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Effects of prepartum and postpartum bolus injections of trace minerals on performance of beef cows and calves grazing native range[1,2]

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ABSTRACT

Our objective was to evaluate the effects of pre- and postpartum bolus injections of a trace mineral solution on reproductive performance, BW change, and BCS change of beef cows and on growth of suckling calves. Mature beef cows (n = 460; initial BW = 497 ± 89 kg, initial BCS = 5.4 ± 0.74) managed in 2 locations were stratified by BCS, age, parity, and predicted calving date and assigned randomly to 1 of 2 treatments: 1) supplemental 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 of 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 of 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 72 h after CIDR removal. Cows were exposed to fertile bulls for natural-service breeding 10 d after AI for 50 d. Conception to AI and final pregnancy rate were assessed 36 d after AI via ultrasound and 120 d after AI via rectal palpation, respectively. 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 did 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 estrous cycles 17 and 8 d before fixed-time 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%). Final pregnancy rate did not differ ($P = 0.24$) between treatments and averaged 92%; however, calving distribution by TM-treated cows was more favorable ($P = 0.01$; i.e., calving was generally earlier) than calving distribution of SA-treated cows. Under the conditions of this study, pre- and postpartum trace-mineral injections improved conception to fixed-time AI and subsequent calving distribution of beef cows.

Key words: beef cow, fixed-time artificial insemination, trace mineral

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INTRODUCTION

Adequate dietary intakes of trace minerals are thought necessary to maximize cow reproduction, calf health, and calf performance. Native forages grazed by beef cattle are generally deficient to marginal in Cu, Mn, Se, and Zn concentrations (Umoh et al., 1982); therefore, these trace minerals are usually added to the diet in supplemental form. The most widely used means of trace-mineral supplementation for grazing cattle is the free-choice, salt-based, granular supplement (Greene, 2000). Even though cattle do not balance their mineral needs when consuming a free-choice mineral supplement (Dent et al., 1956), there are few other practical ways of supplying supplemental minerals under grazing conditions (McDowell, 1985). The greatest limitation to using free-choice 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 compared with free-choice 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 free-choice, salt-based, granular mineral supplements. Bolus injections of trace minerals 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 and Kegley, 2011); however, trace-mineral delivery methods of this type have not been fully evaluated with respect to performance of beef cows and suckling calves. The objective of this study was to evaluate the effects of pre- and postpartum bolus injections of a trace mineral solution on reproductive performance, BW change, and BCS change of beef cows and on growth 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 × Hereford 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). In December 2009, cows were stratified by BCS (1 to 9 scale: 1 = emaciated, 9 = obese; Wagner et al., 1988), parity, and predicted calving date and assigned randomly to 1 of 2 treatments: 1) supplemental s.c. injection with a trace-mineral solution (**TM**; Table 1) or 2) s.c. injection with sterile physiological saline (**SA**). Injections were administered to cows (1 mL/90 kg of BW) 105 d before the first projected calving date and 30 d before fixed-time AI. Calves received the same treatment as their dams and were injected (1 mL/45 kg of BW) at birth and at 71 ± 21 d of age.

Blood samples (10 mL) were collected via jugular venipuncture from 20 randomly selected cows assigned to each treatment at each location (n = 80) immediately before the first injection of either TM or SA, to estimate pretreatment serum concentrations of Cu, Mn, Se, and Zn (Table 2). Blood samples (10 mL) were collected also from 20 randomly selected calves assigned to each treatment at each location (n = 80) immediately after birth and before treatments were applied (Table 2). Blood samples were allowed to clot for 24 h at 4°C and centrifuged (1,500 × *g*; 25°C) for 10 min. Serum was decanted into 12 × 75 mm plastic tubes and immediately frozen (−80°C). Serum samples were analyzed subsequently for Cu, Mn, Se, and Zn concentration via inductively coupled plasma mass spectrometry (Varian ICP/MS/MS, Varian, Santa Clara, CA) using internal standards and control serum samples that bracketed the concentration range of each analyte (S. M. Ensley, unpublished data).

Table 1. Composition of injectable trace-mineral solution administered pre- and postpartum to beef cows and at birth and 71 ± 21 d of age to beef calves

Item	Multimin 90,[1] mg/mL
Zinc	60
Manganese	10
Selenium	5
Copper	15

[1]Multimin USA, Ft. Collins, CO.

