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Effect of supplemental trace minerals from injection on health and performance of highly stressed, newly received beef heifers

J. T. Richeson, PAS, and E. B. Kegley,[1] PAS
Department of Animal Science, University of Arkansas Division of Agriculture, Fayetteville 72701

ABSTRACT

Injectable trace minerals administered on arrival to highly stressed beef calves may improve health and performance during the critical receiving period. Crossbred beef heifers (n = 90; initial BW = 199 ± 6.4 kg) were obtained from auction markets, blocked by BW, and assigned randomly to 1 of 3 treatments: 1) s.c. injection of trace mineral solution containing Zn (20 mg/mL), Mn (20 mg/mL), Cu (10 mg/mL), and Se (5 mg/mL) (TM1; 1 mL/45.5 kg); 2) s.c. injection of trace mineral solution containing Zn (48 mg/mL), Mn (10 mg/mL), Cu (16 mg/mL), and Se (5 mg/mL) (TM2; 1 mL/45.5 kg); or 3) negative control (CON). Calves were offered ad libitum access to a common diet and were evaluated daily for clinical signs of bovine respiratory disease. Overall ADG was greater (P < 0.01) for calves receiving either trace mineral injection compared with CON; however, ADG did not differ (P = 0.59) between the 2 mineral treatments. Total DMI was greater (P = 0.01) for TM1 and TM2 than for CON. Total G:F was also improved (P = 0.02) for the 2 trace mineral treatments. Calves receiving TM1 and TM2 gained 0.18 and 0.19 kg, respectively, per kilogram of feed consumed; CON gained 0.16 kg per kilogram of feed consumed. Calves administered TM1 had reduced (P = 0.02) bovine respiratory disease morbidity rates compared with CON, with TM2 being intermediate. Antibiotic treatment cost was greater (P = 0.03) for CON than for TM1 or TM2. Administration of a trace mineral injection during initial processing of highly stressed, newly received heifers improved ADG, feed efficiency, bovine respiratory disease morbidity, and antibiotic treatment cost.

Key words: beef calf, health, injectable trace mineral, performance, stress

INTRODUCTION

Trace minerals such as Zn, Mn, Cu, and Se are important for immune function (Chirase et al., 1991; Percival, 1998) and growth (Spears and Kegley, 2002), particularly in highly stressed, newly received calves where trace mineral levels may be deficient during bovine respiratory disease (**BRD**) challenge. However, experimental results involving oral or dietary supplementation of trace minerals are inconsistent because differences in absorption efficiency, stress, and the nutritional and trace mineral status can vary considerably in cattle from one study to another (Duff and Galyean, 2007). Providing essential minerals through the diet can be challenging because feed intake of newly received cattle is typically low (Galyean et al., 1999). Another difficulty associated with dietary mineral supplementation is that absorption may be impaired in the rumen because of interactions that occur with other dietary components (Suttle, 1986; Gooneratne et al., 1989). Administration of an injectable, chelated supplemental source of Zn, Mn, Cu, and Se during initial processing may be an effective method of ensuring that highly stressed, newly received calves receive these trace minerals more readily, and performance and health may be improved when calves are injected with a combination trace mineral solution at processing (Berry et al., 2000) in addition to dietary mineral supplementation. Furthermore, inject-

[1] Corresponding author: ekegley@uark.edu

able trace minerals are immediately available and the supplementation rate is more easily controlled than with dietary supplementation, which may be advantageous during critical production periods such as receiving. Therefore, our objective was to determine the effects of 2 product formulations of supplemental trace minerals from injection compared with a negative control on health and performance of highly stressed, newly received beef heifers.

