaning



**Table 6.** Serological response at various time intervals to vaccination with a Mannheimia (Pasteurella) bacterin-toxoid.*

| | Leukotoxin Neutralization | | | Capsular ELISA | | | Whole Cell Agglutination | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of head | Mean titer | Std dev | No. of head | Mean titer | Std dev | No. of head | Mean titer | Std dev |
| **Preweaning** | | | | | | | | | |
| Control mineral | 29 | 4.05[a] | 5.63 | 29 | 50.86[a] | 48.86 | 29 | 13.10[a] | 6.92 |
| Metal-complex mineral | 29 | 4.94[a] | 3.78 | 29 | 134.48[a] | 289.66 | 29 | 23.17[b] | 25.67 |
| Sulfate-based mineral | 30 | 7.33[a] | 11.32 | 30 | 487.50[b] | 883.56 | 30 | 40.93[b] | 55.06 |
| **Weaning** | | | | | | | | | |
| Control mineral | 30 | 12.45[a] | 13.11 | 30 | 447.50[a] | 520.54 | 30 | 31.20[a] | 26.10 |
| Metal-complex mineral | 29 | 9.70[a] | 8.32 | 29 | 737.07[a,b] | 877.36 | 29 | 101.79[b] | 102.72 |
| Sulfate-based mineral | 29 | 12.85[a] | 13.70 | 29 | 951.72[b] | 1123.25 | 29 | 140.97[b] | 168.78 |
| **Postweaning** | | | | | | | | | |
| Control mineral | 29 | 42.14[a] | 32.06 | 29 | 2641.38[a] | 1038.38 | 29 | 201.93[a] | 152.05 |
| Metal-complex mineral | 30 | 39.80[a] | 33.07 | 30 | 2413.33[a] | 1083.97 | 30 | 167.20[a] | 108.16 |
| Sulfate-based mineral | 30 | 46.53[a] | 41.24 | 30 | 2786.67[a] | 869.30 | 30 | 190.93[a] | 102.40 |

*Conducted by Pfizer Animal Health

[a,b]Within a column, within a section (i.e., preweaning, weaning, postweaning) mean values with different super scripts differ significantly ($p<0.05$).

(about 54 days) and weaning to postweaning (about 35 days) time intervals (Table 7). Additionally, there were no differences between groups for mean viral titers (Table 8). Group IBR and BVD titers tended to decrease from the preweaning to weaning period, and increase from the weaning to postweaning period, while the mean BRSV titers tended to increase in both the preweaning to weaning and the weaning to postweaning periods.

Results of fecal examinations are shown in Table 9. Because of the subjective determination of fecal egg counts, these data were not statistically analyzed.

Sick cattle showed signs most often associated with BRD, including depression, anorexia, gauntness and fever. Calves in the MCM and CM treatment groups had lower first-time treatment rates than SBM cattle during the first 28 days postweaning (Table 10). The MCM calves had lower first-time treatment rates than SBM calves for the entire feeding period.

Calves in the MCM group also required fewer retreatments for sickness during the first 28 days postweaning than those in either the SBM or CM groups (Table 10). Calves offered MCM or SBM on pasture experienced a lower retreatment rate than those in the CM group during the period from 57 days on feed to harvest. For the entire feeding period, calves in the MCM group required fewer retreats than those in the SBM and CM groups.

Calves offered MCM on pasture also had fewer repulls from 57 days on feed to harvest than calves supplemented with either the SBM or CM on pasture (Table 10). For the entire feeding period, calves in the MCM group had significantly fewer repulls than those in the CM group. The repull rate for calves in the SBM and CM treatment groups did not differ for the entire feeding period.

Summation of first-time treatments, retreats and repulls into a category designated "sick incidents" revealed that calves in the MCM group had fewer "sick incidents" than either the CM or SBM cattle for the entire feeding period (Table 11). The "sick incidents" rate for the SBM and CM groups was not different.

