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Effect of injectable trace mineral administration on health, performance, and vaccine response of newly received feedlot cattle

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ABSTRACT

Previous research has established that trace minerals are necessary for optimal growth and immunity, yet challenges exist with intake of dietary trace minerals in cattle newly received at feedlots. A total of 128 crossbred beef bull ($n = 40$) and steer ($n = 88$) calves were used for this 42-d receiving study. Cattle were stratified by initial BW (275 ± 9.54 kg) and sex (steer or bull) and then assigned equivalently to treatment pens ($n = 8$ per treatment). Treatments were (1) negative control (CON) or (2) injectable trace mineral solution containing 60 mg of Zn/mL (as Zn disodium EDTA), 10 mg of Mn/mL (as Mn disodium EDTA), 5 mg of Se/mL (as sodium selenite), and 15 mg of Cu/mL (as Cu disodium EDTA) administered s.c. at 2.2 mL/100 kg of BW on d 0 (ITM). Health was monitored daily by trained personnel blinded to treatment pen assignment. Blood samples and BW were obtained on d 0, 14, 28, and 42 to determine bovine viral diarrhea virus (BVDV) type 1a antibody titer and gain performance. Standard processing procedures were applied on d 0, including administration of a respiratory vaccine containing modified-live BVDV antigens. No difference in overall ADG ($P = 0.21$) was detected between CON (1.36) and ITM (1.25 kg/d) steers. Overall DMI was not different ($P = 0.83$) between CON (6.98) and ITM (7.02 kg/d), but G:F tended ($P = 0.08$) to be less for ITM from d 28 to 42. The morbidity rate observed in this study was low (14% average), and there was no difference ($P = 0.71$) in morbidity between treatments, which averaged 15.6 and 12.5% for CON and ITM, respectively. There was a treatment × d interaction ($P = 0.09$) for BVDV-specific antibody titer. On d 14, ITM had a greater ($P = 0.02$) BVDV antibody titer than CON. These data suggest that ITM did not improve performance or morbidity when the incidence was low; however, the BVDV-specific antibody response to a respiratory vaccine was greater for ITM on d 14.

Key words: beef cattle, health, performance, trace mineral, vaccine

INTRODUCTION

Trace minerals are essential for immune function (Arthington and Havenga, 2012) and growth (Spears and Kegley, 2002) of highly stressed, newly received beef cattle. The interactions between nutritional status, immune response, and disease resistance are complex (Spears, 2000). Cole (1993) reported that mineral requirements do not differ between stressed and nonstressed cohorts; however, cattle may have difficulty meeting mineral requirements depending on the mineral status of individual animals and level of feed intake following feedlot arrival. Administration of a measured bolus of trace minerals during initial feedlot processing may prevent losses associated with poor disease resistance or growth performance because preexisting mineral deficiencies are difficult to address in a timely fashion with dietary mineral supplementation. Trace minerals provided at strategic time points such as vaccination have enhanced humoral immune response (Arthington and

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Havenga, 2012; Teixeira et al., 2014). The objective of the current study was to evaluate the effect of administering an injectable trace mineral solution containing Zn, Mn, Se, and Cu (Multimin 90, Multimin USA, Fort Collins, CO) on growth performance, feed efficiency, health, and bovine viral diarrhea virus (**BVDV**)-specific vaccine response of beef calves during the 42-d receiving period in a research feedlot.

MATERIALS AND METHODS

This study was conducted beginning December 2014 at the Texas A&M AgriLife Research Feedlot located near Bushland, Texas. Animals were cared for in accordance with practices and experimental protocols that were approved by the West Texas A&M University Institutional Animal Care and Use Committee (protocol# 01–10–14). A total of 128 crossbred bull (n = 40) and steer (n = 88) calves (BW = 275 ± 9.54 kg) of unknown health or management history were acquired from a single auction market located in south Texas to be used for this study.