MATERIALS AND METHODS

Animal methods were approved by the University of Arkansas Animal Care and Use Committee. Crossbred beef heifer calves (n = 90) were procured from auction barns in south-central Arkansas and eastern Oklahoma and arrived at the University of Arkansas Division of Agriculture Stocker and Receiving Cattle Unit located near Savoy on June 20, 2006. Upon arrival (d −1), heifers were weighed (initial BW = 199 ± 6.4 kg) and tagged in the ear with a unique identification number. The following day (d 0), heifers were weighed and administered an 8-way clostridial bacterin-toxoid (Covexin 8, Intervet Schering-Plough Animal Health, Summit, NJ), a 5-way modified-live virus respiratory vaccine (Pyramid 5, Boehringer Ingelheim Vetmedica Inc., St. Joseph, MO), and a *Manheimia hemolytica* bacterin-toxoid (Presponse SQ, Boehringer Ingelheim Vetmedica Inc.). Also on d 0, animals were branded (hot iron), and those with horns present had them tipped. Calves were sorted by initial BW (heaviest to lightest) into 5 weight blocks and allocated randomly to 1 of 3 treatment pens within each block. Heifers were housed in soil-surfaced pens measuring 30 m × 3.7 m with a 3-m concrete feed bunk in the front of each pen.

Pens, within a block, were assigned randomly to 1 of 3 experimental treatments: 1) s.c. injection of trace mineral solution containing Zn (20 mg/mL), Mn (20 mg/mL), Cu (10 mg/mL), and Se (5 mg/mL) (Inject-A-Min, Mineral Technology, Porterville, CA) on d 0 (**TM1**); 2) s.c. injection of trace mineral solution containing Zn (48 mg/mL), Mn (10 mg/mL), Cu (16 mg/mL), and Se (5 mg/mL) (Mineral Max II, RXVeterinary Products, Westlake, TX) on d 0 (**TM2**); or 3) negative control (**CON**). Both trace mineral injections were administered according to label directions for calves up to 1 yr old at a dosage rate of 1 mL/45 kg of BW. The TM1 solution ingredient listing consisted of zinc oxide, manganese sulfate, sodium carbonate anhydrous, copper carbonate, sodium selenite, disodium EDTA, and sodium hydroxide. The TM2 solution ingredient listing consisted of zinc oxide, manganese sulfate, sodium selenite, copper carbonate, sodium carbonate, EDTA, sodium hydroxide, and benzyl alcohol 1% by volume as a preservative. On d 14, heifers were treated for internal and external parasites with a pour-on anthelmintic solution (Cydectin, Boehringer Ingelheim Vetmedica Inc.).

Calves were observed daily for clinical signs of BRD (depression, ocular or nasal discharge, coughing, gaunt appearance, and labored breathing). Calves with 2 or more clinical signs were brought to the chute, and a rectal temperature was recorded. If the rectal temperature was ≥40°C, calves were considered morbid and administered antibiotic therapy according to a predetermined antibiotic regimen. A recheck temperature was taken 48 h following initial treatment with 40 mg/kg of BW of s.c. florfenicol (Nuflor, Intervet Schering-Plough Animal Health). If the recheck temperature was ≥40°C, a second antibiotic treatment with 6.6 mg/kg of BW of s.c. ceftiofur crystalline free acid (Excede, Pfizer Animal Health, Kalamazoo, MI) was administered. A 72-h posttreatment interval was implemented for cattle administered ceftiofur crystalline free acid, and rectal temperature was reevaluated. If the recheck temperature was ≥40°C, a third and final antibiotic treatment with 6.0 mg/kg of BW of s.c. danofloxacin mesylate (A180, Pfizer Animal Health) was administered and repeated 48 h following the first injection. Cattle that continued to display BRD symptoms after the third treatment were considered nonresponsive and no further antibiotic treatment was administered. If at any time a recheck temperature was <40°C, the animal was left untreated unless further symptoms developed. Treatment data recorded for an individual animal included treatment date, rectal temperature, and the amount and type of antibiotic administered. Animals were immediately returned to their designated home pen after evaluation/treatment. In addition to observing cattle for signs of BRD, the neck region where trace mineral injections were administered was observed daily for the presence of an inflammatory response.

