EFFECTS OF PRE-PARTUM AND POST-PARTUM BOLUS INJECTIONS OF TRACE MINERALS ON PERFORMANCE OF BEEF COWS AND CALVES GRAZING NATIVE RANGE

by

LAUREN RAE MUNDELL

B.S., Kansas State University, 2009

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2011

Approved by:

Major Professor
K. C. Olson

Abstract

Our objective was to evaluate the effects of pre- and post-partum trace mineral bolus injections on beef cow reproductive performance, body weight (**BW**) change, body condition score (**BCS**) change and performance of suckling calves. Angus x cows (n= 460; initial BW = 497 ± 89 kg, initial BCS = 5.4 ± 0.74) were stratified by BCS, age, parity, and predicted calving date and assigned randomly to 2 treatments: 1) s.c. trace mineral (**TM**) injection (15 mg/mL Cu, 5 mg/mL Se, 10 mg/mL Mn, and 60 mg/mL Zn) or 2) s.c. injection of physiological saline (**SA**). Injections were administered to cows (1 mL/90 kg BW) 180 d before the first projected calving date and again 30 d before fixed-time AI. Calves received the same treatment as their dams and were injected (1 mL/45 kg BW) at birth and at 71 ± 21 d of age. Cows grazed native pastures for the duration of the study and had *ad libitum* access to trace mineral supplements and white salt. Ovulation was synchronized using a 5-d CO-Synch + CIDR protocol. Cows were inseminated 60 to 64 h after CIDR removal. Cows were exposed to fertile bulls for natural-service breeding 10 d after AI for 35 d. Conception to AI and final pregnancy rate were assessed 36 and 120 d after AI with ultrasound and rectal palpation, respectively. Change in cow BW and BCS from initiation of the study to calving and from AI to weaning did not differ ($P > 0.12$) between treatments. Conversely, TM cows had greater ($P = 0.04$) BCS increase than SA cows between calving and AI. Calf birth BW, ADG, and age-adjusted weaning BW did not differ ($P > 0.36$) between treatments. Proportion of cows with estrus cycles 21 d before ovulation synchronization was similar ($P = 0.51$) between treatments. Conception to AI was greater ($P = 0.05$) for TM cows (60%) than for SA cows (49%); however, overall pregnancy did not differ ($P = 0.24$) between treatments and averaged 92%. Cows injected with TM under conditions similar to our study may be more likely to conceive to fixed-time AI.

Table of Contents

List of Figures iv
List of Tables v
Acknowledgements vi
Dedication vii
Chapter 1 - General Review of Literature 1
Introduction 1
Broad-Spectrum Trace-Mineral Supplements 1
Supplementation with Specific Minerals 4
Comparisons of Organic and Inorganic Trace-Mineral Supplements 9
Injectable Trace-Mineral Supplements 14
Conclusions 16
Literature Cited 18
Chapter 2 – Effects of Pre-partum and Post-partum Bolus Injections of Trace Minerals on Performance of Beef Cows and Calves Grazing Native Range 22
Abstract 23
Introduction 24
Materials and Methods 24
Results and Discussion 26
Implications 29
Literature Cited 36
Appendix A – Pre-treatment serum mineral concentrations (± SD) of beef cows and calves 39
Appendix B – Approximate cost of Multimin® 90 on 05/04/2011 40

List of Figures

Figure 2.1 Design of ovulation sychronization and timed-AI breeding protocols 30

List of Tables

Table 2.1 Composition of injectable trace mineral solution administered pre- and post-partum to beef cows and at birth and 71 ± 21 d of age to beef calves 31

Table 2.2 Effects of pre- and post-partum bolus injections of either a trace-mineral solution or physiological saline (1 mL/90 kg BW) on body weight and body weight change of beef cows grazing native range 32

Table 2.3 Effects of pre- and post-partum bolus injections of either a trace-mineral solution or physiological saline (1 mL/90 kg BW) on body condition score and body condition score change of beef cows grazing native range 33

Table 2.4 Effects of pre- and post-partum bolus injections of either a trace-mineral solution or physiological saline (1 mL/90 kg BW) on reproductive performance of beef cows grazing native range 34

Table 2.5 Performance of beef calves treated at birth and at 71 ± 21 d of age with bolus injections of either a trace mineral solution or physiological saline (1 mL/45 kg BW) 35

Acknowledgements

First and foremost, I would like to thank Dr. KC Olson for his willingness to lead me on this nutritional journey. I can't explain my appreciation for his patience, suggestions, support, and willingness to listen to my ridiculous questions. He has acted selflessly by pushing others to succeed without much recognition for himself. KC, thanks for everything!

Next, I would like to thank my remaining committee members, Dr. David Grieger and Dr. John Jaeger. Your patience with me is greatly appreciated! Dr. Grieger, thank you for enduring frigid temperatures during my project, providing hot chocolate and jokes, and being willing to help me on short notice. Dr. Jaeger, thank you for your willingness and support to coach me. You have all of my respect!

Finally, I can't thank all of my fellow graduate students and Cow/Calf Unit employees enough for all the fun and help during my time at K-State. I consider you all family, and am so blessed to call you friends! I don't know how a grad student could make it through school without you!

Dedication

I dedicate this work to my husband, Clint. The patience and support you have shown me through these past two years have made me realize how blessed I am to call you my husband. I would also like to thank all of my family. Without your love and support, I would not have made it to the finish line. I love you all!

Chapter 1 - General Review of Literature

Introduction

Adequate trace mineral (**TM**) nutrition is thought to be necessary for normal cow reproduction, health, and performance, as well as normal calf health and performance. Historically, TM have been available to cattle through the plants they consume. Unfortunately, forages from different regions of the United States don't always supply sufficient amounts or ratios of the mineral elements that are critical for the nutrition well-being of beef cows and calves. In order to maximize cow and calf performance, producers must supplement TM. The most widely used means of trace-mineral supplementation for grazing cattle is the self-fed, salt-based, granular supplement (Greene, 2000). Even though cattle do not balance their mineral needs when consuming a self-fed mineral supplement, (Dent et al., 1956) there is usually no other practical way of supplying mineral needs under grazing conditions (McDowell, 1985). The greatest limitation to using self-fed mineral supplements is variation in animal intake. More direct methods of mineral supplementation include adding minerals to drinking water or feed, oral drenching, ruminal boluses, and injections. Variation in mineral intake is reduced relative to self-fed supplementation and the additional labor requirement and expense are relatively small (Olson, 2007).

Delivery of supplemental trace minerals using an injectable solution may be a more reliable means of achieving adequate trace-mineral status than using self-fed, salt-based, granular mineral supplements alone. This review will focus on the effects of injectable TM supplements on beef cows and calves; however, a variety of studies using other experimental models were also included.

Broad-Spectrum Trace-Mineral Supplements

Valdes et al. (1988) evaluated mineral status and response to mineral supplementation by grazing beef cattle in Guatemala. Primiparous Brahman heifers (n = 195) were randomly assigned to 1 of 3 treatments: 1) Control – common salt (NaCl); 2) Control + Ca and P (60% NaCl, 23.5% Ca, and 16.0% P); and 3) Control + complete trace-mineral supplement (60% NaCl, 21.8% Ca, 16.0% P, 0.02% Co, 0.2% Cu, 0.016% I, 1.0 % Fe, 0.5% Mn, 0.002% Se, and 1.0% Zn). All treatments were offered *ad libitum*. Overall pregnancy rate, calf weaning weight, plasma mineral concentrations, liver mineral concentrations, and mineral intakes were recorded. Plasma Cu concentrations of heifers fed the complete mineral supplement were greater than those of heifers fed any of the other treatments. There were no treatment differences in mean plasma Se concentrations; moreover, plasma Zn response was inconsistent between treatments. All liver mineral concentrations were above lower critical levels. Conversely, liver Mo was excessive (NRC, 2000). This could have limited dietary Cu availability. Liver Fe was greater in heifers fed salt + Ca and P when compared to heifers fed salt only or salt + complete trace-mineral supplement. Liver Mo levels were greater in heifers fed salt + Ca and P compared to other treatments. Measures of fertility did not differ among treatment groups.

Ahola et al. (2004) evaluated the effects of Cu, Zn, and Mn supplementation on reproduction, mineral status, and performance of grazing beef cows. Cows were stratified by expected calving date, age, body weight, body condition score, and liver mineral status and assigned to the following treatments: 1) control (no supplement); 2) organic mineral supplement (50% organic and 50% inorganic; 10.7% Ca, 11.4 % P, 1,038.2 mg/kg Cu, 3,173.1 mg/kg Zn, 2,921.3 mg/kg Mn); or 3) inorganic mineral supplement (100% inorganic; 10.7 % Ca, 11.4 % P, 1,087.2 mg/kg Cu, 3,241.0 mg/kg Zn, 2,895.3 mg/kg Mn). In year 1, supplemented cows had greater liver Cu, Zn, and Mn concentrations than control cows. In year 2, supplemented cows only had greater Cu concentrations when compared to control cows. In both years, supplemented cows had greater AI pregnancy rates than control cows. At the end of year 1, cows supplemented with organic TM sources had greater liver Cu concentrations than cows supplemented with inorganic mineral sources; however, liver Cu concentrations were similar between these treatments at the end of year 2. Liver Mn and Zn concentrations were not different between cows supplemented with organic or inorganic sources of TM. In year 1, cows supplemented with organic sources of TM tended to have greater pregnancy rate to AI than did cows supplemented with inorganic sources of TM. In year 2, pregnancy rate to AI was not different between cows supplemented with organic or inorganic sources of TM.

Manickam et al. (1977) attempted to estimate the Fe, Cu, Mn, and Zn contents of whole blood and plasma in regular- and repeat-breeder cows. Regular breeders were classified as cows that required 1-3 inseminations to achieve pregnancy. Repeat breeders were cows that required 4 or more inseminations to conceive. Twenty-five regular-breeder and 26 repeat-breeder cows were used in this study. All cows were classified as being in good, fair, or poor body condition.

Two blood samples were collected from each cow for estimation of TM in blood and plasma. In regular breeders' blood, concentrations of TM were greater than in the repeat breeders' blood. Plasma concentrations of TM were greater also in regular breeders than in repeat breeders. There was a negative relationship between BCS and inseminations required per conception. Cows in good condition conceived with fewer inseminations than cows in poor condition. There were also negative relationships between Fe and Zn content in blood and plasma and the number of inseminations required to achieve conception.

Rudert and O'Donovan (1976) compared the performance of cows and their progeny maintained under 3 different mineral supplementation programs. The study was conducted over 3 years. Three different mineral supplements were offered to groups of female Mashona cattle. All cows were assigned randomly to 1 of 3 groups based on cow BW. Treatments were: 1) Group A - offered individual minerals *ad libitum*; 2) Group B - offered a mineral mixture *ad libitum*; 3) Group C-offered coarse rock salt only. There were no differences between treatments in calving rates or BW changes during the study. In addition, there were no treatment differences in calf birth BW or WW. In contrast, post-weaning growth rates were greater for the Group A calves than Group B calves.