Upon arrival to the feedlot (d −1), cattle were individually weighed, tagged in the ear with a uniquely numbered tag, classified according to sex (bull or steer), and received an ear notch that was tested for persistent infection with BVDV at a commercial laboratory (CattleStats LLC, Oklahoma City, OK). Calves were stratified by sex and d −1 BW and assigned randomly within stratification schema to treatment pens such that sex (bull or steer upon arrival) and d −1 BW were equivalent across treatment pens with 8 pens per treatment and 8 cattle per pen. This resulted in 8 treatment pens (n = 4 per treatment) that contained 3 bulls and 5 steers, and 8 treatment pens (n = 4 per treatment) that contained 2 bulls and 6 steers. Experimental treatments included (1) negative control (**CON**) that did not receive injection of a trace mineral solution during initial processing or (2) injectable trace mineral solution containing 60 mg of Zn/mL (as Zn disodium EDTA), 10 mg of Mn/mL (as Mn disodium EDTA), 5 mg of Se/mL (as sodium selenite), 15 mg of Cu/mL (as Cu disodium EDTA) administered s.c. at 2.2 mL/100 kg of BW on d 0 (**ITM**; Multimin 90, Multimin USA). Cattle were processed identically on d 0 with the exception of ITM or CON treatment application. Processing included administration of a pentavalent (BVDV type 1 and 2, infectious bovine rhinotracheitis virus, bovine respiratory syncytial virus, and parainfluenza-3 virus) modified-live virus respiratory vaccine combined with a *Mannheimia haemolytica* toxoid (Pyramid 5 + Presponse SQ, Boehringer Ingelheim Vetmedica Inc., St Joseph, MO) and a clostridial-tetanus (*Clostridium chauvoei*, *Clostridium septicum*, *Clostridium novyi* type B, *Clostridium haemolyticum*, *Clostridium tetani*, and *Clostridium perfringens* Types C and D) bacterin-toxoid (Covexin 8, Merck Animal Health, Summit, NJ), application of a topical anthelmintic (Cydectin Pour-on, Boehringer Ingelheim Vetmedica Inc.), and castration of bulls using a restrictive rubber band (Callicrate Bander, No-Bull Enterprises LLC, St. Francis, KS). Also during initial processing on d 0, antimicrobial metaphylaxis was administered using tilmicosin phosphate (Micotil, Elanco Animal Health, Greenfield, IN) at 13 mg/kg of BW. On d 14, a growth implant (Component E-S with Tylan, Elanco Animal Health) containing 200 mg of progesterone, 20 mg of estradiol benzoate, and 29 mg of tylosin tartrate was administered s.c. in the caudal aspect of the right ear.

Cattle health was observed daily at approximately 0800 h by trained personnel who were blinded to treatment pen assignment. Clinical illness signs included depression, coughing, ocular or nasal discharge, gaunt appearance, or labored breathing. A 3-d postmetaphylaxis interval was allowed to expire before daily health observation began. Cattle were removed from their pen if they were assigned a clinical illness score ≥2 on a 0 to 4 severity scale with a score of 0 indicating normal and a score of 4 indicating moribund (Perino and Apley, 1998). Upon further examination, cattle were considered morbid if rectal temperature was ≥39.7°C or if their automated lung auscultation score was ≥3 on a 1 to 5 severity scale. Lung auscultation scores were determined using an electronic stethoscope coupled with diagnostic software (Whisper Veterinary Stethoscope, Plymouth, MN). If classified as morbid, treatment was administered according to a predetermined antimicrobial regimen. The primary antimicrobial treatment was enrofloxacin (Baytril, Bayer Animal Health, Shawnee Mission, KS) at 50 mg/kg of BW. A 2-d posttreatment interval was implemented before calves were eligible for re-treatment. Secondary antimicrobial treatment included the administration of florfenicol (Nuflor, Merck Animal Health) at 40 mg/kg of BW. No cattle in this study met criteria for a third antimicrobial treatment. Following antimicrobial treatment, calves were immediately returned to their original pen. Morbidity rate and the proportion of those treated twice was determined for each treatment pen and averaged across treatment pens. Antimicrobial treatment cost was calculated by determining the fixed cost per milliliter of drug multiplied by milliliter administered, and averaged across all animals within treatment group.