A common receiving diet was offered initially at 2.3 kg/d and increased stepwise with the desired goal of maximum feed intake (Table 1). The amount of feed delivered to each pen was weighed and recorded daily to determine DMI and feed efficiency. Individual BW was recorded on d −1, 0, 28, 54, and 55 to determine interim and overall ADG. Feed refusals at the end of each period were weighed and recorded to calculate DMI and feed efficiency. To determine plasma mineral concentrations, blood samples were collected on d 0 and 28 via jugular venipuncture into vacuum tubes containing sodium heparin and designed specifically for trace mineral analysis (Vacutainer, BD Inc., Franklin Lakes, NJ). Within 12 h after sampling, blood was centrifuged at 2,100 × *g* for 20 min at 20°C, and plasma was stored frozen at −20°C until analysis. Plasma was deproteinated by mixing 0.5 mL of plasma with 9.5 mL of 1 *N* trace metal grade HNO_3; after 24 h tubes were centrifuged at 1,700 × *g* for 20 min at 20°C, and the supernatant was analyzed for Zn and Cu by inductively coupled plasma atomic emission spectroscopy (Ciros, Spectro Analytical Instruments Inc., Mahwah, NJ).

Pen was considered the experimental unit and incorporated in a ran-

Table 1. Ingredient and calculated nutrient composition of diet fed to newly received beef heifers

Item	Amount
Ingredient, % DM	
Cracked corn	54.47
Cottonseed hulls	28.00
Soybean meal	11.50
Molasses	4.00
Limestone	0.95
Dicalcium phosphate	0.50
Salt, white	0.40
Rumensin premix[1]	0.10
Vitamin premix[2]	0.07
Trace mineral[3]	0.01
Nutrient composition, % DM unless noted	
DM[4]	93.2
CP[4]	13.1
Crude fiber[5]	15.3
Fat[5]	2.9
NE_m,[5] Mcal/kg	1.84
NE_g,[5] Mcal/kg	1.07
Ca[5]	0.66
P[5]	0.38

[1]Rumensin 80 (Elanco Animal Health, Greenfield, IN) premix supplied 24 mg of monensin per kilogram of diet (DM basis).

[2]Supplied 4,700 IU of vitamin A, 940 IU of vitamin D_3, and 12 IU vitamin E per kilogram of diet (DM basis).

[3]Supplied 64 mg of Zn, 42 mg of Mn, 21 mg of Cu, 1.1 mg of I, 0.33 mg of Se, and 0.26 mg of Co per kilogram of diet (DM basis).

[4]Analyzed values.

[5]Values calculated with the Oklahoma State University Ration Calculator (as-fed version) software (www.ansi.okstate.edu/software/OSUNRCAF.xls; Accessed February 28, 2002).

Table 2. Effect of supplemental trace minerals from injection on performance of newly received beef heifers

	Treatment[1]				
Item	CON	TM1	TM2	SEM	*F*-test[2]
Initial BW, kg	199.0	198.7	199.2	6.42	0.53
Final BW, kg	248.9[b]	258.4[a]	260.1[a]	7.02	0.003
ADG, kg/d					
d 0 to 14	0.03	0.03	0.15	0.07	0.31
d 0 to 28	0.73[b]	0.84[ab]	0.94[a]	0.06	0.10
d 0 to 55	0.91[b]	1.08[a]	1.11[a]	0.03	0.002
DMI, kg/d					
d 0 to 14	2.85	2.91	2.82	0.06	0.48
d 0 to 28	3.98	4.17	4.12	0.08	0.11
d 0 to 55	5.23[b]	5.66[a]	5.57[a]	0.13	0.01
G:F					
d 0 to 14	0.01	0.01	0.06	0.03	0.27
d 0 to 28	0.18[b]	0.20[ab]	0.23[a]	0.01	0.08
d 0 to 55	0.17[b]	0.19[a]	0.20[a]	0.005	0.02

[a,b]Least squares means within a row without a common superscript differ ($P \leq 0.05$) according to *t*-test.

[1]CON = negative control, TM1 = Inject-A-Min injectable trace mineral solution (Mineral Technology, Porterville, CA), TM2 = Mineral Max II injectable trace mineral solution (RXVeterinary Products, Westlake, TX).