Arthington and Pate (2002) investigated the TM status of growing beef heifers offered TM in corn- or molasses-based carriers. In experiment 1, 36 nonpregnant, Simbrah-sired heifers with adequate liver Cu concentrations were assigned randomly to bahiagrass pastures of equal size. One of 2 supplements was allotted randomly to each pasture. Supplement treatments were 1) corn-based (368 g cottonseed meal, 1,544 g corn, and 57 g complete mineral per head daily) or 2) molasses-based (2,270 g molasses, 454 g cottonseed meal, and 57 g complete mineral per head daily). The complete mineral provided 140, 76, and 63 mg of Cu, Mn, and Zn, respectively, per heifer daily.

In experiment 2, 24 pregnant, Braford-sired heifers with adequate liver Cu concentrations were assigned randomly to bahiagrass pastures of equal size. Three supplement treatments were formulated, 1) corn-based (368 g cottonseed meal, 1,544 g ground corn, and 57 g complete mineral); 2) molasses-based (2.270 g molasses, 454 g cottonseed meal, and 57 g complete mineral daily) or 3) corn + S (368 g cottonseed meal, 1,544 g ground corn, 57 g complete mineral). Supplements were formulated to provide the same feeding rates of minerals used in experiment 1.

There were no differences in heifer BW change during either study. Molybdenum tended to accumulate in the livers of heifers fed molasses-based supplements. In both studies, liver Cu and plasma ceruloplasmin were greater in heifers receiving corn-based supplements than in heifers receiving molasses-based supplements.

Supplementation with Specific Minerals

Gunter et al. (2003) examined the effects of Se supplementation and Se source on performance, reproduction, and blood parameters in gestating and lactating beef cows fed grass hay and pasture that were marginally deficient in Se. Pregnant crossbred beef cows (n = 120) were stratified by BCS, BW, breed, and age. Cows were assigned to 1 of 3 treatment groups: 1) no supplemental Se; 2) 26 mg of supplemental Se/kg of self-fed mineral from sodium selenite; or 3) 26 mg of supplemental Se/kg of a self-fed mineral from seleno-yeast. Self-fed minerals were designed to be consumed at a rate of 113 g/cow daily. All cows grazed dormant common bermudagrass. In early December, cows had *ad libitum* access to warm-season grass hay; in addition, they were allowed limited access to a winter-annual paddock. Cows and calves were weighed and BCS was assigned at regular intervals throughout the trial. At the same time points, blood samples were collected from 4 randomly selected cows and their calves assigned to each treatment group.

Cow BW, cow BCS, pregnancy rates, and post-partum intervals did not differ between supplemented and unsupplemented cows. There were no differences in birth date, BW, BW of calves, total BW gain, and ADG between Se-supplemented calves and unsupplemented calves. At calving, Se-supplemented dams had greater whole blood Se concentrations than unsupplemented cows. In addition, sodium selenite-supplemented cows had less whole blood Se than cows supplemented with seleno-yeast. The seleno-yeast-supplemented cows maintained greater relative levels of Se throughout the calving season than other treatments. Whole blood Se concentrations at birth in calves from cows fed Se-fortified minerals were greater than in calves from cows fed minerals with no Se. Similar to the cows, calves of cows fed the seleno-yeast supplement had greater whole blood Se than the calves of cows supplemented with sodium selenite.

Koller et al. (1984) investigated whether Se could effectively cross the placenta from dam to the fetus or could be transferred through colostrum and milk in sufficient quantities to avoid injecting the neonate with Se. Twenty-four Hereford heifers of similar weight and stages of gestation were selected for the study. Eight were verified as Se adequate while the remaining 16 were Se deficient. The group of 16 Se-deficient heifers was split into 2 groups of 8 heifers each. The Se-adequate heifers were fed a pelleted-alfalfa diet supplemented with soybean oil meal (the basal diet contained 0.085 mg Se/kg). They were given *ad libitum* access to a salt-mineral mix that contained 90 mg of Se/kg (Se-A). One group of Se-inadequate heifers were fed the same diet as the Se-adequate group, except that the salt-mineral mix was free of Se (Se-I). The second group of Se-inadequate heifers was fed the basal diet without soybean oil meal (Se-R). Two wk before calving, the pelleted alfalfa diet fed to Se-R heifers was replaced with a similar diet that contained 0.125 mg of Se/kg.

Prior to calving, at calving, and 8 wk after calving, blood was collected from all heifers. Blood was collected from calves at calving and 8 weeks after calving. The blood glutathione peroxidase (GSH-Px) values for Se-A cows remained stable for 8 wk after the initiation of the experiment and then increased to an average of 144 mU/mg of hemoglobin by calving. Blood GSH-Px increased in cows assigned to Se-I from initiation of the experiment through calving. The GSH-Px in Se-R cows increased slowly during the first 13 wk of experimentation but nearly doubled by calving. Cows and calves assigned to Se-A had greater blood GSH-Px and Se concentrations than other treatment groups. Eight wk after calving, cow and calf blood GSH-Px concentrations were similar between treatments. Calf GSH-Px activity decreased in all treatment groups from birth to 8 wk of age.

Forages often do not provide the amounts of Mn, Cu, and Zn necessary to meet requirements of beef cows. DiCostanzo et al. (1986) studied the effects of supplemental Mn alone or supplemental Mn, Cu, and Zn on reproductive performance of beef cows fed corn silage-based diets. Ninety-three Angus cows were assigned randomly within parity group to treatment diets from parturition to wk 19 postpartum. After calving, all cows were fed 9.4 kg of corn silage DM and 1 of 3 corn-urea-based mineral supplements: 1) control (40 ppm Mn, 4 ppm Cu, and 45 ppm Zn); 2) added Mn (+Mn; 54 ppm Mn, 4 ppm Cu, and 45 ppm Zn); or 3) added Mn, Cu and Zn (+MnCuZn; 54 ppm Mn, 9 ppm Cu, and 55 ppm Zn). Estrus was observed twice daily beginning 3 wk after calving. Females were artificially inseminated 12 to 14 hr after they were observed in standing estrus. In the heifers, +Mn induced estrus and conception sooner than +MnCuZn or control treatments. Treatment did not influence days to first estrus in cows;

however, the +MnCuZn supplement tended to reduce days to conception compared to the +Mn and control groups. Compared to control cows, +Mn- and +MnCuZn- treated cows and heifers required fewer services per conception.

Bailey et al. (2001) evaluated the effects of different dietary Cu concentrations and sources on heifers fed diets that contained Cu antagonists. Heifers were either individually fed or pen-fed. Treatments were: 1) no supplemental Cu; 2) 49 mg Cu/kg DM (Cu sulfate; 5X-SO_4); 3) 22 mg Cu/kg DM ($CuSO_4$; 2X- SO_4); 4) 22 mg Cu/kg DM ((50% $CuSO_4$ + 50% Cu-amino acid complex; 50:50); or 5) 22 mg Cu/kg DM ((25% $CuSO_4$, 50% Cu-amino acid complex, and 25% CuO; 25:50:25). Heifer diets were spiked with Mo, S, and Fe. Heifer performance and cell-mediated immune function were not affected by treatment. Individually-fed heifers consuming the 25:50:25 supplement initially lost hepatic Cu rapidly when compared to control, 50:50, and 2X- SO_4 heifers. Total hepatic Cu loss by pen-fed heifers tended to be greater for the 25:50:25 and 2X- SO_4 treatments compared to the 5X-SO_4 and 50:50 treatments.

Muehlenbein et al. (2001) studied the effects of inorganic and organic Cu supplementation on reproductive rate, liver Cu, and serum Cu of beef heifers. Subsequently, calf health and calf performance were also examined. Cows were assigned randomly by estimated calving date and BCS to 1 of 3 treatments: 1) control (no supplement); 2) inorganic supplemental Cu (0.29% of dietary DM as $CuSO_4$); or 3) organic supplemental Cu (0.35 % of dietary DM as a Cu-amino acid complex). Liver Cu of unsupplemented cows decreased after calving, while liver Cu of supplemented cows increased. Copper supplementation had no effect on calf liver Cu concentrations, calf health, calf serum Cu concentrations, calf WW, colostral Cu concentrations, cow BW change, or cow 60-d pregnancy rates.

Arthington et al. (1995) evaluated the effects of slow-release Cu boluses on cow reproductive performance and calf growth. Two herds were utilized in this study. In herd 1, the cattle (n = 34 pair) were diagnosed as Cu deficient before the study began, as evidenced by abnormal hair coats and serum and liver samples. Cows were assigned randomly to either a treated or an untreated group. Cows in the treated group received 2 Cu boluses (20 g of CuO needles), and their calves received 1 bolus (10 g CuO needles). Copper and Fe status were determined via analysis of serum and liver samples. There were no differences in liver Cu levels between the treated and the untreated cows. Liver Fe levels tended to be lower in treated cows. Treated calves tended to have lower ADG than untreated calves and there were no differences in

ADG between the treated and control cows. Authors noted that hair coat condition in treated cattle returned to normal by the end of the study, whereas hair-coat condition of untreated cattle remained abnormal.

In herd 2, fall-calving cows were divided into either treated (n = 276) or untreated (n = 830) groups. Cows in the treated group received 2 Cu boluses (20 g of CuO needles) and their calves received one bolus (10 g CuO needles). Pregnancy rate to artificial insemination (AI), AI first-service conception rate, and number of inseminations/female were evaluated. Liver and serum samples were collected randomly within treatment groups and analyzed. On d 97 and 154 of the study, treated cows had greater liver Cu than untreated cows; however, there was no difference in serum Cu between treatments. Pregnancy to AI, AI first-service conception rate, and number of inseminations per female did not differ between treatments. Weaning weight of treated calves was greater than that of untreated calves.

Stahlhut et al. (2006) evaluated the effects of supplemental Cr and Cu on performance and reproduction of beef cows. Pregnant Angus and Simmental cows (n = 152) were blocked by age and breed and assigned randomly to 1 of 2 self-fed mineral supplements. Supplements consisted of: 1) control (no supplemental Cr) or 2) 40 mg Cr/kg of mineral. In addition, half of the cows in each treatment were assigned randomly to receive a 25-g CuO needle bolus. The study was initiated approximately 75 d pre-partum. Calves born to Cu-supplemented cows also received a 12.5 g CuO-needle bolus. Plasma and liver samples were collected from 36 cows and calves chosen at random.