A common receiving diet (Table 1) that contained a mineral and vitamin supplement (Table 2) was fed twice daily. Diet and mineral and vitamin supplement was formulated to meet or exceed the nutrient requirements established for beef cattle (NRC, 2000). Individual BW were collected on d 0, 14, 28, and 42. The amount of feed delivered and feed refusals were recorded daily to determine pen DMI and feed efficiency. Feed to gain was calculated by dividing the kilograms of BW gained for animals in the pen by DMI for the same pen during a given interim period or overall. Blood samples (10 mL) were collected on d 0, 14, 28, and 42 via jugular venipuncture using an evacuated tube (BD Vacutainer SST, Franklin Lakes, NJ). Blood was stored in an insulated container without ice, intended to achieve room temperature (20°C) conditions during cold ambient temperature, and immediately transported to the West Texas A&M University Animal Health Laboratory, where blood was centrifuged at 1,250 × g at 20°C for 20 min. Serum was separated and divided into duplicate aliquots to create a primary and secondary sample in case of freezer failure or lost samples. Primary and secondary serum aliquots were stored frozen at −20°C in separate freezers until all samples were compiled, and the primary aliquot was subsequently packaged on ice and transported to the Texas A&M Veterinary Medical Diagnostic Laboratory (Amarillo, TX) for determination of BVDV type 1a-specific antibody titer using the virus neutralization assay (Rosenbaum et al., 1970). The minimum dilution of serum tested was 4:1, and samples with a resulting titer of <4 were considered seronegative for BVDV type 1a antibodies, whereas those with a titer ≥4 were considered seropositive. The absolute BVDV antibody titer values were $\log_2$ transformed before statistical analysis.

This complete randomized design study used pen as the experimental unit for all dependent variables analyzed. Performance, feed efficiency, morbidity, and antimicrobial treatment cost were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Treatment means for performance and health variables were determined and analyzed statistically using the F-test, with a resulting P-value ≤0.05 considered significant and a P-value between 0.06 and 0.10 considered a tendency. The BVDV antibody seropositive and titer data were analyzed using PROC MIXED with repeated measures. The antibody titer data were $\log_2$ transformed before statistical analysis. Fixed effects of treatment, day, and their interaction were evaluated for repeated measures. The repeated statement was day, the subject was pen, and the compound symmetry covariance structure and Kenward-Roger df method were used. Significance was established for the treatment × d interaction if $P \leq 0.10$, and means within d were considered significant if the resulting P-value was ≤0.05 as determined by the least significant difference mean separation method.

Table 1. Ingredient and calculated nutrient composition of diet fed to newly received feedlot cattle

Item	Amount
Ingredient, % DM	
Steam-flaked corn	30.00
Wet corn gluten feed	40.00
Prairie hay	17.00
Corn stalks	10.00
Supplement[1]	3.00
Calculated nutrient composition[2]	
DM, %	71.48
TDN, %	71.00
CP, %	13.30
NDF, %	35.00
Ca, %	0.82
P, %	0.50
S, %	0.23
NE_m, Mcal/kg	1.85
NE_g, Mcal/kg	1.06

[1] The composition of the mineral and vitamin supplement is presented in Table 2. The supplement was composed of wheat middlings, salt, calcium carbonate, ferrous sulfate, ethylenediamine dihydroiodide, soybean oil, zinc sulfate, manganese sulfate, copper sulfate, cobalt sulfate, vitamin E, Tylan 100 (Elanco, Greenfield, IN), vitamin A, ROC Technology Premix (Cargill, Minneapolis, MN), Rumensin (Elanco), and BeefMax 0510 (Cargill).

[2] Calculated from NRC (2000).