[2]Analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC), $P > F$.

domized complete block design. The model included treatment as a fixed effect, and BW block was a random effect. Performance data, antibiotic treatment cost, and G:F were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Plasma mineral concentrations were analyzed using the MIXED procedure with repeated measures. The AR(1) covariance structure was specified. Using the PDIFF option of SAS, *F*-protected ($P \leq 0.10$) *t*-tests were used for mean separations. Morbidity was analyzed using the GENMOD procedure. The model included BW block and treatment; binomial distribution of data and type 3 analysis were specified. The reported means were generated using the frequency procedure.

RESULTS AND DISCUSSION

Performance

For the entire 55-d trial, ADG was greater ($P = 0.002$) for calves administered either TM1 or TM2 trace mineral injection compared with CON; however, gain among the 2 injectable trace mineral treatments (TM1 vs. TM2) was not different at any time during the study (Table 2). Overall ADG for TM2, TM1, and CON were 1.11, 1.08, and 0.91 kg/d, respectively. Likewise, final BW was greater ($P = 0.003$) for TM1 and TM2 than for CON. These results suggest that administering either TM1 or TM2 during initial processing improves ADG during the receiving period in highly stressed calves. Daily feed intake was also increased ($P = 0.01$) from d 0 to 55 by both injectable trace minerals.

Overall G:F was improved ($P < 0.05$) for both TM2 and TM1 compared with CON, averaging 0.20, 0.19, and 0.17 kg of BW gain per kilogram of DM consumed, respectively. From d 0 to 28, G:F tended to be greater ($P = 0.07$) for TM2 calves than for CON; however, TM1 was intermediate and did not differ ($P > 0.10$) from either treatment. Similarly, Berry et al. (2000) reported increased feed intake from d 29 to 42, and ADG and G:F tended to be improved for newly received calves given an injectable trace mineral versus a negative control. Using a constant 5-mL dosage rate of an injectable trace mineral product (Multimin USA Inc., Fort Collins, CO) that provided 75 mg of Cu, 200 mg of Zn, 50 mg of Mn, and 25 mg of Se, Clark et al. (2006) evaluated the effects of trace mineral injection in auction market steers at high risk for developing BRD versus

Table 3. Comparison of the supplementation rate (mg/kg of initial BW) of trace minerals from injection among referenced studies

	Rate of supplementation,[1] mg/kg of BW			
Study	Zn	Mn	Cu	Se
Berry et al. (2000)[2]	0.41	0.41	0.21	0.10
Clark et al. (2006)[3]	0.75	0.19	0.28	0.09
This study				
TM1[4]	0.44	0.44	0.22	0.11
TM2[5]	1.05	0.22	0.35	0.11

[1]Calculated from initial BW and dosage and concentration of injectable trace mineral solutions reported in each respective study.

[2]Administered 3 mL of injectable trace mineral solution containing Zn (20 mg/mL), Mn (20 mg/mL), Cu (10 mg/mL), and Se (5 mg/mL).

[3]Administered 5 mL of injectable trace mineral solution containing Zn (40 mg/mL), Mn (10 mg/mL), Cu (15 mg/mL), and Se (5 mg/mL).

[4]Administered 4.37 mL of injectable trace mineral solution containing Zn (20 mg/mL), Mn (20 mg/mL), Cu (10 mg/mL), and Se (5 mg/mL).