Long-acting oxytetracycline or tilmicosin were used for first-time treatments of BRD at the discretion of feedlot personnel and the attending veterinarian (Table 12). There were no statistical differences in numbers of animals retreated or repulled between treatments.

**Table 7.** Seroconversion at various time intervals following vaccination with IBR, BVD or BRSV vaccine.*

| | **Seroconversion: preweaning to weaning** | **Seroconversion: preweaning to postweaning** | **Seroconversion: weaning to postweaning** |
|---|---|---|---|
| Time interval (days) | 19 | 50-57 | 31-37 |
| | No. head (%) | No. head (%) | No. head (%) |
| **IBR seroconversion** | | | |
| Control | 0 (0.0) [a] | 19 (65.5) [a] | 19 (65.5) [a] |
| Metal complex | 0 (0.0) [a] | 17 (58.6) [a] | 19 (65.5) [a] |
| Sulfate-based | 0 (0.0) [a] | 16 (55.2) [a] | 16 (55.2) [a] |
| Total | 0 (0.0) | 52 (59.1) | 54 (61.4) |
| **BVD seroconversion** | | | |
| Control | 2 (6.7) [a] | 15 (51.7) [a] | 21 (72.4) [a] |
| Metal complex | 1 (3.4) [a] | 12 (41.4) [a] | 15 (51.7) [a] |
| Sulfate-based | 1 (3.4) [a] | 14 (48.3) [a] | 17 (58.6) [a] |
| Total | 4 (4.5) | 41 (46.6) | 53 (60.2) |
| **BRSV seroconversion** | | | |
| Control | 9 (30.0) [a] | 18 (62.1) [a] | 15 (51.7) [a] |
| Metal complex | 16 (55.2) [a] | 23 (79.3) [a] | 14 (48.3) [a] |
| Sulfate-based | 9 (31.0) [a] | 22 (75.9) [a] | 15 (51.7) [a] |
| Total | 34 (38.6) | 63 (71.6) | 44 (50.0) |

Conducted by University of Nebraska Veterinary Diagnostic Laboratory System
*Viral seroconversion definition: any increase above ≤2, or four-fold change.
[a]Within a column, within a section, (i.e., IBR seroconversions, BVD seroconversions, BRSV seroconversions), values with different superscripts differ significantly ($p<0.05$).

**Table 8.** Relationship of antibody response to vaccination with IBR, BVD or BRSV vaccine to trace mineral supplementation and time.

| | IBR | | | BVD | | | BRSV | | |
|---|---|---|---|---|---|---|---|---|---|
| | **No. of head** | Mean viral titer | Std dev | No. of head | Mean viral titer | Std dev | No. of head | Mean viral titer | Std dev |
| **Preweaning** | | | | | | | | | |
| Control mineral | 30 | 2.8[a] | 3.13 | 30 | 35.5[a] | 56.44 | 30 | 2.8[a] | 3.11 |
| Metal-complex mineral | 29 | 2.8[a] | 2.43 | 29 | 33.8[a] | 51.36 | 29 | 4.8[a] | 11.54 |
| Sulfate-based mineral | 30 | 2.7[a] | 1.87 | 30 | 27.2[a] | 47.73 | 30 | 2.4[a] | 1.79 |
| **Weaning** | | | | | | | | | |
| Control mineral | 30 | 2.2[a] | 1.85 | 30 | 16.3[a] | 26.30 | 30 | 11.2[a] | 18.94 |
| Metal-complex mineral | 29 | 1.9[a] | 1.13 | 29 | 25.4[a] | 34.16 | 29 | 24.6[a] | 48.90 |
| Sulfate-based mineral | 29 | 2.0[a] | 1.48 | 29 | 14.4[a] | 27.11 | 29 | 7.2[a] | 9.39 |
| **Postweaning** | | | | | | | | | |
| Control mineral | 29 | 22.9[a] | 47.95 | 29 | 198.8[a] | 276.58 | 29 | 58.1[a] | 86.17 |
| Metal-complex mineral | 30 | 14.7[a] | 23.62 | 30 | 115.9[a] | 206.48 | 30 | 63.4[a] | 80.53 |
| Sulfate-based mineral | 29 | 10.3[a] | 13.97 | 29 | 287.6[a] | 793.91 | 29 | 66.8[a] | 86.01 |

Conducted by University of Nebraska Veterinary Diagnostic Laboratory System
[a]Within a column, within a section (i.e., preweaning, weaning, postweaning), mean values with different superscripts differ significantly ($p<0.05$).