Simmental cows had lower initial and final liver and plasma Cu concentrations than the Angus cows. Cows that received the Cu bolus had greater final liver Cu concentrations than cows that did not receive the bolus. Cows supplemented with Cr tended to have greater pregnancy rates than control cows. This trend was most pronounced among the youngest cows in the study. Two- and 3-yr old cows receiving supplemental Cr lost less BW than similarly-aged cows that did not receive supplemental Cr. In contrast, Cr supplementation did affect BW change in the older cows. In calves, Cr supplementation increased final plasma Cu concentration; however, Cu supplementation did not affect plasma Cu concentration. Chromium supplementation and Cu status did not affect BW, WW, morbidity, or mortality of calves.

Mayland et al. (1980) evaluated weight gain responses to supplemental Zn by cows and calves grazing forage containing less than 20 ppm Zn. This experiment consisted of 3 studies during 3 consecutive years. In the first 2 years, 100 cow-calf pairs were used, whereas 120 pairs were used in the third year. All cows were stratified by origin, calf sex, and initial BW, and assigned to 1 of 2 treatments: 1) grass + basal supplement; 2) grass + basal supplement + Zn supplement. Estimated intakes for each treatment were: 1) 0.032 g Zn/animal /day for grass + basal supplement; 2) 0.930 g Zn/animal/day for grass + basal supplement + Zn supplement. Fecal, hair, forage, supplement, soil, and blood samples were collected and analyzed. Calves fed supplemental Zn gained more weight each year of the experiment than calves in the unsupplemented group. In contrast, cow weight gains were not affected by Zn supplementation. Fecal Zn excretion was greater by calves than cows in the supplemented group; moreover, supplemented cows and calves had greater fecal Zn excretion than unsupplemented cows and calves. Hair Zn content was greater for the Zn-supplemented cows and calves than unsupplemented cows and calves.

Doyle et al. (1988) studied the effects of P and TM supplementation on reproductive performance of beef cattle under range conditions. Forty-five Brangus × cows were divided randomly into 3 pasture groups. Cows were allotted to 1 of 4 treatments: 1) negative control (NC); 2) feed control (FC; 1000 g/d of a sorghum grain-urea supplement); 3) FC + 15 g P (P); and 4) P + 64 mg Zn + 10 mg Cu + 20 mg Mn (TM). All animals had *ad libitum* access to salt. Cows were individually supplemented using Calan feeding gates from 25 d prepartum until the end of breeding season. Ten d prior to breeding and at palpation, serum and liver samples were collected for analysis. Treatments did not influence serum or liver mineral concentrations, whereas a pasture effect was observed for serum and liver Zn and Cu values. Body condition scores and adjusted WW were not influenced by treatment. Average days to conception were 42, 35, 29, and 22 d for NC, FC, P, and TM, respectively.

Waggoner et al. (1979) studied the efficacy of K supplementation of beef cows under winter-range conditions. This study used 271 pregnant beef cows that were assigned to 1 of 2 winter supplements by age and projected calving date. Treatment 1 received 37%-CP blocks *ad libitum* that contained 2.25% K (LK). Treatment 2 received 37%-CP blocks *ad libitum* that contained 4.15% K (HK). Both block supplements were formulated for a daily consumption between 0.68 to 0.91 kg/hd/d. Cows and calves were weighed throughout the trial. All cows were artificially inseminated. Cows in both groups lost similar amounts of weight during the study; however, LK cows lost more weight than the cows consuming the HK supplement during early lactation. Calves suckling HK cows weighed more at branding than calves suckling LK dams. Conversely, weaning BW was not different between treatment groups. Three-year old cows in the HK group tended to have greater pregnancy rates than those in the LK group. Conception rates to AI tended to be greater in the HK group than the LK group as well.

Comparisons of Organic and Inorganic Trace-Mineral Supplements

Trace minerals can be offered in either organic or inorganic forms. Organic TM are so named because they are chemically associated with an organic ligand (AAFCO, 2000). In contrast, inorganic TM exist in complex with an inorganic salt. Previous research indicated that organic TM may be of greater bioavailability compared to their inorganic counterparts (Brown and Zeringue, 1994). Manspeaker et al. (1987) suggested that chelated minerals can be absorbed and metabolized 300 to 500% more efficiently than inorganic minerals; however, studies comparing performance of animals fed either organic or inorganic TM have reported contrasting results.

Stanton et al. (2000) supplemented cows with low-level inorganic TM fed at 62 g/d per head (501 ppm Cu, 2160 ppm Zn, 1225 ppm Mn, and 11 ppm Co), high-level inorganic TM fed at 63 g/d per head (1086 ppm Cu, 3113 ppm Zn, 1764 ppm Mn, and 110 ppm Co), or high-level organic TM fed at 59 g/d per head (1086 ppm Cu, 3113 ppm Zn, 1767 ppm Mn, and 110 ppm Co) to determine effects on cow and calf performance, liver TM content, and immune function. Cow weight and BCS were not affected by treatment. Calf BW at birth was not affected by treatment; however, ADG was greater for calves fed high levels of organic TM compared to other treatments. Pregnancy rates for cows receiving the high level of organic TM were greater than that for any other treatments, as well (75% high-level organic; 61% low-level inorganic; and 56% high-level inorganic). Trace mineral type and level did not affect immune function.

Arthington and Swenson (2004) evaluated the performance and mineral status of grazing Braford cows in a 3-year study using a 2 x 2 factorial arrangement of treatments. Factors were: 1) trace mineral source (inorganic or organic sources of Cu, Zn, Mn, and Co) and 2) feeding method (*ad libitum* or limit-fed mineral provided in a molasses-based carrier). Braford cows (n = 160) were stratified by age and allotted randomly to 1 of 8 bahiagrass pastures (2 pastures/treatment combination). As needed, cull cows were replaced with 3-yr-old pregnant heifers. Cows were offered 2.27 kg of a liquid molasses supplement, fortified with 3.9% urea from early November until mid April each year.

In yr 1, inorganic and organic mineral supplements were designed to provide 28.0 ppm Cu, 80.1 ppm Zn, 109.2 ppm Mn, and 1.20 ppm Co. In yr 2 and 3, inorganic supplements supplied 16.4, 63.7, 100.1, and 0.53 ppm Cu, Zn, Mn, and Co, respectively. In contrast, organic supplements supplied 22.5, 75.4, 127.6, 1.46 ppm Cu, Zn, Mn, and Co, respectively, during yr 2 and 3. Both inorganic and organic supplements were offered to cows at an average rate of 57 g/hd/d. Limit-fed treatments received their mineral supplement 3 times/wk (Monday, Wednesday, and Friday) at a rate of 133 g of mineral supplement per head at each feeding. Cows given *ad libitum* access to mineral were fed via covered mineral feeders on a weekly basis. Individual cow BW, cow BCS, and calf BW were collected at the start of the production cycle and at weaning. In yr 1 and 2, liver biopsy samples were collected from six randomly-chosen cows per treatment combination.

Voluntary intake of the mineral fed *ad libitum* was 23% less than intake of limit-fed mineral. Cows offered *ad libitum* access to mineral had less liver Zn and Cu than cows offered limit-fed mineral. Mineral source and feeding method had no effect on cow BW or BCS. Calf BW and WW were not affected by mineral source or feeding method. There were no interactions between feeding method and cow age on postpartum interval or pregnancy rate. Conversely, young cows receiving organic TM had shorter calving intervals than young cows consuming inorganic TM during yr 1 and 3.

Swenson et al. (1998) evaluated the effects of supplemental TM form (organic vs. inorganic) fed in the presence of an antagonistic mineral element on first-calf heifer post-partum interval, milk production, and progeny performance. Black and Red Angus heifers (n=118) were allotted to 1 of 5 supplemental treatments. Treatments were as follows: 1) organic mineral fed for 60-d precalving; 2) organic mineral fed for 30-d precalving; 3) inorganic mineral fed for 60-d precalving; 4) inorganic mineral fed for 30-d precalving; or 5) unsupplemented . Experimental supplements were fed at a daily rate of 0.22 kg/hd. The organic and inorganic mineral supplements provided approximately 25 ppm Cu, 72 ppm Zn, 41 ppm Mn, and 2 ppm Co of the daily DMI.

Milk production tended to be greater for heifers fed the organic mineral for 60 d prior to calving when compared to the unsupplemented heifers. The increase in milk production had no effect on calf performance. In addition, there were no differences in adjusted 205-d WW among treatments. Mineral supplementation tended to decrease the incidence of scours compared to no mineral supplementation. Heifers consuming organic mineral had shorter post-partum intervals compared to unsupplemented heifers and heifers fed inorganic trace mineral supplement.

Olson et al. (1999) measured the effects of supra-nutritional feeding rates of Cu, Co, Mn, and Zn in either organic or inorganic forms on heifers and calves. Treatments were: 1) control (no supplemental mineral); 2) supplemental organic mineral (131 mg/d Cu, 23 mg/d Co, 249 mg/d Mn, and 378 mg/d Zn); and 3) supplemental inorganic mineral (131 mg/d Cu, 23 mg/d Co, 249 mg/d Mn, and 378 mg/d Zn). Cows in the organic and inorganic treatments had lower conception rates than unsupplemented cows. Liver Zn and Mn concentrations were not different between treatments; however, liver Cu was greater in supplemented heifers than in unsupplemented heifers. Results indicated that feeding Cu, Co, Mn, and Zn at supra-nutritional rates can reduce reproductive performance.

Lamb et al. (2008) evaluated the effects of organic and inorganic TM supplements on follicular response, ovulation, and embryo production in super-ovulated Angus heifers. All heifers received a diet consisting of *ad libitum* hay, and a corn-soybean meal supplement. Treatments were initiated 23 d prior to embryo recovery. Animals were not fed any mineral supplements during a 45-d adaptation period before the initiation of the study. Treatments were: 1) no supplement (control); 2) 108 g/head/d organic mineral supplement (0.89 % Ca, 0.36 % P, 0.37 % Mg, 1.90 % K, 0.04% Na, 0.23 % S, 0.99 mg Co/kg, 51 mg Cu/kg, 219 mg Fe/kg, 156 mg Mn/kg, 3.18 mg Mo/kg, and 221 mg Zn/kg); or 3) 108 g/head/d inorganic mineral supplement (0.89 % Ca, 0.35 % P, 0.38 % Mg, 1.92 % K, 0.03 % Na, 0.22 % S, 0.70 mg Co/kg, 55 mg Cu/kg, 217 mg Fe/kg, 142 mg Mn/kg, 3.12 mg Mo/kg, 187 mg Zn/kg). The average numbers of recovered eggs and embryos were similar among treatments; however, the number of unfertilized eggs was greater for heifers receiving inorganic mineral and unsupplemented heifers than for heifers receiving organic mineral.