Table 2. Mineral and vitamin content of supplement[1] included in diet fed to newly received feedlot cattle

Item	Amount
Mineral composition	
Calcium, %	22.93
Phosphorous, %	0.26
Magnesium, %	0.23
Potassium, %	0.33
Sodium, %	4.37
Cobalt, mg/kg	5.52
Copper, mg/kg	368.00
Iodine, mg/kg	36.80
Iron, mg/kg	2,208.00
Manganese, mg/kg	920.00
Selenium, mg/kg	3.86
Zinc, mg/kg	1,472.00
Vitamin composition	
Vitamin A, IU/g	55.2
Vitamin D, IU/g	5.52
Vitamin E, IU/g	324.21

[1] The supplement was formulated to meet or exceed vitamin and mineral requirements of beef cattle (NRC, 2000).

RESULTS AND DISCUSSION

Performance and Feed Efficiency

Performance and feed efficiency is reported in Table 3. Initial (d 0) BW was the same between treatment groups (275 ± 9.54 kg; $P = 0.96$). Final (d 42) BW was not different ($P = 0.54$) between CON (332 kg) and ITM (328 kg); likewise, no differences were detected for any of the interim BW evaluated ($P \geq 0.74$). No differences ($P > 0.21$) in ADG were detected during the 42-d study. Also, overall DMI was not different ($P = 0.83$) between CON (6.98 kg/d) and ITM (7.02 kg/d). There was a tendency ($P = 0.08$) for G:F to be reduced for

Table 3. Effect of injectable trace mineral administration on performance and feed efficiency of newly received feedlot cattle

	Treatment[1]			
Item	CON	ITM	SEM	*P*-value
BW, kg				
d 0	275	275	9.54	0.96
d 14	291	291	9.06	0.93
d 28	312	310	10.39	0.74
d 42	332	328	10.56	0.54
ADG, kg/d				
d 0 to 14	1.27	1.11	0.28	0.39
d 14 to 28	1.28	1.36	0.23	0.60
d 28 to 42	1.48	1.31	0.21	0.21
d 0 to 28	1.31	1.23	0.16	0.44
d 0 to 42	1.36	1.26	0.12	0.21
DMI, kg/d				
d 0 to 14	5.40	5.17	0.29	0.24
d 14 to 28	7.91	8.06	0.33	0.49
d 28 to 42	7.75	7.97	0.42	0.44
d 0 to 28	6.61	6.56	0.28	0.80
d 0 to 42	6.98	7.02	0.27	0.83
G:F				
d 0 to d 14	0.23	0.21	0.03	0.42
d 14 to 28	0.16	0.17	0.01	0.66
d 28 to 42	0.19	0.16	0.01	0.08
d 0 to 28	0.20	0.19	0.01	0.41
d 0 to 42	0.19	0.18	0.01	0.14

[1] CON = negative control cattle that did not receive an injectable trace mineral solution, ITM = injectable trace mineral solution (Multimin 90, Multimin USA, Fort Collins, CO) containing 60 mg of Zn/mL (as Zn disodium EDTA), 10 mg of Mn/mL (as Mn disodium EDTA), 5 mg of Se/mL (as sodium selenite), and 15 mg of Cu/mL (as Cu disodium EDTA) administered s.c. at 2.2 mL/100 kg of BW on d 0.

ITM from d 28 to 42 (0.19 vs. 0.16). No other differences in G:F were detected ($P \geq 0.14$). Under conditions of the current study, administration of an ITM at feedlot arrival did not improve animal performance and tended to reduce feed efficiency from d 28 to 42.