Average pretreatment serum concentrations of Zn were within the normal range for cows and calves assigned to TM and SA (Puls, 1994; Herdt and Hoff, 2011; Table 2). Cows assigned to TM and SA had average pretreatment serum Cu and Se concentrations that were also within the normal range; however, calves assigned to TM and SA had average serum concentrations of Cu and Se at birth that were slightly below the normal range. Average pretreatment serum Mn was below normal for cows and calves assigned to TM and SA.

Within location, cows and heifers were managed as a single group from December 17, 2009, through the end of a 60-d calving season in 2010. In Manhattan, cows were stratified by treatment and parity and assigned randomly to 5 native pastures on May 15, 2010; in Hays, cows were stratified by treatment and parity and assigned randomly to 2 native pastures on May 1, 2010. Cows grazed assigned pastures until October 5, 2010; a free-choice trace-mineral supplement (19% Ca, 6.5% P, 17% NaCl, Mg 1.9%, 1,300 mg/kg Cu, 12 mg/kg Co, 60 mg/kg I, 2,000 mg/kg Mn, 26 mg/kg Se, and 2,000 mg/kg Zn) and white salt were available to all cattle ad libitum for a minimum of 12 mo before and throughout the study. Availability of free-choice trace mineral and

Table 2. Pretreatment[1] serum mineral concentrations (±SD) of beef cows and calves

Item	Cu, mg/kg	Mn, µg/kg	Se, µg/kg	Zn, mg/kg
TM[2] cows	0.9 ± 0.26	3.5 ± 1.84	98 ± 18.4	1.0 ± 0.43
TM[3] calves	0.6 ± 0.21	2.7 ± 1.46	68 ± 11.0	1.1 ± 0.59
SA[4] cows	1.0 ± 0.29	2.2 ± 0.52	93 ± 15.6	0.9 ± 0.19
SA[5] calves	0.6 ± 0.13	2.5 ± 0.80	64 ± 9.7	1.0 ± 0.37
Normal range[6]	0.7 to 1.5	6.0 to 70.0	70 to 300	0.8 to 1.4

[1]Measured in blood samples collected on December 17, 2009, for cows and blood samples collected at birth for calves.

[2]Cows treated with injectable trace-mineral supplement (1 mL/90 kg of BW; Multimin 90, Multimin USA, Ft. Collins, CO).

[3]Calves treated with injectable trace-mineral supplement (1 mL/45 kg of BW; Multimin 90).

[4]Cows injected with physiological saline (1 mL/90 kg of BW).

[5]Calves injected with physiological saline (1 mL/45 kg of BW).

[6]Adapted from Puls (1994) and Herdt and Hoff (2011).

white salt was verified visually on a daily basis.

Cow BW and BCS measurements were obtained 105 d before the first projected calving date (December 17, 2009), on the day individual cows calved (average calving date = April 6, 2010), at the time of fixed-time AI (June 16, 2010), and at weaning (October 29, 2010). At each time point, cow BCS was assigned by 3 trained observers that were blinded to treatment; the average of 3 scores was recorded. Calf BW was recorded at birth, on June 16, and at weaning.

Blood samples (10 mL) were collected from each cow 17 and 8 d before fixed-time AI via coccygeal venipuncture and immediately placed on ice. Samples were allowed to clot for 24 h at 4°C and centrifuged (1,500 × g; 25°C) for 10 min. Serum was decanted into 12 × 75 mm plastic tubes and immediately frozen (−20°C). Concentration of progesterone in serum was quantified subsequently by RIA (Skaggs et al., 1986). Intra- and interassay CV were 7.0 and 7.9%, respectively. If either or both samples contained concentrations of progesterone ≥1 ng/mL, cows were considered to have established estrous cycles after calving.

Ovulation was synchronized using a 5-d CO-Synch + CIDR protocol, and cows were inseminated 72 h after CIDR removal. Cows were exposed to fertile bulls for natural-service breeding beginning 10 d after fixed-time AI for 50 d. 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. Subsequent calving dates were recorded to establish distribution over a 60-d calving season.

Cow and calf performance were analyzed by ANOVA (PROC GLM; SAS Institute Inc., Cary, NC) as a randomized complete block design. The original model included effects for treatment, location, and pasture. Pasture effects and associated interactions were not significant ($P \geq 0.67$) and were removed from the model. Treatment × location effects were not detected ($P \geq 0.26$).