[5]Administered 4.37 mL of injectable trace mineral solution containing Zn (48 mg/mL), Mn (10 mg/mL), Cu (16 mg/mL), and Se (5 mg/mL).

preconditioned, single-source steers. In contrast to results from the current study, ADG was less for steers administered an injectable trace mineral than for controls during the receiving period; however, G:F during the subsequent feeding period was improved for steers injected with a trace mineral solution. Differences in the trace mineral status of experimental animals or variation in the level of trace minerals provided by each product and the dosage rate used may have resulted in the inconsistent ADG results among studies. In the current study, dosage rate (1 mL of injectable trace mineral solution per 45.5 kg) was administered according to arrival BW, whereas Clark et al. (2006) administered a constant 5-mL dosage rate. Clark et al. (2006) reported an initial BW of 266 kg; therefore, the average dosage rate was slightly less (0.86 mL/45.5 kg vs. 1 mL/45.5 kg) than that in the current study. Berry et al. (2000) reported an initial BW of 144 kg; therefore, the average dosage rate was similar (0.94 mL/45.5 kg vs. 1 mL/45.5 kg) to that in the current study. Furthermore, differences in trace mineral concentrations of the different products used among studies resulted in various supplementation rates (mg/kg of initial BW) of the trace minerals (Table 3). Additional research is needed to determine the optimum concentrations of injectable trace minerals for highly stressed, newly received cattle and whether potential performance differences are directly attributable to an improved trace mineral status or an indirect benefit from improved animal health associated with trace mineral injection.

Health

The rate of BRD morbidity (Table 4) was less ($P < 0.05$) for TM1 compared with CON, whereas the BRD morbidity rate for TM2 was intermediate. Fewer calves ($P = 0.01$) required treatment with a second antibiotic for BRD for both TM1 and TM2 than for CON. Furthermore, a lower ($P < 0.05$) percentage of TM1 and TM2 calves were treated with the third and final antibiotic compared with CON. Several trace minerals, including Cu (Percival, 1998), Se (Droke and Loerch, 1989; Nicholson et al., 1993), and Zn (Chirase et al., 1991), have been shown to be important for immune function in cattle, and results from the current study suggest that administering an injectable trace mineral solution on arrival in highly stressed calves may reduce BRD morbidity during receiving. In a study where cattle were fed either a control diet with basal levels of Zn (31 mg of Zn/kg of DM), or Zn methionine added to the control diet (90 mg of Zn/kg of DM), DMI was decreased for a longer duration and the mean rectal temperature was greater for cattle consuming the control diet after an infectious bovine rhinotracheitis challenge (Chirase et al., 1991). Berry et al. (2000) reported a tendency for reduced morbidity in newly received calves administered an injectable trace mineral solution (Table 3) at processing versus a negative control, whereas Clark et al. (2006) did not observe a reduction in morbidity for calves administered 5 mL of an injectable trace mineral solution (Table 3).

Differences were also observed for antibiotic treatment cost. Compared with CON, TM1 and TM2 had a lower ($P < 0.05$) antibiotic treatment cost. The average antibiotic treatment cost per animal was $13.66 for CON, $9.47 for TM2, and $8.07 for TM1. Therefore, the reduction in antibiotic treatment cost exceeded the cost of administering either injectable trace mineral solution during processing, which was less than $1.50 per animal. Although injection of Cu from Cu glycinate has been previously reported to cause injection-site abscesses (Chirase et al., 1994), no injection-site abscesses were observed in cattle administered either of the trace mineral injections in the current study.

Plasma Zinc and Copper Concentrations

Plasma Zn and Cu concentrations on d 28 were not affected ($P \geq 0.18$) by treatment (Figures 1 and 2). Injectable trace minerals are intended to provide rapid availability of trace minerals, yet plasma levels are elevated for a period of $\leq$24 h (Bohman et al., 1984); therefore, any differences in plasma Zn or Cu due to trace mineral injection would have occurred before

Table 4. Effect of supplemental trace minerals from injection on health and antibiotic treatment cost of newly received beef heifers

	Treatment[1]				
Item	CON	TM1	TM2	SEM	*P*-value
Morbidity, %	87.1[a]	54.8[b]	67.9[ab]	—	0.02[2]
Treated with 2nd antibiotic, %	51.6[a]	19.4[b]	17.9[b]	—	0.01[2]
Treated with 3rd antibiotic, %	32.3[a]	9.7[b]	10.7[b]	—	0.02[2]
Antibiotic cost, $/calf	13.66[a]	8.07[b]	9.47[b]	1.22	0.03[3]

[a,b]Least squares means within a row without a common superscript differ ($P \leq 0.05$) according to *t*-test.