Manspeaker et al. (1987) examined the relationship between chelated-mineral supplementation, endometrial histopathology, and bovine fertility. Forty first-calf Holstein heifers were divided into 2 equal groups according to their predicted calving dates. Twenty heifers received a standard balanced diet with no additional mineral supplement (control). The other 20 heifers received a chelated-mineral supplement in addition to the standard diet (treated group). Each heifer in the treated group was given 56.75 g Albion Breeder Pac (Mg, Fe, Mn, Cu, and Zn were each bonded to 2 or more amino acids to form a stable organic heterocyclic ring compound) daily for 30 d prior to its estimated calving date. After calving, heifers were given 113.5 g Albion Breeder Pac daily until they conceived and were confirmed pregnant. Biopsy specimens were collected from the left and right uterine horns and body of the uterus of each animal. Treated heifers had greater ovarian activity, more effective uterine involution, more rapid regeneration of endometrial tissue, less periglandular fibrosis, less endometritis, and less embryonic death than untreated heifers. In addition, treated heifers conceived 45 d earlier than untreated heifers.

Ho et al. (1977) studied the effects of a chelated TM supplement on the Cu and Fe status of pregnant beef cows fed hay or grass silage during winter. Sixty pregnant, Shorthorn cows were assigned randomly to 1 of 2 diets (hay or grass silage) and 1 of 3 TM supplements (none, inorganic, or organic). Composition of mineral mixtures were as follows: 1) control: 59% cobalt-iodized salt, 35% dicalcium phosphate, 5% vitamins A and D premix, and 1% selenium vitamin E concentrate; 2) inorganic: 53% cobalt-iodized salt, 35% dicalcium phosphate, 5% vitamins A and D premix, 1% selenium vitamin E concentrate, 6% inorganic TM supplement; 3) organic: 56% cobalt-iodized salt, 35% dicalcium phosphate, 5% vitamins A and D premix, 1% selenium-vitamin E concentrate, and 3% organic TM supplement. The group fed grass silage without a TM supplement had lower plasma Cu levels than any group fed silage. During the following summer, more than half of this group was hypocupremic and their average plasma Cu concentration was less than other treatment groups. Plasma Fe, hemoglobin, packed cell volume, cow BW, and calf BW were not different between treatment groups.

Kropp (1990) examined the effectiveness of a combination of organic and inorganic trace minerals in enhancing bovine reproductive performance and calf weaning weights. Forty 2- and 3-year-old first-calf heifers consisting of Angus, Horned Hereford, Polled Hereford, Brangus, and Simmental breeds were used for this study (n = 5/breed). Prior to the study, all females had unrestricted access to a 50:50 mixture of salt and TM. All females were maintained on dormant old-world bluestem pasture and supplemented with 9 kg of mature, native tallgrass hay and 2.3 kg of a 20%-CP range cube per head daily.

After calving, heifers were blocked by breed and assigned randomly to 1 of 2 mineral-supplementation programs by breed, calving date, and BCS. The mineral treatments were: 1) organic TM (amino-acid chelates of Cu, Zn, Mn, Mg, and K) or 2) inorganic TM ($CuSO_4$, $ZnSO_4$, MnO, MgO, and KCl). Both treatments were fed at a rate of 454 g per head per day to supply 178 mg Cu, 275 mg Mn, 563 mg Zn, 1,352 mg Mg, and 823 mg K. Fourteen d prior to breeding, heifers were offered additional supplemental mineral at a rate of 56.75 g/d in 454 g ground corn. Heifers treated with the organic TM supplement received the standard Albion Breeder Pac formula (5.5% Mg, 3.8% K, 400,000 IU vitamin A/lb, 85,000 IU vitamin D/lb, 570 IU vitamin E/lb, 21 mg Cu, 44 mg Mn, and 110 mg Zn per 28.4 g). Heifers treated with the inorganic TM supplement received a similar pre-breeding mineral except the Cu, Mn, Zn, Mg, and K amino-acid chelates were replaced by inorganic sources. Heifers treated with organic TM had more standing heats, greater first-service conception, and weaned heavier calves than heifers treated with inorganic TM.

Pehrson et al. (1999) evaluated whether the Se status of Se-deficient calves would be improved if the sodium selenite in supplemental TM was replaced with an organic Se compound. A commercial Hereford herd of 103 cows was used. All cows had *ad libitum* access to grass hay and a vitamin/mineral supplement during the winter. The mineral supplement contained 30 mg Se/kg as sodium selenite. In the spring, the cows were divided into 2 groups. One group of 70 cows was given *ad libitum* access to a TM supplement containing sodium selenite. Remaining cows were given *ad libitum* access to mineral that contained 30 mg Se/kg in the form of seleno-yeast. Both minerals contained 9.9% Ca, 12.2% P, 7.0% Mg, 7.8% Na, 5,000 mg/kg Zn, 4,000 mg/kg Mn, 500 mg/kg Cu, 300 mg/kg I, 20 mg/kg Co, 400,000 IU/kg vitamin A, 75,000 IU/kg vitamin D_3, and 500 IU/kg vitamin E. The estimated daily mineral intake of the seleno-yeast-treated group was 110 g/cow; cows treated with sodium selenite consumed an average of 107 g TM supplement/cow. Blood and milk samples and BW were collected from 11 cows and their calves from each treatment.

Whole blood Se concentrations were not different between treatments; however, calves of cows fed seleno-yeast had greater whole blood and plasma Se concentrations than the calves of cows fed sodium selenite. Milk from cows fed seleno-yeast contained greater concentrations of Se than milk from cows fed sodium selenite. There were positive correlations between the concentration of Se in cows' milk, whole blood and plasma, and the activity of GSH-Px in calves. Also, there was a positive correlation between the concentration of Se in the whole blood of the cows and calves' whole blood Se concentration. There were no differences in adjusted calf WW between treatments.

Chelated minerals may have greater bioavailability than their inorganic counterparts; they can be included as a portion of supplemental trace mineral when known deficiencies exist and a rapid change in mineral status is needed (Greene, 2000). Conversely, MacPherson (2000) indicated that claims about organic TM have not been substantiated by unequivocal scientific evidence. Citing studies in which inorganic and chelated minerals were compared at the same feeding rates, that author claimed that no consistent productive benefit of chelates had been demonstrated.

Injectable Trace-Mineral Supplements

Daugherty et al. (2002) injected crossbred beef cows with a TM solution to evaluate the effects on reproductive performance and health and survival of subsequent offspring. Injectable TM products are thought to increase the consistency of mineral status compared to supplementing dietary minerals via self-fed, salt-based, granular products. Cows were assigned randomly to control (saline) or TM/vitamin E injections (0.18, 0.18, 0.09, and 0.05 mg/lb BW of Cu, Zn, Mn, and Se, respectively and 2.8 IU/lb BW of vitamin E). Trace mineral/Vitamin E-injected cows had greater liver Cu status than saline-treated cows. Despite increased Cu status, the TM/vitamin E treatment had no effect on conception rates of cows, survival rates of calves, or passive immune status of calves.

During shipping and receiving, calves may exhibit temporal deficiencies in certain trace minerals. Hansen (2010a) examined the effect of an injectable TM supplement on trace mineral status of Angus and Simmental calves. Ten Angus and 10 Simmental calves were blocked by breed and initial BW. Calves were either injected with a TM solution (MIN) or sterilized saline (CON) at a dose of 1 mL/45 kg BW. The TM solution contained 60 mg Zn/mL, 10 mg Mn/mL, 15 mg Cu/mL, and 5 mg Se/mL.

Plasma concentrations of Mn, Se, Cu, and Zn were greater on d1 in MIN calves compared to those in the CON group. Plasma Se remained elevated through d 8 in MIN calves; however, plasma concentrations of Cu, Zn, and Mn were not different between treatments by d 8 post-injection. On d 1, liver Cu, Se, and Zn concentrations were greater in MIN calves than in

CON calves. Liver concentrations of Cu and Se in MIN calves remained elevated throughout the 8-d period of measurement, while Zn concentrations declined after d 1.

Under the same experimental conditions as the previous study, Hansen et al. (2010b) examined the effects of cattle breed on the rate of TM metabolism in calves injected with a TM solution or saline. Simmental calves had lesser plasma Cu at 10 h post injection than the Angus calves. Simmental calves tended also to have greater plasma Mn concentrations on d 1 and greater liver Mn concentrations on d 15 compared to the Angus calves. In summary, Angus calves appeared to metabolize Mn at a faster rate than Simmental calves.

In a similar study, Berry et al. (2000) studied the efficacy of injecting stressed cattle with a TM solution in order to alleviate sickness and improve feedlot performance. Crossbred bull calves (n = 141) were assigned randomly to receive an injectable TM solution or to receive no injection (control). All cattle received the same diet *ad libitum*. Calves that received the injectable TM had greater feed intake from d 29 to 42 of the receiving period when compared to the calves that were not injected. Injectable TM tended to improve feed efficiency, ADG, and decrease sickness when compared to the control treatment.

Richeson et al. (2009) evaluated the effects of 2 sources of supplemental, injectible TM on stressed cattle. Ninety crossbred heifer calves were blocked by initial BW and assigned randomly to 1 of 3 treatment pens. Pens were assigned randomly to treatment: 1) Inject-A-Min® trace mineral injection on d 0 (ITM; 1 mL/100 lb); 2) Mineral Max II® trace mineral injection on d 0 (MTM; 1 mL/100 lb); or 3) negative control (no injection; CON). The ITM injection provided 20 mg Zinc/mL, 20 mg Mn/mL, 5 mg Se/mL, and 10 mg Cu/mL. The MTM injection provided 48 mg Zn/mL, 10 mg Mn/mL, 5 mg Se/mL, and 16 mg Cu/mL. Heifers receiving either TM injection had greater ADG and feed efficiency than the animals in the CON group. There were no differences in ADG and feed efficiency between the two supplemental TM injections. Similarly, calves receiving a TM injection showed fewer signs of morbidity than their untreated counterparts.

Clark et al. (2006) studied the effects of a single bolus dose of Cu, Se, Mn, and Zn on receiving and finishing performance of preconditioned and non-preconditioned steer calves (n = 189). Steers were considered to be at low (LO) or high (HI) risk for developing respiratory disease. All cattle from each of the LO and HI groups were assigned randomly to receive either a 5 mL subcutaneous injection of TM or a subcutaneous injection of saline. Each TM injection provided 75 mg of Cu, 25 mg of Se, 50 mg of Mn, and 200 mg of Zn. Calves that received the TM injection gained less during the receiving period than steers injected with saline. In contrast, the TM injection was associated with increased gain:feed during the finished period compared to the saline injection. There were no differences in finishing ADG or carcass characteristics between treatments.