Pregnancy rates and calving distribution were analyzed using logistic regression (PROC CATMOD in SAS). The original model used to assess differences in fixed-time AI pregnancy rates, final pregnancy rates, and calving distribution included effects for treatment, parity, location, and pasture. Pasture effects and associated interactions were not significant ($P \geq 0.49$) and were removed from the model. Treatment × location effects and parity effects were not detected ($P \geq 0.70$). 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

No clinical symptoms of mineral deficiency were observed in cows before or during our study; however, average pretreatment serum Mn was below the normal range (Puls, 1994; Herdt and Hoff, 2011; Table 2). In addition, SD in pretreatment serum concentrations of Cu, Se, and Zn indicated that a notable portion of our cow population may have been marginal to slightly deficient in these minerals. These conditions occurred despite ad libitum availability of a free-choice trace-mineral supplement (19% Ca, 6.5% P, 17% NaCl, Mg 1.9%, 1,300 mg/kg Cu, 12 mg/kg Co, 60 mg/kg I, 2,000 mg/kg Mn, 26 mg/kg Se, and 2,000 mg/kg Zn) and white salt for a minimum of 12 mo before our study was initiated.

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 SA (Tables 3 and 4). Conversely, TM cows had greater ($P = 0.04$) BCS increase than did SA cows between calving and AI. Effects of trace-mineral 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 characteristics 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 trace-mineral supplementation on performance of beef cows and calves under range conditions and reported that BCS and age-adjusted weaning BW were not influenced by treatment. Similarly, Arthington and Swenson (2004) evaluated the effects of organic or inorganic trace mineral fed

Table 3. Effects of pre- and postpartum bolus injections of a trace-mineral solution or physiological saline (1 mL/90 kg of BW) on BW and BW change of beef cows grazing native range

Item	Saline	Trace mineral[1]	SE	*P*-value
Cow BW,[2] kg				
Pregnancy diagnosis	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 diagnosis 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

[1]Multimin 90, Multimin USA, Ft. Collins, CO.

[2]Cow BW were measured at pregnancy diagnosis (December 17, 2009), parturition (average date = April 6, 2010), AI breeding (June 16, 2010), and weaning (October 29, 2010).

either ad libitum or on a restricted basis and reported that trace-mineral source and feeding method had no effect on cow BW or BCS. In contrast, Manickam et al. (1977) measured Fe, Cu, Mn, and Zn concentrations in whole blood and plasma from 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 trace-mineral status was associated with greater postpartum body condition as well.

Proportion of cows with established estrous cycles before timed AI was similar ($P \geq 0.51$) between treatments (Table 5). 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%). Overall pregnancy rate did not differ ($P = 0.24$) between treatments and averaged 92%; however, subsequent calving distribution by TM-treated cows was more favorable ($P = 0.01$; i.e., calving was generally earlier) than that by SA-treated cows (Figure 1). The strong timed AI and calving distribution responses to TM injection were not anticipated because all cows in our study had ad libitum access to free-choice oral trace-mineral supplements and white salt for a minimum of 12 mo before and during our study. In addition, Umoh et al. (1982) indicated that mean concentrations of trace minerals in Kansas native forages were sufficient to meet at least 50% of beef cow requirements. Consumption of free-choice trace mineral on a per-pasture basis was within manufacturer recommendations during our study. Therefore, we speculated that the trace-mineral status of individual cows may not have been optimal because of nonconsumption of or erratic intake of free-choice trace-mineral supplement.

As with gross measures of beef cow performance, the effects of oral trace-mineral supplementation on cow reproductive performance are inconsistent (Olson et al., 1999; Stanton et al., 2000; Ahola et al., 2004; Vanegas 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 did 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 with supplemental Mn alone and no supplemental trace mineral.

Muehlenbein et al. (2001) examined the effects of organic and inorganic Cu supplementation on reproductive efficiency of heifers and reported that final pregnancy rates were not different compared with unsupplemented heifers. Similarly, Arthington et al.