[1]CON = negative control, TM1 = Inject-A-Min injectable trace mineral solution (Mineral Technology, Porterville, CA), TM2 = Mineral Max II injectable trace mineral solution (RXVeterinary Products, Westlake, TX).

[2]Analyzed using the GENMOD procedure of SAS (SAS Institute Inc., Cary, NC), $P >$ chi-square.

[3]Analyzed using the MIXED procedure of SAS, $P > F$.

the d-28 collection period. The extent to which plasma Zn and Cu differences may have occurred more immediately after processing is unknown because samples before the d-28 interim period were not collected.

In a review of trace mineral status of ruminants, Kincaid (1999) adapted criteria from previous studies for determining the Zn and Cu status of cattle. Depending on Zn and Cu concentrations (μg/mL) in plasma, cattle can be classified as deficient, marginal, adequate, high, or toxic. It was noted in the review that conditions such as physiological stress and bacterial or viral infection can elevate plasma Zn (Wellinghausen and Rink, 1998) or Cu (Etzel et al., 1982). Based on the criteria in Kincaid (1999), plasma Zn in the current study was marginal (0.59 mg/L) on d 0, increasing to adequate levels (1.72 mg/L) by d 28. Similarly, overall plasma Cu increased from 0.84 mg/L (adequate) on d 0 to 1.42 mg/L (toxic) on d 28. Because the calves were stressed and most required treatment for BRD, it is likely that plasma Zn and Cu indices measured in the current study did not provide a true indication of the biological trace mineral status; concentrations may have been falsely increased by physiological stress, pathogenic bacteria or virus, or both. However, the extent to which this may have occurred is not known.

The increase in plasma Zn and Cu concentrations resulted in an overall day effect; Zn and Cu concentration increased ($P \leq 0.001$) from d 0 to 28, and the increase was likely a result of supplemental mineral provided in the diet rather than injectable trace minerals administered on d 0. In the current study, both TM1 and TM2 solutions were administered at the exact same dosage rate (1 mL/45.5 kg of BW); however, the TM2 solution contained greater concentrations of Zn and Cu but less Mn compared with the TM1 solution. Nevertheless, differences in the concentration of these particular trace minerals for the 2 solutions did not significantly affect performance, health, or plasma Zn and Cu concentrations on d 28.