Berry et al. (2000) also reported that steers receiving a trace mineral injection upon arrival had no improvement in final BW or DMI compared with noninjected control animals; however, a tendency to improve overall ADG was reported. A study testing the effect of ITM, following a trace mineral depletion period, found that trace mineral injection did not affect BW or DMI between adequate and deficient animals; however, a tendency was reported for greater ADG in deficient steers compared with adequate steers (Genther and Hansen, 2014). In contrast, a study using heifers of auction market origin reported greater final BW, ADG, and overall DMI with ITM supplementation (Richeson and Kegley, 2011). Chirase et al. (1994) reported that during a 28-d trial a subcutaneous injection of Cu solution reduced DMI and reduced BW, and they concluded that the Cu solution may have been inflammatory and poorly absorbed by the animal. Tóthová et al. (2009) reported that s.c. injection of a mineral supplement caused tissue inflammation and production of the acute phase proteins haptoglobin and serum amyloid A. It is important to note that these mineral solutions differ in their formulation from the ITM treatment evaluated in the current study. Nevertheless, Arthington et al. (2014) reported increased production of the acute phase proteins ceruloplasmin, haptoglobin, and plasma acid soluble protein following ITM administration at weaning that resulted in a reduction in BW gain. Reduction in BW attributable to ITM may be further explained by increased synthesis of acute phase proteins and proinflammatory cytokines, which are known to alter animal growth and metabolism via repartitioning of nutrients, and catabolic and anorectic effects (Carroll and Forsberg, 2007). However, Richeson and Kegley (2011) reported that trace mineral injection upon arrival in heifers with a high bovine respiratory disease (**BRD**) morbidity rate (69.9% average) had greater ADG. The contrasting performance outcomes between studies are likely a result of differences in natural disease challenge. Trace mineral injections may result in stimulation of humoral immunity and when coupled with high disease challenge might result in improved performance due to a reduction in disease incidence or severity. However, the low disease incidence in combination with a more pronounced inflammatory response could explain why ADG was numerically reduced for ITM in the current study.

Health

Health variables of cattle are reported in Table 4. There was no difference ($P = 0.71$) in the BRD-associated morbidity rate (12.5 and 15.6% for ITM and CON, respectively); however, for the typical small-pen study, such as the current one, it is difficult to detect treatment differences in morbidity, especially when the overall incidence is low. In a previous study that observed a very high incidence of BRD (69.9% average; Richeson and Kegley, 2011), a reduction in morbidity in heifers receiving either of 2 ITM formulations was observed. In the current study, average days to first antimicrobial treatment was not different

($P = 0.21$) between CON (4.9 d) and ITM (6.6 d). No difference ($P = 0.73$) was observed in rectal temperature in cattle treated for BRD from CON (40.0°C) or ITM (39.9°C). The antimicrobial treatment cost was not different ($P = 0.53$) between treatments and averaged \$3.08 and \$4.60 per animal for ITM and CON, respectively. A decrease in antimicrobial treatment cost with administration of an ITM was reported by Richeson and Kegley (2011); however, the additional cost of ITM administration should also be considered (ITM cost is approximately \$0.50/mL). A decrease in the use of antimicrobials to treat clinically ill cattle would be financially beneficial to producers and simultaneously address consumer and regulatory concerns regarding antimicrobial resistance. Nevertheless, the slight numerical reduction in antimicrobial treatment cost observed for ITM in the current study, offset by the numerical reduction in performance, would suggest that ITM administration was not cost effective under the conditions of low disease incidence that existed for the current study population.

Vaccine Response

On d 0 none of the calves had antibodies specific for BVDV type 1a in serum and no calves tested positive for persistent infection with BVDV. There was no treatment × d interaction ($P = 0.44$) nor treatment effect ($P = 0.33$) for percentage of calves that were seropositive for BVDV type 1a-specific antibodies (Figure 1), but a day effect ($P < 0.01$) was detected. By d 28, all animals were seropositive for BVDV type 1a-specific antibodies. However, analysis of BVDV-specific antibody titer (Figure 2) resulted in a treatment × d interaction ($P = 0.09$) such that an increase ($P = 0.02$) in BVDV-specific antibody titer existed for ITM on d 14. There were no other antibody differences observed on sample days in this study, yet the increase in BVDV-specific antibody on d 14 is potentially important. This indicates that the BVDV-specific

Table 4. Effect of injectable trace mineral administration on health and antimicrobial treatment cost of newly received feedlot cattle

	Treatment[1]			
Item	CON	ITM	SEM	*P*-value
Morbidity,[2] %	15.6	12.5	0.06	0.71
Treated twice, %	3.0	0.0	0.01	0.15
Days to first treatment	4.9	6.6	0.99	0.21
Rectal temperature at first treatment, °C	40.0	39.9	0.55	0.73
Antimicrobial treatment cost,[3] \$/animal	4.60	3.08	13.96	0.53

[1] CON = negative control cattle that did not receive an injectable trace mineral solution, ITM = injectable trace mineral solution (Multimin 90, Multimin USA, Fort Collins, CO) containing 60 mg of Zn/mL (as Zn disodium EDTA), 10 mg of Mn/mL (as Mn disodium EDTA), 5 mg of Se/mL (as sodium selenite), and 15 mg of Cu/mL (as Cu disodium EDTA) administered s.c. at 2.2 mL/100 kg of BW on d 0.