Table 4. Effects of pre- and postpartum bolus injections of a trace-mineral solution or physiological saline (1 mL/90 kg of BW) on BCS and BCS change of beef cows grazing native range

Item	Saline	Trace mineral[1]	SE	*P*-value
Cow BCS[2,3]				
Pregnancy diagnosis	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 diagnosis 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

[1]Multimin 90, Multimin USA, Ft. Collins, CO.

[2]BCS units, 1 to 9 scale (1 = emaciated, 9 = obese).

[3]Cow BCS were assigned at pregnancy diagnosis (December 17, 2009), parturition (average date = April 6, 2010), AI breeding (June 16, 2010), and weaning (October 29, 2010).

Table 5. Effects of pre- and postpartum bolus injections of a trace-mineral solution or physiological saline (1 mL/90 kg of BW) on reproductive performance of beef cows grazing native range

Item	Saline	Trace mineral[1]	SE	*P*-value
Cows cycling before timed AI,[2] %	56.3	59.5	0.04	0.51
Timed AI pregnancy rate,[3] %	51.2	60.2	0.03	0.05
Final pregnancy rate,[4] %	89.9	93.0	0.02	0.24

[1]Multimin 90, Multimin USA, Ft. Collins, CO.

[2]Determined from serum samples collected 17 and 8 d before timed AI.

[3]Proportion of cows classified as being pregnant from timed AI only.

[4]Proportion of cows classified as being pregnant from either timed AI or natural-service breeding.

(1995) indicated that reproductive performance of beef cows with a documented Cu deficiency did not respond to supplemental Cu. Other researchers indicated also that supplementation with specific minerals of interest or with broad-spectrum trace-mineral supplements did not change reproductive performance of cows compared with unsupplemented cows (Doyle et al., 1988; Gunter et al., 2003; Stahlhut et al., 2006). In certain cases, trace mineral supplementation at supranutritional doses may be associated with decreased reproductive performance of beef cows (Olson et al., 1999).

Inconsistent responses to trace-mineral supplementation may be related to sporadic intake of conventional, free-choice, salt-based trace-mineral supplements (Olson, 2007). Arthington and Swenson (2004) evaluated the performance and mineral status of grazing cows offered free-choice or hand-fed trace-mineral supplements. Voluntary intake of free-choice trace-mineral supplements was 23% less than intake of hand-fed supplements. As a result, cows that were self-fed trace mineral had less liver Zn and Cu than did cows that were hand-fed trace mineral; 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 free-choice trace-mineral supplement by beef cows maintained in a drylot was 32% greater than the minimum amount needed to meet animal requirements. In addition, the CV in intake of free-choice trace mineral from day to day was 81%, whereas intake of hand-fed trace mineral did not vary.

Injectable trace-mineral supplements may be useful for increasing the consistency of trace-mineral delivery to beef cows compared with free-choice trace-mineral supplements and may have particular value for increasing trace-mineral status immediately before calving and breeding. Few studies have been conducted on this topic; moreover, published literature is conflicting. Sales et al. (2011) reported that crossbred heifers subcutaneously injected with a trace-mineral product similar to the one used in our study had greater pregnancy rates 23 and 48 d after embryo transfer compared with untreated heifers. In contrast, Vanegas et al. (2004) reported that treatment of dairy cows with an injectable trace-mineral solution before calving and before breeding resulted in decreased first-service conception compared with untreated cows. Daugherty et al. (2002) treated crossbred beef cows with a bolus injection of Cu, Zn, Mn, Se, and vitamin E. Cows receiving trace mineral + vitamin E had greater serum concentrations of Cu than did unsupplemented cows. Despite increased Cu status, the trace mineral + vitamin E treatment had no effect on conception rates of cows.

Calf BW at birth was not different ($P > 0.91$) between treatments (Table 6). Calf ADG from birth to June 16, from June 16 to weaning, and from birth to weaning were not different ($P \geq 0.36$) between TM and SA. Similarly, adjusted 205-d BW was not different ($P = 0.48$) between treatments. Evaluations of injectable trace-mineral supplements given to suckling calves are few in number. Daugherty et al. (2002) injected crossbred beef cows with a trace-mineral solution to evaluate effects on health of the subsequent calf crop. In spite of documented improvements in cow trace-mineral status, treatment of cows with injectable trace mineral