Fisher et al. (2008) evaluated the efficacy of injectable TM and growth-promoting implants for overcoming mineral deficiencies, poor growth, and poor health in weaned beef calves. Heifers (n = 131) were allotted randomly to 1 of 4 treatments: 1) control (no mineral injection, no implant); 2) injection of TM (40 mg/mL Zn, 10 mg/mL Mn, 5 mg/mL Se, and 15 mg/mL Cu) + no implant; 3) no mineral injection + a 36-mg zeranol implant; and 4) injection of TM + a 36-mg zeranol implant. There were no differences in ADG between TM-treated and untreated calves; however, TM-treated calves had greater GSH-Px activity values than untreated calves. In addition, implanted calves gained more weight than non-implanted calves.

Conclusions

In summary, TM supplementation has variable effects on beef cow and calf productivity. Supplementing beef cow diets with either specific minerals or broad-spectrum mineral products is usually associated with improved mineral status as measured via liver, plasma, or blood mineral concentrations. In contrast, cow or calf performance seems to be only rarely changed or improved. Inconsistent performance responses to traditional types of TM supplementation could be the result of varying mineral levels in feedstuff and soils across different regions of the world. Alternatively, inconsistent responses to TM supplementation may be related to sporadic intake of conventional, self-fed, salt-based TM supplements (Olson, 2007). Arthington and Swenson (2004) evaluated the performance and mineral status of grazing cows offered self-fed or hand-fed organic or inorganic TM supplements. Voluntary intake of self-fed TM supplements was 23% less than intake of hand-fed supplements. As a result, cows that were self-fed TM had less liver Zn and Cu than cows that were hand-fed TM; however, feeding method had no effect on cow BW, cow BCS, calf BW, or calf WW. Variation in mineral intake may be even greater among beef cows fed in confinement. Ominski et al. (2006) reported that voluntary intake of a self-fed TM supplement by beef cows maintained in a drylot was 32% greater than that of a hand-fed TM supplement. In addition, the coefficient of variation in intake of self-fed TM from day to day was 81%, whereas intake of hand-fed TM did not vary.

Organic TM supplements may be absorbed with greater efficiency from the gut than conventional inorganic TM supplements; however, performance responses by beef cattle have been inconsistent. Organic minerals are advertised as helpful for improving fertility, uterine health, calf performance, and calf immune function compared to inorganic minerals; however, results of studies in which organic and inorganic minerals were compared at similar feeding rates show no consistent benefit for organic TM.

Injecting cattle with a bolus dose of TM has been hypothesized to increase the consistency of TM intake, improve animal performance, and reduce waste compared to supplementing self-fed TM. In some cases, beef calves treated with injectable TM had greater ADG, feed efficiency, and immune response compared to untreated calves. In beef cows, TM injections increased liver Cu concentrations but had no effect on conception, calf survival, or calf passive immune function. Provided injectable TM products are competitively priced compared to self-fed TM products, this method of TM supplementation shows promise and warrants further investigation.

Literature Cited

AAFCO. 2000. Official Publication. Association of American Feed Control Officials, Inc., Oxford, IN.

Ahola, J. K., D. S. Baker, P. D. Burns, R. G. Mortimer, R. M. Enns, J. C. Whittier, T. W. Geary, and T. E. Engle. 2004. Effect of copper, zinc, and manganese supplementation and source on reproduction, mineral status, and performance in grazing beef cattle over a two-year period. J. Anim. Sci. 82:2375-2383.

Arthington, J. D., R. L. Larson, and L. R. Corah. 1995. The effects of slow-release copper boluses on cow reproductive performance and calf growth. Prof. Anim. Sci. 11:219-222.

Arthington, J. D., and F. M. Pate. 2002. Effect of corn- vs molasses-based supplements on trace mineral status of beef heifers. J. Anim. Sci. 80:2787-2791.

Arthington, J. D., and C. K. Swenson. 2004. Effects of trace mineral source and feeding method on the productivity of grazing Braford cows. Prof. Anim. Sci. 20:155-161.

Bailey, J. D., R. P. Ansotegui, J. A. Paterson, C. K. Swenson, and A. B. Johnson. 2001. Effects of supplementing combinations of inorganic and complexed copper on performance and liver mineral status of beef heifers consuming antagonists. J. Anim. Sci. 79:2926-2934.

Berry, B. A., W. T. Choat, D. R. Gill, C. R. Krehbeil, and R. Ball. 2000. Efficacy of Multimin™ in improving performance and health in receiving cattle. 2000 Anim. Sci. Rep. Oklahoma Agr. Exp. Sta. Available at: http://www.ansi.okstate.edu/research/research-reports-1/2000/2000-1%20Berry%20Research%20Report.pdf. Accessed 04/11/2011.

Brown, T. F., and L. K. Zeringue. 1994. Laboratory evaluations of solubility and structural integrity of complexed and chelated trace mineral supplements. J. Dairy Sci. 77:181-189.

Clark, J. H., K. C. Olson, T. B. Schmidt, R. L. Larson, M. R. Ellersieck, D. O. Alkire, D. L. Meyer, G. K. Rentfrow, and C. C. Carr. 2006. Effects of respiratory disease risk and a bolus injection of trace minerals at receiving on growing and finishing performance by beef steers. Prof. Anim. Sci. 22:245-251.

Daugherty, S. R., G. E. Carstens, D. B. Herd, K. S. Barling, and R. D. Randel. (2002) Effects of prenatal and prebreeding trace mineral/Vitamin E injections on calf health and reproductive performance of beef cows. Texas A&M 2002/2003 Beef Cattle Research in Texas, pages 39-43.

Dent, W. E., H. B. Howell, F. W. Adams, and J. P. Mehlig. 1956. Growth performance and blood and liver copper values in Hereford calves offered certain mineral elements free choice. J. Anim. Sci. 15:1103-1111.

DiCostanzo, A., J. C. Meiske, S. D. Plegge, D. L. Haggard, and K. M. Chaloner. 1986. Influence of manganese, copper, and zinc on reproductive performance of beef cows. Nutrition Reports International. 34:287-293.

Doyle, J. C., J. E. Huston, and D. W. Spiller. 1988. Influence of phosphorus and trace mineral supplementation on reproductive performance of beef cattle under range conditions. J. Anim. Sci. . 66(Suppl. 1):462.

Fisher, A. E., W. W. Gill, C. D. Lane, Jr., R. L. Ellis, S. B. Blezinger, and G. M. Pighetti. 2008. Evaluation of Multimin™ to enhance weaned calf productivity. Journal of Anim. Sci. 86 (Suppl. 1): 197-198.

Greene, L. W. 2000. Designing mineral supplementation of forage programs for beef cattle. J. Anim. Sci. 78(E-Suppl.):E13-22.

Gunter, S. A., P. A. Beck, and J. M. Phillips. 2003. Effects of supplementary selenium source on the performance and blood measurements in beef cows and their calves. J. Anim. Sci. 81:856-864.

Hansen, S. L. 2010a. Effects of Multimin®90 on trace mineral status of Angus and Simmental calves. Animal Science Research Report, Iowa State University. Available at: http://www.multiminglobal.com/usa/viewTrial.asp?DocID=8. Accessed 04/11/2011.

Hansen, S. L., E. L. Richter, and M. E. Drewnoski. 2010b. Angus and Simmental calves exhibit differential trace mineral metabolism. J. Anim. Sci. 88(E-Suppl. 2):298.

Ho, S. K., M. Hidiroglou, J. M. Wauthy, K. J. Jenkins, and J. Proulx. 1977. Effects of a chelated trace mineral supplement on the copper and iron status of wintering pregnant beef cows fed hay or grass silage. Can. J. Anim. Sci. 57:727-734.

Koller, L. D., G. A. Whitbeck, and P. J. South. 1984. Transplacental transfer and colostral concentrations of selenium in beef cattle. Am. J. Vet. Res. 45:2507-2510.

Kropp, J. R. 1990. Reproductive performance of first calf heifers supplemented with amino acid chelate minerals, pp 35-43Oklahoma Agric. Exp. Sta. Anim. Sci. Res. Rep. MP-129.

Lamb, G. C., D. R. Brown, J. E. Larson, C. R. Dahlen, N. DiLorenzo, J. D. Arthington, and A. DiCostanzo. 2008. Effect of organic and inorganic trace mineral supplementation on follicular response, ovulation, and embryo production in superovulated Angus heifers. Anim. Repro. Sci. 106:221-231.

MacPherson, A. 2000. Trace-mineral status of forages. Pages 345-371 in Forage Evaluation in Ruminant Nutrition. D. I. Givens, E. Owen, R.F.E. Axford, and H. M. Omed, eds. CABI Publishing, New York, pp. 345-71.

Manickam, R., C. A. Gopalakrishnan, G. Ramanathan, M. Mookkappan, and R. Nagarajan. 1977. Studies on the relationships between trace elements and fertility in cows. Indian J. Anim. Res. 11:23-28.

Manspeaker, J. E., M. G. Robl, G. H. Edwards, and L. W. Douglass. 1987. Chelated minerals: Their role in bovine fertility. Vet. Med. 82: 951-952 & 954-956.

Mayland, H. F., R. C. Rosenau, and A.R. Florence. 1980. Grazing cow and calf response to zinc supplementation. J. Anim. Sci. 51:966-974.

McDowell, L. R. 1985. Free-choice mineral supplementation and methods of mineral evaluation. Pages 383-407 in Nutrition of Grazing Ruminants in Warm Climates. L. R. McDowell, ed. Academic Press, San Diego, CA.

Muehlenbein, E. L., D. R. Brink, G. H. Deutscher, M. P. Carlson, and A. B. Johnson. 2001. Effects of inorganic and organic copper supplemented to first-calf cows on cow reproduction and calf health and performance. J. Anim. Sci. 79:1650-1659.

NRC. 2000. Nutrient Requirements of Beef Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Olson, K. C. 2007. Management of mineral supplementation programs for cow-calf operations. Pages 69-90 in Veterinary Clinics of North American Food Animal Practice, Volume 23, Number 1: Cow Calf Nutrition and Management. K. Olson and L. Hollis, eds. Elsevier Saunders, Philadelphia, PA.

Olson, P. A., D. R. Brink, D. T. Hickok, M. P. Carlson, N. R. Schneider, G. H. Deutscher, D. C. Adams, D. J. Colburn, and A. B. Johnson. 1999. Effects of supplementation of organic and inorganic combinations of copper, cobalt, manganese, and zinc above nutrient requirement levels on postpartum two-year-old cows. J. Anim. Sci. 77:522-532.

Ominski, K. H., D. A. Boadi, and K. M. Wittenberg. 2006. Utilization of fortified cubes to deliver trace minerals and monensin in forage-based diets. Can. J. Anim. Sci. 86:291-298.

Pehrson, B., K. Ortman, N. Madjid, and U. Trafikowska. 1999. The influence of dietary selenium as selenium yeast or sodium selenite on the concentration of selenium in the milk of suckler cows and on the selenium status of their calves. J. Anim. Sci. 77:3371-3376.