[2] Morbidity is the proportion of cattle requiring at least one antimicrobial treatment as determined by ≥2 clinical respiratory signs coupled with rectal temperature ≥39.7°C or if automated lung auscultation score was ≥3 on a 1 to 5 severity scale. Lung auscultation scores were determined using an electronic stethoscope coupled with diagnostic software (Whisper Veterinary Stethoscope, Plymouth, MN).

[3] Antimicrobial treatment cost was calculated by determining the fixed cost milliliter of antimicrobial multiplied by milliliter administered, averaged across all animals within treatment group.

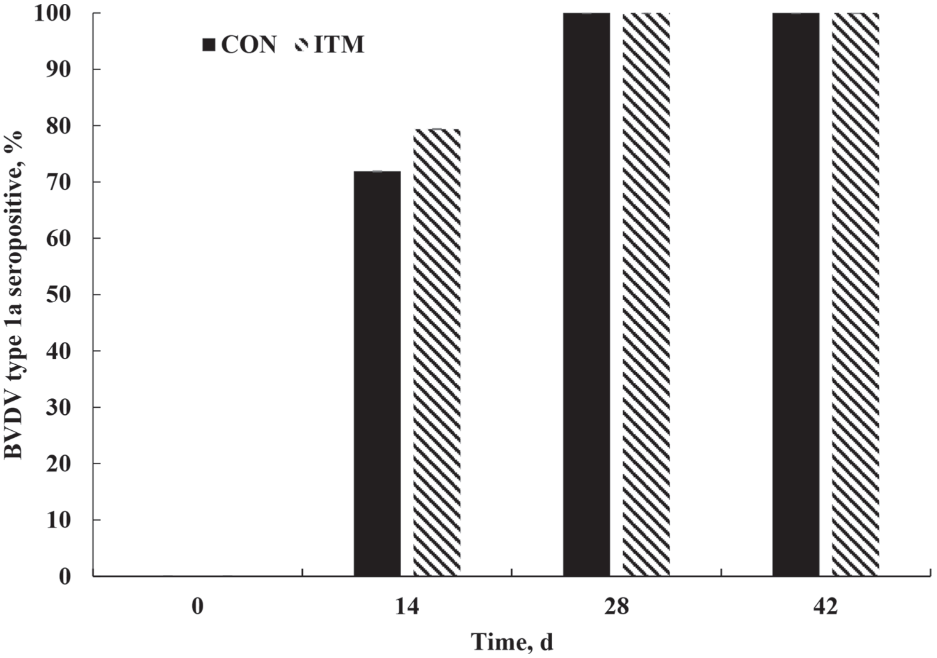

Figure 1. Effect of injectable trace mineral administration on percentage of newly received feedlot cattle with bovine viral diarrhea virus (BVDV) type 1a antibodies detected in serum. Day effect, $P < 0.01$; Treatment effect, $P = 0.33$; Treatment × day interaction, $P = 0.44$. CON = negative control cattle that did not receive an injectable trace mineral solution, ITM = injectable trace mineral solution (Multimin 90, Multimin USA, Fort Collins, CO) containing 60 mg of Zn/mL (as Zn disodium EDTA), 10 mg of Mn/mL (as Mn disodium EDTA), 5 mg of Se/mL (as sodium selenite), and 15 mg of Cu/mL (as Cu disodium EDTA) administered s.c. at 2.2 mL/100 kg of BW on d 0.