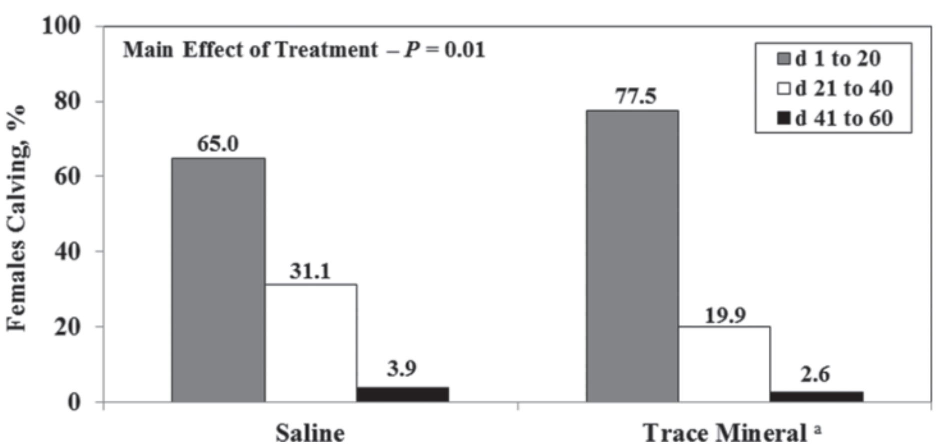

Figure 1. Effects of pre- and postpartum bolus injections of a trace-mineral solution or physiological saline (1 mL/90 kg of BW) on subsequent calving distribution of beef cows grazing native range. Bars represent 20-d periods during the 60-d calving season following treatment. [a]Multimin 90, Multimin USA, Ft. Collins, CO.

Table 6. Performance of beef calves treated at birth and at 71 ± 21 d of age with bolus injections of a trace-mineral solution or physiological saline (1 mL/45 kg of BW)

Item	Saline	Trace mineral[1]	SE	*P*-value
Calf BW,[2] kg				
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[3]	231.5	229.0	0.86	0.48
ADG, kg				
Early season (birth to June 16)	0.94	0.94	0.004	0.89
Late season (June 16 to weaning)	0.91	0.89	0.010	0.36
Overall (birth to weaning)	0.94	0.93	0.005	0.48

[1]Multimin 90, Multimin USA, Ft. Collins, CO.

[2]Calf BW were measured at birth (average date = April 6, 2010), AI breeding of cows (June 16, 2010), and weaning (October 29, 2010).

[3]Adjusted 205-d BW = birth BW + (205 × overall ADG).

had no effects on survival rates or passive immune status of calves.

Calf responses to injectable trace-mineral supplements seem to have been more widely evaluated postweaning in confined feeding situations. During shipping and receiving, calves may exhibit temporal deficiencies in certain trace minerals. Berry et al. (2000) studied the efficacy of injecting stressed cattle with a trace-mineral solution to ameliorate shipping stress and to improve feedlot performance. Calves that received injectable trace minerals had greater feed intake during receiving when compared with calves that were not injected. Injectable trace minerals tended also to improve feed efficiency, to improve ADG, and to decrease morbidity when compared with untreated calves. Similarly, Richeson and Kegley (2011) evaluated the effects of 2 sources of supplemental, injectable trace minerals on stressed heifers. Heifers receiving either trace-mineral product had greater ADG and feed efficiency than did untreated animals; moreover, calves receiving either product showed fewer clinical signs of morbidity compared with 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 bolus injection gained less weight during the receiving period than did steers injected with saline. In contrast, the trace-mineral injection was associated with increased G:F during the finishing period compared with the saline injection. There were no differences in finishing-period ADG or carcass characteristics between treatments.

IMPLICATIONS

Under the conditions of our study, pre- and postpartum trace-mineral injections improved conception to fixed-time AI and calving distribution by beef cows. Supplementing trace minerals to beef cows using an injectable solution may be a more reliable method of ensuring adequate trace-mineral status than offering a free-choice, salt-based, granular mineral supplement alone; however, further research is warranted to substantiate this hypothesis. Cost of the injectable trace-mineral product used in our study was approximately $0.40/mL (L. J. Havenga, unpublished data). Cost per dose (1 mL/90 kg of BW) for a beef cow weighing 540 kg was $2.40/animal, and total treatment cost (i.e., 2 doses) for a beef cow weighing 540 kg, as described in our study, was $4.80/animal.

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