Total mortality for the entire feeding period was 16 head (2.66%). There were no differences in the death rates for any measured time period or for the entire feeding period between the three treatment groups. Five head (3.01%) died in the CM group, seven (3.27%) died in the MCM group and four (1.80%) died in the SBM group. Deaths were attributed to bovine respiratory disease and digestive causes.

## Discussion

Management of the cows and calves used in this study was typical of many beef operations in this region. The age of this herd was not typical, however, it presented a unique opportunity to obtain data from this age set. It is likely that the outcome of this study is reflective of calves raised under similar conditions, but representing a more normal age distribution.

Intake of zinc, copper, manganese and cobalt from mineral was markedly less in the MCM group compared to the SBM groups. The content of zinc, copper, manganese and cobalt in the SBM was about twice the content of the MCM (Table 1). There were periods of time molybdenum levels in the forage could have interfered with copper availability. If a copper-molybdenum ratio of 3:1 is used as a minimum, two MCM pastures had ratios below the minimum at one or more samplings.[18] Other variability in pasture mineral levels appears minimal. It is not known when calves began consuming mineral or how much they ate during the grazing season. However, calf fall liver mineral levels appeared to be influenced by mineral treatment (Table 5). Even though the trace mineral supplementation level in the SBM was considerably higher than in the MCM, no differences in zinc, copper or manganese were seen in liver biopsy samples taken from cows in the fall. Both mineral treatments were associated with increases in liver mineral concentrations. Trace mineral supplementation as well as the mineral source (MCM or SBM) influenced liver levels in both cows and calves.

This study focused on liver mineral differences between treatment groups, rather than comparison to ac-

**Table 9.** Results of fecal examination using Modified Wisconsin Fecal Flotation Technique from 2-animal composite samples.

| Sampling date | Control | | | | | | Metal complex | | | | | | Sulfate-based | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. samples | Score results* | | | | | No. samples | Score results* | | | | | No. samples | Score results* | | | | |
| | | Neg | 1 | 2 | 3 | 4 | | Neg | 1 | 2 | 3 | 4 | | Neg | 1 | 2 | 3 | 4 |
| June 3 | 16 | 16 | | | | | 19 | 17 | 2 | | | | 23 | 22 | 1 | | | |
| July 13 | 10 | 10 | | | | | 9 | 8 | 1 | | | | 10 | 8 | | 1 | 1 | |
| Sept. 17 | 28 | 28 | | | | | 22 | 21 | 1 | | | | 31 | 31 | | | | |

* Subjective determination of 1-4 with score of 4 being heaviest ova concentration.