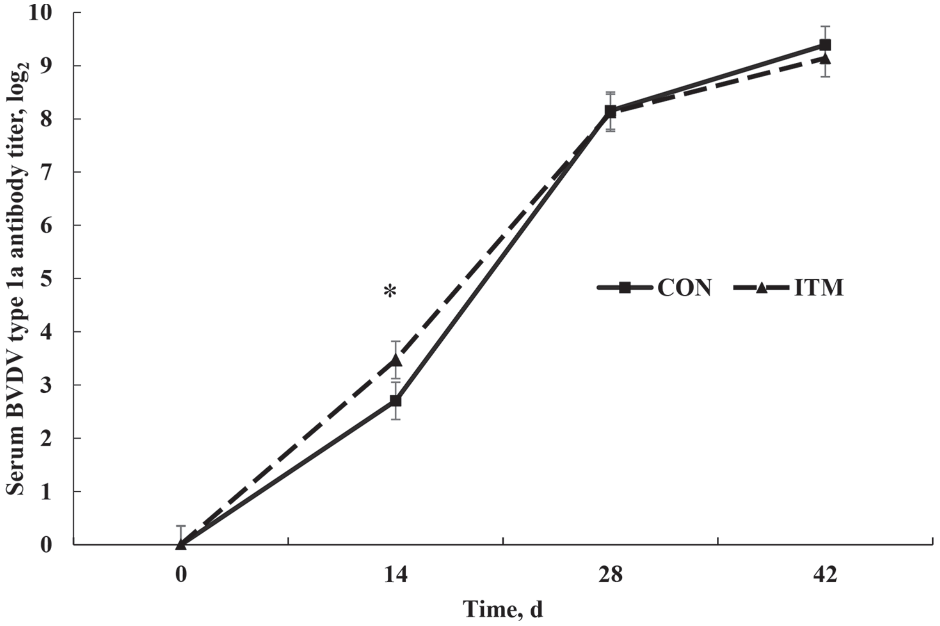

Figure 2. Effect of injectable trace mineral administration on serum bovine viral diarrhea virus (BVDV) type 1a antibody titer in newly received feedlot cattle. Treatment × d interaction, $P = 0.09$; asterisk indicates treatment difference within d, $P = 0.03$. CON = negative control cattle that did not receive an injectable trace mineral solution, ITM = injectable trace mineral solution (Multimin 90, Multimin USA, Fort Collins, CO) containing 60 mg of Zn/mL (as Zn disodium EDTA), 10 mg of Mn/mL (as Mn disodium EDTA), 5 mg of Se/mL (as sodium selenite), and 15 mg of Cu/mL (as Cu disodium EDTA) administered s.c. at 2.2 mL/100 kg of BW on d 0. Error bars indicate the SEM.

antibody response to the respiratory vaccine increased earlier for ITM, and BRD signs are typically observed early in the receiving period (Cole, 1996). Furthermore, the increased humoral immune response for ITM suggests that other components of the immune system were stimulated. Arthington and Havenga (2012) found that ITM-treated steers had a greater infectious bovine rhinotracheitis virus–specific antibody response from a concurrently administered respiratory vaccine, and thus supports our findings. Likewise, Palomares et al. (2015) reported an increased antibody titer to BVDV type 1 in dairy calves administered ITM concurrent with vaccination. The increase in antibody production could be influenced by several of the trace minerals included in ITM, but particularly Zn that has functions in protein production and disulfide bond formation (Charlton and Ewing, 2007), because antibodies are protein structures linked by disulfide bonds. Similarly, Se in combination with vitamin E has been shown to increase IgG concentration in cattle (Droke and Loerch, 1989).

IMPLICATIONS

When disease incidence of a cattle population is low, as was observed for the current study, administration of ITM did not affect growth performance and tended to briefly reduce feed efficiency. The BVDV-specific antibody response to modified-live BVDV antigen contained in the respiratory vaccine was greater for ITM on d 14, which suggests that humoral immunity may be enhanced by ITM. Therefore, further research is warranted to determine the potential benefit of ITM-associated immune enhancement, particularly during the time of vaccination or conditions of natural disease challenge in feedlot cattle.

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