Richeson, J. T., E. B. Kegley, D. L. Galloway, Sr., and J. A. Hornsby. 2009. Supplemental trace minerals from injection for shipping-stressed cattle. Arkansas Animal Science Department Report. AAES Research Series 574, pp 85-88. University of Arkansas – Fayetteville. Available at: http://arkansasagnews.uark.edu/574-24.pdf. Accessed on 04/11/2011. .

Rudert, C. P., and W. M. O'Donovan. 1976. The productivity of beef cows and their progeny when offered different mineral supplements over three breeding seasons. Rhod. J. Agric. Res. 14:3-10.

Stahlhut, H. S., C. S. Whisnant, and J. W. Spears. 2006. Effect of chromium supplementation and copper status on performance and reproduction of beef cows. Anim. Feed Sci. and Tech. 128:266-275.

Stanton, T. L., J. C. Whittier, T. W. Geary, C. V. Kimberling, and A. B. Johnson. 2000. Effects of trace mineral supplementation on cow-calf performance, reproduction, and immune function. Prof. Anim. Sci. 16:121-127.

Swenson, C. K., R. P. Ansotegui, E. J. Swensson, J. A. Paterson, and A. B. Johnson. 1998. Trace mineral supplementation effects on first-calf beef heifer reproduction, milk production and calf performance. Proc. West. Sec. Am. Soc. Anim. Sci. 49:327-331.

Valdes, J. L. L. R. McDowell, and M. Koger. 1988. Mineral status and supplementation of grazing beef cattle under tropical conditions in Guatemala. II. Microelements and animal performance. J. Prod. Agric. 1:351-355.

Waggoner, J. W., Jr., C. C. Kaltenbach, W. W. Smith, T. R. Varnell, D. H. Clark, S. L. Applegate, G. E. Nelms, and H. D. Radloff. 1979. Potassium in the winter supplement of range beef cows. Proc. West. Sec. Am. Soc. Anim. Sci. 30:284-286.

Chapter 2 – Effects of Pre-partum and Post-partum Bolus Injections of Trace Minerals on Performance of Beef Cows and Calves Grazing Native Range

L. R. Mundell*, J. R. Jaeger[†], J. S. Stevenson*, D. M. Grieger*, L. A. Pacheco*, J. W. Bolte[†], N. A. Aubel*, G. J. Eckerle*, M. J. Macek*, L. J. Havenga[‡], and K. C. Olson*

[*]Department of Animal Sciences and Industry, Kansas State University, Manhattan, KS, USA
[†]Western Kansas Agricultural Research Centers, Kansas State University, Hays, KS, USA
[‡]Multimin USA, Fort Collins, CO, USA

Abstract

Our objective was to evaluate the effects of pre- and post-partum bolus injections of a trace mineral solution on beef cow reproductive performance, BW change, and BCS change and on performance of suckling calves. Mature beef cows (n = 460; initial BW = 497 ± 89 kg, initial BCS = 5.4 ± 0.74) were stratified by BCS, age, parity, and predicted calving date and assigned randomly to 1 of 2 treatments: 1) s.c. trace mineral (**TM**) injection containing 15 mg/mL Cu, 5 mg/mL Se, 10 mg/mL Mn, and 60 mg/mL Zn or 2) s.c. injection of physiological saline (**SA**). Injections were administered to cows (1 mL / 90 kg BW) 105 d before the first projected calving date and again 30 d before fixed-time AI. Calves received the same treatment as their dams and were injected (1 mL / 45 kg BW) at birth and again at 71 ± 21 d of age. Cows grazed native pastures for the duration of the study; trace mineral supplements and white salt were available to all cattle *ad libitum* before and during the study. Ovulation was synchronized using a 5-d CO-Synch + CIDR protocol and cows were inseminated 60 to 64 h after CIDR removal. Cows were exposed to fertile bulls for natural-service breeding 10 d after AI for 35 to 50 d. Conception to AI and final pregnancy rate were assessed 36 d after AI with ultrasound and 120 d after AI via rectal palpation. Change in BW and BCS from initiation of the study to calving and from AI to weaning did not differ ($P \geq 0.15$) between TM and SA cows. Conversely, TM cows had greater ($P = 0.04$) BCS increase than SA cows between calving and AI. Calf BW at birth, ADG, and age-adjusted weaning BW did not differ ($P \geq 0.36$) between treatments. Proportion of cows with estrus cycles 17 and 8 d before ovulation synchronization was similar ($P \geq 0.51$) between treatments. Conception to AI was greater ($P = 0.05$) for cows receiving TM (60.2%) than for cows receiving SA (51.2%); however, overall pregnancy did not differ ($P = 0.24$) between treatments and averaged 92%. Under the conditions of our study, pre- and post-partum TM injections improved conception to fixed-time AI by beef cows.

Key words: beef cows, fixed-time AI, trace minerals

Introduction

Adequate dietary intakes of trace minerals are thought necessary in order to maximize cow reproduction, calf health, and calf performance. Diets grazed by beef cattle are generally deficient to marginal in Cu, Mn, Se, and Zn concentrations; therefore, these trace minerals are usually added to the diet in supplement form.

The most widely used means of trace-mineral supplementation for grazing cattle is the self-fed, salt-based, granular supplement (Greene, 2000). Even though cattle do not balance their mineral needs when consuming a self-fed mineral supplement (Dent et al., 1956), there is usually no other practical way of supplying mineral needs under grazing conditions (McDowell, 1985). The greatest limitation to using self-fed mineral supplements is variation in animal intake (Arthington and Swenson, 2004; Ominski et al., 2006). More direct methods of mineral supplementation include adding minerals to drinking water or feed, oral drenching, ruminal boluses, and injection. Variation in mineral intake is reduced relative to self-fed supplementation and the additional labor requirement and expense are relatively small (Olson, 2007).

Delivery of supplemental trace minerals using an injectable solution may be a more reliable means of achieving adequate trace-mineral status than using self-fed, salt-based, granular mineral supplements. Bolus injections of trace minerals (**TM**) were associated with improved ADG, feed efficiency, DMI, or health status of beef calves fed in confinement (Berry et al., 2000; Clark et al., 2006; Richeson et al., 2009); however, TM delivery methods of this type have not been fully evaluated with respect to performance of beef cows and suckling calves. The objective of our study was to evaluate the effects of pre- and post-partum bolus injections of a trace mineral solution on beef cow reproductive performance, BW change, and BCS change and on performance of suckling calves.

Materials and Methods

All procedures involving the handling and care of animals used in our experiment were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol # 2650).

Angus × cows and heifers (n = 460; initial BW 497 ± 89 kg) managed in 2 locations were used in our study (193 cows and 81 heifers at Manhattan, KS and 132 cows and 54 heifers at Hays, KS). At the end of December 2009, cows were stratified by BCS (1 = emaciated, 9 =

obese), parity, and predicted calving date and assigned randomly to 1 of 2 treatments: 1) subcutaneous injection with a trace mineral solution (**TM;** Table 2.1) or 2) subcutaneous injection with autoclaved physiological saline (**SA**). Injections were administered to cows (1 mL / 90 kg BW) 105 d before the first projected calving date and again approximately 30 d before fixed-time AI. Calves received the same treatment as their dams and were injected (1 mL / 45 kg BW) at birth and again at 71 ± 21 d of age.

Within location, cows and heifers were managed as a single group from 12/17 through the end of the calving season. In Manhattan, cows were evenly distributed by treatment and parity into 5 native pastures on May 15; in Hays, cows were evenly distributed by treatment and parity into 2 native pastures on May 1. Cows grazed assigned pastures until October 5; self-fed TM supplements (19% Ca, 6.5% P, 17% NaCl, 1300 ppm Cu, 26 ppm Se, and 2,000 ppm Zn) and white salt were available to all cattle *ad libitum* for a minimum of 12 mo before and throughout the study. Availability of self-fed TM and white salt were visually verified on a daily basis.

Cow BW and BCS measurements were obtained 105 d before the first projected calving date, at calving, at the time of fixed-time AI, and at weaning. Calf BW measurements were recorded at birth, on 06/16, and at weaning.

Blood samples were collected from each cow 17 and 8 d before fixed-time AI via jugular venipuncture and immediately placed on ice. Samples were allowed to clot for 24 h at 4 °C and centrifuged (1,500 × *g*) for 10 min. Serum was decanted into 12 × 75 mm plastic tubes and immediately frozen (-20 ºC). Concentration of progesterone in serum was subsequently quantified by RIA (Skaggs et al., 1986). Intra- and inter-assay CV were 7.0 and 7.9%, respectively. When samples contained concentrations of progesterone ≥ 1 ng/mL cows were considered to be cycling.

Ovulation was synchronized using a 5-d Co-synch + CIDR protocol and cows were inseminated 60 to 64 h after CIDR removal (Figure 1). Cows were exposed to fertile bulls for natural-service breeding beginning 10 d after fixed-time AI for 35 d in Hays and 50 d in Manhattan. Conception to fixed-time AI was determined via ultrasound 36 d after AI and final pregnancy rate was determined via rectal palpation 120 d after AI.

Cow and calf performance were analyzed as a randomized complete block. The original model included effects for treatment, location, and pasture. Treatment within location was considered the experimental unit. Pasture effects and associated interactions were not significant and were removed from the model. Treatment × location effects were not detected. When protected by a significant F-test ($P < 0.05$), Least Squares treatment means were separated using the method of Least Significant Difference.

Pregnancy rates were analyzed using PROC CATMOD (SAS Inst. Inc., Cary, NC). The original model used to assess differences in fixed-time AI pregnancy rates and overall pregnancy rates included effects for treatment, parity, location, and pasture. Pasture effects and associated interactions were not significant and were removed from the model. Treatment × location effects and parity effects were not detected. Least Squares means for pregnancy rates were reported. Treatment differences in performance and pregnancy data were discussed when $P \leq 0.05$.

Results and Discussion

Change in cow BW and BCS from initiation of the study to calving and from AI breeding to weaning did not differ ($P \geq 0.15$) between cows injected with TM and cows injected with saline (**SA**; Tables 2.2 & 2.3). Conversely, TM cows had greater ($P = 0.04$) BCS increase than SA cows between calving and AI. Effects of TM supplementation on cow BW and BCS have been inconsistent. Gunter et al. (2003) examined the effects of Se supplementation and Se source on performance, reproduction, and blood parameters in gestating and lactating beef cows fed grass hay and pasture that were marginally deficient in Se. Cow BW and cow BCS did not differ between supplemented and unsupplemented cows. Doyle et al. (1988) also studied the effects of TM supplementation on performance of beef cows under range conditions and reported that body condition scores and adjusted WW were not influenced by treatment. Similarly, Arthington and Swenson (2004) evaluated the effects of organic or inorganic TM fed either *ad libitum* or on a restricted basis and reported that TM source and feeding method had no effect on cow BW or BCS. In contrast, Manickam et al. (1977) measured the Fe, Cu, Mn, and Zn contents of whole blood and plasma in cows with varying histories of reproductive success. In whole blood of cows with a history of early conception, all 4 trace elements were present in greater concentration than in whole blood of cows with a history of delayed conception. More favorable TM status was associated with greater post-partum body condition as well.