**Table 10.** Morbidity of calves at various times following feedlot entry.

| | First-time treatments | | | | Retreats | | | | Repulls | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Metal complex | Sulfate-based | Total all groups | Control | Metal complex | Sulfate-based | Total all groups | Control | Metal complex | Sulfate-based | Total all groups |
| **0-28 day** | | | | | | | | | | | | |
| No. at risk* | 171 | 221 | 226 | 618 | 43[a] | 51[a] | 93 | 187 | 43[a] | 51[a] | 93 | 187 |
| Treats (%) | 43[a] | 51[a] | 93[b] | 187 | 6[c] | 0[d] | 14[c] | 20 | 1[e] | 1[e] | 2[e] | 4 |
| | (25.1) | (23.1) | (41.2) | (30.3) | (14.0) | (0) | (15.1) | (10.7) | (2.3) | (2.0) | (2.2) | (2.1) |
| **29-56 days** | | | | | | | | | | | | |
| No. at risk | 127 | 169 | 132 | 428 | 61 | 71 | 103 | 23.5 | 61 | 71 | 103 | 235 |
| Treats (%) | 18[a] | 20[a] | 10[a] | 48 | 2[c] | 2[c] | 2[c] | 6 | 9[e] | 6[e] | 6[e] | 21 |
| | (14.2) | (11.8) | (7.6) | (11.2) | (3.3) | (2.8) | (1.9) | (2.6) | (14.8) | (5.8) | (5.8) | (8.9) |
| **57 days to harvest** | | | | | | | | | | | | |
| No. at risk | 109 | 147 | 121 | 377 | 77 | 77 | 119 | 273 | 77 | 91 | 119 | 287 |
| Treats (%) | 16[a] | 20[a] | 16[a] | 52 | 19[c] | 6[d] | 13[d] | 38 | 16[e] | 7[f] | 24[e] | 47 |
| | (14.7) | (13.6) | (13.2) | (13.8) | (24.7) | (7.8) | (10.9) | (13.9) | (20.8) | (7.7) | (20.2) | (16.4) |
| **Total all periods** | | | | | | | | | | | | |
| No. at risk | 171 | 221 | 226 | 618 | 77 | 91 | 119 | 287 | 77 | 91 | 119 | 287 |
| Treats (%) | 77[a,b] | 91[a] | 119[b] | 287 | 27[c] | 8[d] | 29[c] | 64 | 26[e] | 14[f] | 32[e,f] | 72 |
| | (45.0) | (41.2) | (52.7) | (46.4) | (35.1) | (8.8) | (24.4) | (22.3) | (33.8) | (15.4) | (26.9) | (25.1) |

*Calves entering feedlot were fewer in number than calves placed in pastures due to marketing of animals, straying from pastures, and death loss. Feedlot mortalities are subtracted from subsequent risk groups.

**Treats** (treatment, first-time treatment): Animals removed from home pen and treated because of illness.

**Retreats:** Animals requiring treatment greater than 3 days after initial treatment and remaining in recovery pen, or if returned to home pen and removed for treatment in less than 14 days.

**Repulls:** Animals requiring treatment after initial treatment and retreatment, if done, with a 14 day or greater interval, and having been returned to home pens.

[a-f]Within a row, within a morbidity group (i.e., first-time treatments, retreats, and repulls) values with different superscripts differ significantly ($p<0.05$) by Chi-square analysis.

cepted laboratory values. Adequate values used by the laboratory conducting the analyses were: copper, 90-540 ppm; manganese, 9.1-15 ppm; molybdenum, 0.5-5 ppm; and zinc, 90-730 ppm. For example, cows biopsied in the spring were copper deficient, but copper levels were at adequate levels in both the MCM and SBM groups by fall. Copper levels in the CM group remained at slightly less than adequate levels. Also, calves in the CM group had less than adequate levels of liver copper in the fall.

Because of drought, calves from two pastures offered the CM were fed a supplemental ration for a period of time prior to weaning, and were therefore adapted to a processed ration and mechanical feeding. This supplemental ration contributed to some variability of

**Table 11.** "Sick incidents" (first-time treats, retreats, repulls) of calves at various time intervals in the feedlot.

| | Control | Metal complex | Sulfate-based | Total all groups |
|---|---|---|---|---|
| **0-28 days** | | | | |
| No. at risk * | 171 | 221 | 226 | 618 |
| Sick (incidents/hd) | 50 (.29)[a] | 52 (.24)[a] | 109 (.48)[b] | 211 (.34) |
| **29-56 days** | | | | |
| No. at risk | 170 | 220 | 225 | 615 |
| Sick (incidents/hd) | 29 (.17)[a] | 28 (.13)[a,b] | 18 (.08)[b] | 75 (.12) |
| **57 days to harvest** | | | | |
| No. at risk | 170 | 218 | 224 | 612 |
| Sick (incidents/hd) | 51 (.30)[a] | 33 (.15)[b] | 53 (.24)[a] | 137 (.22) |
| **Total all periods** | | | | |
| No. at risk | 171 | 221 | 226 | 618 |
| Sick (incidents/hd) | 130 (.76)[a] | 113 (.51)[b] | 180 (.80)[a] | 423 (.68) |