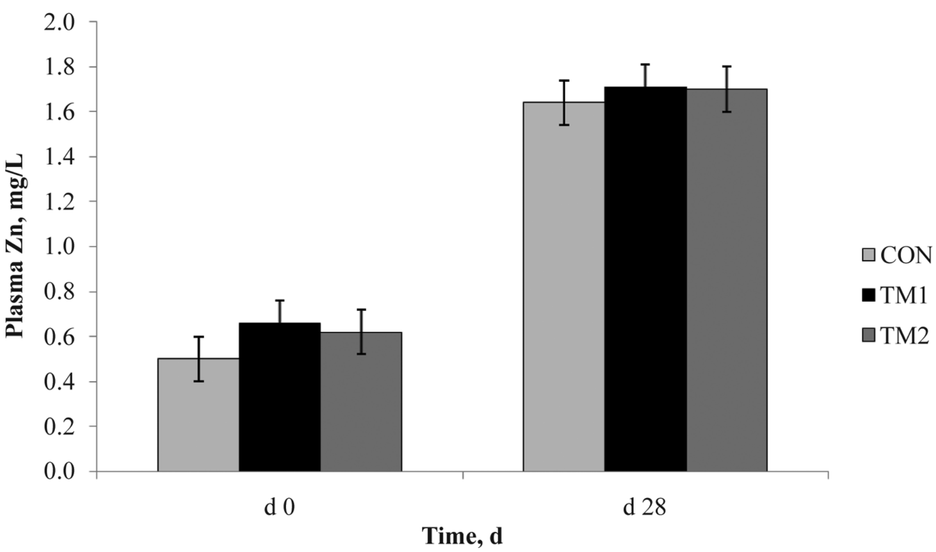

Figure 1. Plasma Zn concentration (mg/L) of newly received beef heifers on d 0 and 28 (day effect; $P < 0.001$). CON = negative control; TM1 = Inject-A-Min (Mineral Technology, Porterville, CA) injectable trace mineral solution containing Zn (20 mg/mL), Mn (20 mg/mL), Cu (10 mg/mL), and Se (5 mg/mL); TM2 = Mineral Max II (RXVeterinary Products, Westlake, TX) injectable trace mineral solution containing Zn (48 mg/mL), Mn (10 mg/mL), Cu (16 mg/mL), and Se (5 mg/mL).

IMPLICATIONS

Administering either of 2 commercial injectable trace mineral solutions (Inject-A-Min or Mineral Max II) at initial processing of highly stressed heifers improved gain and feed efficiency during the receiving period. In addition, the rate of BRD morbidity and antibiotic treatment cost were less for calves receiving either of the injectable trace mineral products. Both Zn and Cu plasma concentrations increased by d 28 for all treatments. Because published research pertaining to injectable trace mineral supplementation is both limited and unclear, further investigation is needed to determine the effects of injectable trace mineral supplementation for newly received calves experi-

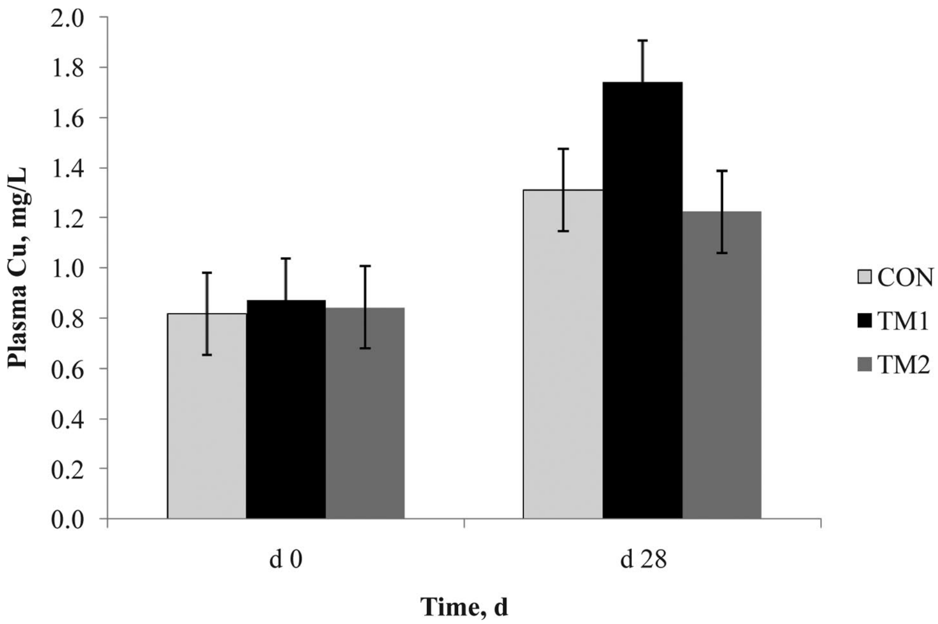

Figure 2. Plasma Cu concentration (mg/L) of newly received beef heifers on d 0 and 28 (day effect; $P = 0.001$). CON = negative control; TM1 = Inject-A-Min (Mineral Technology, Porterville, CA) injectable trace mineral solution containing Zn (20 mg/mL), Mn (20 mg/mL), Cu (10 mg/mL), and Se (5 mg/mL); TM2 = Mineral Max II (RXVeterinary Products, Westlake, TX) injectable trace mineral solution containing Zn (48 mg/mL), Mn (10 mg/mL), Cu (16 mg/mL), and Se (5 mg/mL).

encing physiological stress and clinical signs of BRD.

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