Proportion of cows with estrus cycles 17 or 8 d prior to timed AI was similar ($P \geq 0.51$) between treatments. In contrast, conception to fixed-time AI was greater ($P = 0.05$) for cows receiving TM (60.2%) than for cows receiving SA (51.2%); however, overall pregnancy did not differ ($P = 0.24$) between treatments and averaged 92% (Table 2.4). The strong timed-AI response to TM injection was not anticipated because all cows in our study had *ad libitum* access to self-fed oral TM supplements and white salt for a minimum of 12 mo prior to our study and during our study. Consumption of self-fed TM on a per-pasture basis was within manufacturer recommendations before and during our study; therefore, we speculated that the TM status of individual cows may not have been optimal due to non-consumption or erratic intake of self-fed TM supplement.

As with gross measures of beef cow performance, the effects of oral TM supplementation on cow reproductive performance appear inconsistent (Olson et al., 1999; Stanton et al., 2000; Vanegas et al., 2004; Ahola et al., 2004; Olson, 2007; Sales et. al 2011). DiCostanzo et al. (1986) studied the effects of supplemental Mn alone or a combination of supplemental Mn, Cu, and Zn on reproductive performance of beef cows and heifers fed corn silage-based diets. Heifers treated with supplemental Mn returned to estrus sooner and conceived earlier during the breeding season than heifers supplemented with the combination of Mn, Cu, and Zn or unsupplemented heifers. Treatment did not influence days to first estrus in cows; however, the combination of Mn, Cu, and Zn tended to reduce days to conception compared to supplemental Mn alone and no supplemental TM.

Muehlenbein et al. (2001) examined the effects of organic and inorganic Cu supplementation on reproductive efficiency of heifers and reported that overall conception rates were not different compared to unsupplemented heifers. Similarly, Arthington et al. (1995) indicated that reproductive performance of beef cows with a documented Cu deficiency did respond to supplemental Cu. Other researchers indicated also that supplementation with specific minerals of interest or with broad-spectrum TM supplements did not change reproductive performance of cows compared to unsupplemented cows (Doyle et al., 1988; Gunter et al., 2003; Stahlhut et al., 2006). In certain cases, TM supplementation at supra-nutritional levels may be associated with decreased reproductive performance by beef cows (Olson et al., 1999).

Inconsistent responses to TM supplementation may be related to sporadic intake of conventional, self-fed, salt-based TM supplements (Olson, 2007). Arthington and Swenson (2004) evaluated the performance and mineral status of grazing cows offered self-fed or hand-fed organic or inorganic TM supplements. Voluntary intake of self-fed TM supplements was

23% less than intake of hand-fed supplements. As a result, cows that were self-fed TM had less liver Zn and Cu than cows that were hand-fed TM; however, feeding method had no effect on cow BW, cow BCS, calf ADG, or calf weaning BW. Variation in mineral intake may be even greater among beef cows fed in confinement. Ominski et al. (2006) reported that voluntary intake of a self-fed TM supplement by beef cows maintained in a drylot was 32% greater than the minimum amount needed to meet animal requirements. In addition, the coefficient of variation in intake of self-fed TM from day to day was 81%, whereas intake of hand-fed TM did not vary.

Injectable TM supplements may be useful for increasing the consistency of TM delivery to beef cows compared to self-fed TM supplements and may have particular value for increasing TM status immediately prior to calving and breeding. Few studies have been conducted on this topic; moreover, available reports conflict. Sales et al. (2011) reported that crossbreed heifers subcutaneously injected with a TM product similar to the one used in our study had a 1.72 fold greater chance of becoming pregnant to timed embryo transfer compared to unsupplemented counterparts. Heifers treated with injectable TM in that study had greater implantation rates 23 and 48 d after embryo transfer than untreated heifers. In contrast, Vanegas et al. (2004) reported that treatment of dairy cows with an injectable TM solution before calving and before breeding resulted in decreased first-service conception compared to untreated cows. Daugherty et al. (2002) treated crossbred beef cows with a bolus injection of Cu, Zn, Mn, Se, and vitamin E. Cows receiving TM + vitamin E had greater serum concentrations of Cu than unsupplemented cows. Despite increased Cu status, the TM + vitamin E treatment had no effect on conception rates of cows.

Calf BW at birth was not different ($P > 0.91$) between treatments (Table 2.5). Calf ADG from birth to 06/16, from 06/16 to weaning, and from birth to weaning were not different ($P \geq 0.36$) also between TM and SA. Similarly, adjusted 205-day BW was not different ($P = 0.48$) between treatments. Evaluations of injectable TM supplements given to suckling calves appear to be few in number. Daugherty et al. (2002) injected crossbred beef cows with a TM solution in order to evaluate effects on health of the subsequent calf crop. In spite of documented improvements in cow TM status, treatment of cows with injectable TM had no effects on survival rates or passive immune status of calves.

Calf responses to injectable TM supplements appear to have been more widely evaluated in confined feeding situations. During shipping and receiving, calves may exhibit temporal deficiencies in certain TM. Berry et al. (2000) studied the efficacy of injecting stressed cattle with a TM solution in order to ameliorate shipping stress and to improve feedlot performance. Calves that received injectable TM had greater feed intake during receiving when compared to calves that were not injected. Injectable TM tended also to improve feed efficiency, improve ADG, and decrease incidence of illness when compared to untreated calves. Similarly, Richeson et al. (2009) evaluated the effects of 2 sources of supplemental, injectible TM on stressed heifers. Heifers receiving either TM product had greater ADG and feed efficiency than untreated animals; moreover, calves receiving either TM product showed fewer signs of morbidity than their untreated counterparts. Clark et al. (2006) examined the effects of a single bolus dose of Cu, Se, Mn, and Zn on receiving and finishing performance of steer calves. Calves that received the TM injection gained less weight during the receiving period than steers injected with saline. In contrast, the TM injection was associated with increased gain:feed during the finished period compared to the saline injection. There were no differences in finishing ADG or carcass characteristics between treatments.

Implications

Under the conditions of our study, pre- and post-partum TM injections improved conception to fixed-time AI by beef cows. Supplementing trace minerals to beef cows using an injectable solution may be a more reliable way of assuring adequate trace-mineral status than offering a self-fed, salt-based, granular mineral supplement alone; however, further research is warranted to substantiate this idea. At the time of this writing, cost of the injectable TM product used in our study was approximately $0.40 USD/mL (L. J. Havenga, 2011, Multimin USA, Ft Collins, CO, personal communication). Cost per dose (1 mL/90 kg BW) for a beef cow weighing 540 kg was $2.40 USD and total treatment cost (i.e., 2 doses) for a beef cow weighing 540 kg, as described in our study, was $4.80 USD.

Figure 2.1 Design of ovulation synchronization and timed-AI breeding protocols

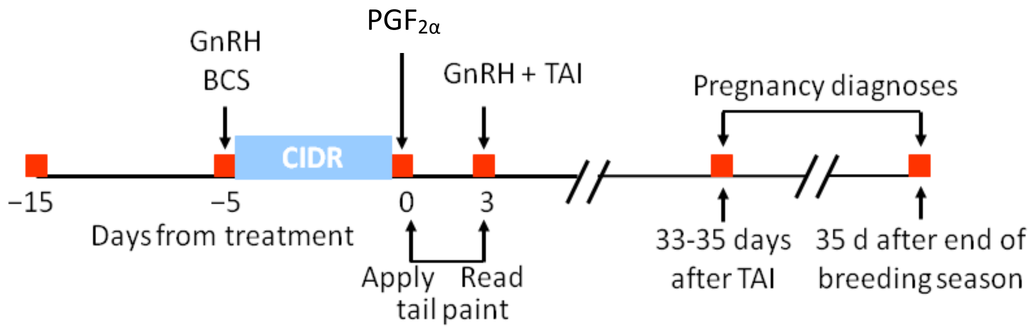

Table 2.1 Composition of injectable trace mineral solution administered pre- and post-partum to beef cows and at birth and 71 ± 21 d of age to beef calves

Item	Multimin®90[a]
Zinc	60 mg/mL
Manganese	10 mg/mL
Selenium	5 mg/mL
Copper	15 mg/mL

[a] Multimin USA, Ft Collins, CO

Table 2.2 Effects of pre- and post-partum bolus injections of either a trace-mineral solution or physiological saline (1 mL/90 kg BW) on body weight and body weight change of beef cows grazing native range

	Treatment			
Item	Saline	Trace Mineral [a]	SE	*P*-value
Cow BW, kg[b]				
Pregnancy check	502.3	502.6	2.62	0.97
Parturition	494.3	494.0	2.52	0.96
AI breeding	532.7	533.0	3.64	0.98
Weaning	538.9	540.9	5.62	0.83
Cow BW change, kg				
Pregnancy check to parturition	-7.9	-8.7	0.04	0.85
Parturition to AI breeding	38.4	39.2	1.51	0.81
AI breeding to weaning	43.5	45.9	2.72	0.59

[a] Multimin® 90, Multimin USA, Ft Collins, CO.
[b] Cow body weights were measured at pregnancy check (12/17), parturition (average date = 04/06), AI breeding (06/16), and weaning (10/29).

Table 2.3 Effects of pre- and post-partum bolus injections of either a trace-mineral solution or physiological saline (1 mL/90 kg BW) on body condition score and body condition score change of beef cows grazing native range

	Treatment			
Item	Saline	Trace Mineral [a]	SE	*P*-Value
Cow BCS [b, c]				
Pregnancy check	5.51	5.45	0.009	0.29
Parturition	5.17	5.08	0.004	0.13
AI breeding	5.44	5.47	0.029	0.66
Weaning	5.29	5.28	0.003	0.94
Cow BCS change				
Pregnancy check to parturition	-0.34	-0.37	0.013	0.57
Parturition to AI breeding	0.26	0.38	0.021	0.04
AI breeding to weaning	0.10	0.19	0.008	0.15

[a] Multimin® 90, Multimin USA, Ft Collins, CO.

[b] Body condition score units, 1 to 9 scale (1 = emaciated, 9 = morbidly obese).

[c] Cow body condition scores were assigned at pregnancy check (12/17), parturition (average date = 04/06), AI breeding (06/16), and weaning (10/29).