**Number at risk - Morbid**: Total number of animals at the beginning of the study minus the number of animals who died during any previous period minus the number of animals counted as morbid during any previous period.
**Number at risk - Retreats and repulls**: Sum of number of morbids during the current and any previous periods.
[a,b]Within a row, values with different superscripts differ significantly ($p<0.05$) by Chi-square analysis.

**Table 12.** Response of sick calves to treatment with long-acting oxytetracycline or tilmicosin.

| | No. first treatment | No. retreated | No. repulled | No. retreated or repulled |
|---|---|---|---|---|
| **Long-acting oxytetracycline** | 140 | 15[a] | 25[a] | 40[a] |
| **Tilmicosin** | 203 | 12[a] | 41[a] | 53[a] |

[a]Within a column, values with different superscripts differ significantly ($p<0.05$).

forage mineral content between groups. However, trace mineral levels in the supplemental ration were not markedly different from those of late-season grass clippings, and were well below NRC requirements for copper and zinc (Table 2). Adaptation to supplemental feeding of the CM calves on pasture may have reduced weaning stress. It is possible that this may have confounded the weight gain and first-time treatment rates. Pasture differences could also influence weaning weight.

Trace mineral supplementation influenced the response to vaccination with a pasteurella bacterin-toxoid, as evidenced by results of capsular ELISA and whole cell agglutination tests. Calves offered MCM or SBM on pasture responded better to vaccination with the pasteurella bacterin-toxoid than those receiving CM (Table 6). Comparisons of response between calves in the MCM and SBM groups, however, were mixed. Leukotoxin neutralization tests showed differences in relation to time but not to trace mineral treatment. Calf response to this antigen was generally good in all three groups. However, trace mineral supplementation appeared to enhance response as measured by two of the three tests.

No statistical differences in virus titers between treatment groups were detected (Tables 7 and 8). Many serologically naive calves were present at preweaning, suggesting that a large number of calves may have been susceptible to viral respiratory pathogens. Seroconversion following vaccination with a MLV vaccine containing IBR, BVD and BRSV occurred in a significant proportion of calves in all three treatment groups. The large standard deviations, as well as utilizing only one test, limited the likelihood of detecting statistically significant differences in response to virus vaccination. Results of this study are in contrast to other published reports.[17]

The relationship between mineral treatment, sickness and treatment was mixed (Table 10), while there were no differences in mortality rates. Calves in the MCM group required fewer first-time treatments than those in the SBM group, had fewer retreats than SBM and CM groups and a lower repull rate than those in the CM group. The first-time treatment rate for calves fed the CM was not different from those in the MCM group. The retreat and repull rates for the calves in the SBM group were similar to those in the CM group. Feeding of the supplemental ration to calves in the CM group may have influenced sickness rates for that group, especially early in the feeding period. However, if it did, this effect did not exist for the duration of the feeding period. "Sick incident" rates, tabulations of first-time treatments, retreats and repulls, statistically favored those calves in the MCM group, with 49.0% and 56.9% fewer "sick incidents" than CM and SBM groups, respectively (Table 11). Overall, cattle in the MCM group were treated fewer times.

## Conclusion

Results of this study suggest that trace mineral supplementation to cow/calf pairs during the summer grazing period influences liver mineral levels, immune response to pasteurella vaccination and some aspects of feedlot morbidity. By improving mineral status prior to weaning, morbidity, especially "sick incidents," was reduced in MCM fed calves when they were placed in the feedlot. Ranch mineral programs designed to improve trace mineral status of weaned calves prior to feedlot entry may offer economic advantages through improved health performance of calves under stressful conditions. Further research is needed to better define optimal cost-benefit relationships and to provide a better understanding of the association of trace mineral status and feedlot performance under field conditions.

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