Table 2.4 Effects of pre- and post-partum bolus injections of either a trace-mineral solution or physiological saline (1 mL/90 kg BW) on reproductive performance of beef cows grazing native range

	Treatment			
Item	Saline	Trace Mineral [a]	SE	*P*-Value
Cows cycling before timed AI, %[b]	56.3	59.5	0.04	0.51
Timed-AI pregnancy, %[c]	51.2	60.2	0.03	0.05
Final pregnancy, %[d]	89.9	93.0	0.02	0.24

[a] Multimin® 90, Multimin USA, Ft Collins, CO.
[b] Determined from serum samples collected 17 and 8 d before timed AI.
[c] Proportion of cows classified as being pregnant from timed AI only.
[d] Proportion of cows classified as being pregnant from either timed AI or natural-service breeding.

Table 2.5 Performance of beef calves treated at birth and at 71 ± 21 d of age with bolus injections of either a trace mineral solution or physiological saline (1 mL/45 kg BW)

	Treatment			
Item	Saline	Trace Mineral [a]	SE	*P*-Value
Calf BW, kg[b]				
Birth	38.4	38.4	0.01	0.92
AI breeding	147.2	146.2	0.26	0.90
Weaning	212.8	209.1	0.98	0.28
Adjusted 205-d BW[c]	231.5	229.0	0.86	0.48
ADG, kg				
Early season (birth to 06/16)	0.94	0.94	0.004	0.89
Late season (06/16 to weaning)	0.91	0.89	0.010	0.36
Overall (birth to weaning)	0.94	0.93	0.005	0.48

[a] Multimin® 90, Multimin USA, Ft Collins, CO
[b] Calf body weights were measured at birth (average date = 04/06), AI breeding of cows (06/16), and weaning (10/29).
[c] Adjusted 205-d BW = birth BW × 205 × overall ADG.

Literature Cited

Ahola, J. K., D. S. Baker, P. D. Burns, R. G. Mortimer, R. M. Enns, J. C. Whittier, T. W. Geary, and T. E. Engle. 2004. Effect of copper, zinc, and manganese supplementation and source on reproduction, mineral status, and performance in grazing beef cattle over a two-year period. J. Anim. Sci. 82:2375-2383.

Arthington, J. D., R. L. Larson, and L. R. Corah. 1995. The effects of slow-release copper boluses on cow reproductive performance and calf growth. Prof. Anim. Sci. 11:219-222.

Arthington, J. D., and C. K. Swenson. 2004. Effects of trace mineral source and feeding method on the productivity of grazing Braford cows. Prof. Anim. Sci. 20:155-161.

Bailey, J. D., R. P. Ansotegui, J. A. Paterson, C. K. Swenson, and A. B. Johnson. 2001. Effects of supplementing combinations of inorganic and complexed copper on performance and liver mineral status of beef heifers consuming antagonists. J. Anim. Sci. 79:2926-2934.

Berry, B. A., W. T. Choat, D. R. Gill, C. R. Krehbeil, and R. Ball. 2000. Efficacy of Multimin™ in improving performance and health in receiving cattle. 2000 Anim. Sci. Rep. Oklahoma Agr. Exp. Sta. Available at: http://www.ansi.okstate.edu/research/research-reports-1/2000/2000-1%20Berry%20Research%20Report.pdf. Accessed 04/11/2011.

Clark, J. H., K. C. Olson, T. B. Schmidt, R. L. Larson, M. R. Ellersieck, D. O. Alkire, D. L. Meyer, G. K. Rentfrow, and C. C. Carr. 2006. Effects of respiratory disease risk and a bolus injection of trace minerals at receiving on growing and finishing performance by beef steers. Prof. Anim. Sci. 22:245-251.

Daugherty, S. R., G. E. Carstens, D. B. Herd, K. S. Barling, and R. D. Randel. 2002. Effects of prenatal and prebreeding trace mineral/Vitamin E injections on calf health and reproductive performance of beef cows. Texas A&M 2002/2003 Beef Cattle Research in Texas, pages 39-43.

Dent, W. E., H. B. Howell, F. W. Adams, and J. P. Mehlig. 1956. Growth performance and blood and liver copper values in Hereford calves offered certain mineral elements free choice. J. Anim. Sci. 15:1103-1111.

DiCostanzo, A., J. C. Meiske, S. D. Plegge, D. L. Haggard, and K. M. Chaloner. 1986. Influence of manganese, copper, and zinc on reproductive performance of beef cows. Nutrition Reports International. 34:287-293.

Doyle, J. C., J. E. Huston, and D. W. Spiller. 1988. Influence of phosphorus and trace mineral supplementation on reproductive performance of beef cattle under range conditions. J. Anim. Sci. . 66(Suppl. 1):462.

Greene, L. W. 2000. Designing mineral supplementation of forage programs for beef cattle. J. Anim. Sci. 78(E-Suppl.):E13-22.

Gunter, S. A., P. A. Beck, and J. M. Phillips. 2003. Effects of supplementary selenium source on the performance and blood measurements in beef cows and their calves. J. Anim. Sci. 81:856-864.

Manickam, R., C. A. Gopalakrishnan, G. Ramanathan, M. Mookkappan, and R. Nagarajan. 1977. Studies on the relationships between trace elements and fertility in cows. Indian J. Anim. Res. 11:23-28.

McDowell, L. R. 1985. Free-choice mineral supplementation and methods of mineral evaluation. Pages 383-407 in Nutrition of Grazing Ruminants in Warm Climates. L. R. McDowell, ed. Academic Press, San Diego, CA.

Muehlenbein, E. L., D. R. Brink, G.H. Deutscher, M. P. Carlson, and A. B. Johnson. 2001. Effects of inorganic and organic copper supplemented to first-calf cows on cow reproduction and calf health and performance. J. Anim. Sci. 79:1650-1659.

NRC. 2000. Nutrient Requirements of Beef Cattle. 7th rev. ed. Natl. Acad. Press, Washington, DC.

Olson, K. C. 2007. Management of mineral supplementation programs for cow-calf operations. Pages 69-90 in Veterinary Clinics of North American Food Animal Practice, Volume 23, Number 1: Cow Calf Nutrition and Management. K. Olson and L. Hollis, eds. Elsevier Saunders, Philadelphia, PA.

Olson, P. A., D. R. Brink, D. T. Hickok, M. P. Carlson, N. R. Schneider, G. H. Deutscher, D. C. Adams, D. J. Colburn, and A. B. Johnson. 1999. Effects of supplementation of organic and inorganic combinations of copper, cobalt, manganese, and zinc above nutrient requirement levels on postpartum two-year-old cows. J. Anim. Sci. 77:522-532.

Ominski, K. H., D. A. Boadi, and K. M. Wittenberg. 2006. Utilization of fortified cubes to deliver trace minerals and monensin in forage-based diets. Can. J. Anim. Sci. 86:291-298.

Richeson, J. T., E. B. Kegley, D. L. Galloway, Sr., and J. A. Hornsby. 2009. Supplemental trace minerals from injection for shipping-stressed cattle. Arkansas Animal Science Department Report. AAES Research Series 574, pp 85-88. University of Arkansas – Fayetteville. Available at: http://arkansasagnews.uark.edu/574-24.pdf. Accessed on 04/11/2011. .

Rudert, C. P. and W. M. O'Donovan. 1976. The productivity of beef cows and their progeny when offered different mineral supplements over three breeding seasons. Rhod. J. Agric. Res. 14:3-10.

Sales, J. N. S., R. V. V. Pereira, R. C. Bicalho, P. S. Baruselli. 2011. Effect of injectable copper, selenium, zinc and manganese on the pregnancy rate of crossbreed heifers (*Bos indicus* x *Bos taurus*) synchronized for timed embryo transfer. Unpublished.

Skaggs, R. A., B. V. Able, and J. S. Stevenson. 1986. Pulsatile or continuous infusion of luteinizing hormone releasing hormone and hormonal concentrations in prepubertal beef heifers. J. Anim. Sci. 62:1034-1048.

Stahlhut, H. S., C. S. Whisnant, and J. W. Spears. 2006. Effect of chromium supplementation and copper status on performance and reproduction of beef cows. Anim. Feed Sci. and Tech. 128:266-275.

Stanton, T. L., J. C. Whittier, T. W. Geary, C. V. Kimberling, and A. B. Johnson. 2000. Effects of trace mineral supplementation on cow-calf performance, reproduction, and immune function. Prof. Anim. Sci. 16:121-127.

Valdes, J. L. L. R. McDowell, and M. Koger. 1988. Mineral status and supplementation of grazing beef cattle under tropical conditions in Guatemala. II. Microelements and animal performance. J. Prod. Agric. 1:351-355.

Vanegas, J. A., J. Reynolds, and E. R. Atwill. 2004. Effects of an injectable trace mineral supplement on first-service conception rate of dairy cows. J. Dairy Sci. 87:3665–3671.

Appendix A - Pre-treatment[a] serum mineral concentrations (± SD) of beef cows and calves

Item	Cu, ppm	Mn, ppb	Se, ppb	Zn, ppm
TM[b] Cows	0.9 ± 0.26	4.7 ± 4.32	98 ± 18.4	1.0 ± 0.43
TM[c] Calves	0.6 ± 0.21	22.8 ± 61.36	89 ± 56.0	1.1 ± 0.59
SA[d] Cows	1.0 ± 0.29	2.3 ± 0.56	93 ± 15.6	0.9 ± 0.19
SA[e] Calves	0.6 ± 0.13	4.2 ± 8.94	64 ± 9.7	1.0 ± 0.37
Normal Range	0.5 - 1.5	18 - 35	80 - 300	0.8 - 1.4

[a] Measured in blood samples collected on 12/17 for cows and blood samples collected at birth for calves.
[b] Cows treated with injectable trace-mineral supplement (1 mL/90 kg BW; Multimin® 90, Multimin USA, Ft Collins, CO).
[c] Calves treated with injectable trace-mineral supplement (1 mL/45 kg BW; Multimin® 90, Multimin USA, Ft Collins, CO).
[d] Cows treated injected with physiological saline (1 mL/90 kg BW).
[e] Calves treated injected with physiological saline (1 mL/45 kg BW).

Appendix B - Approximate cost of Multimin® 90 on 05/04/2011

Cow BW, kg	Dose,[a] mL/cow	Multimin®90 Cost,[b] $ USD/mL	Cost / dose, $ USD	Total treatment cost,[c] $ USD
450	5.0	0.40	2.00	4.00
500	5.6	0.40	2.24	4.48
550	6.1	0.40	2.44	4.88
600	6.7	0.40	2.68	5.36
650	7.2	0.40	2.88	5.76

[a] Manufacturer-recommended dose (1 mL/90 kg BW; Multimin® 90, Multimin USA, Ft Collins, CO).
[b] L. J. Havenga, 2011, Multimin USA, Ft Collins, CO, personal communication.
[c] Manufacturer-recommended dose frequency for beef cows (4 wk prior to parturition and 4 wk prior to breeding; Multimin USA, Ft Collins, CO).