Influence of pre-weaning trace mineral exposure on subsequent performance and trace mineral status of beef calves during finishing

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Abstract
Objectives of these experiments were to **1)** evaluate the accumulation of Co, Cu, Mn and Zn in liver tissue during the finishing period of calves with or without previous mineral supplement exposure; and **2)** evaluate the performance of calves provided either organic or inorganic sources of Co, Cu, Mn and Zn. One-hundred twenty steers (584 ± 62.4 lb initial BW) of unknown mineral history, and 48 steers (564 ± 26.7 lb initial BW) of known mineral history prior to weaning were comingled and used in experiment 1. Steers were allocated to pens, with pens assigned to receive either an inorganic (8 pens) or organic (8 pens) trace minerals. For experiment 2, 83 steers (650 ± 57.3 lb initial BW) with or without exposure to mineral supplements during gestation and the subsequent lactation, were utilized in a 181-d finishing experiment. In experiment 1, ADG tended to be greater ($P = 0.09$) during the first 53 days on feed in calves provided organic trace minerals. Calves with trace mineral access prior to weaning were heavier at the time of feedlot arrival ($P = 0.06$), but not at slaughter ($P = 0.37$). Providing access to mineral supplements to cow-calf pairs during grazing increased ($P < 0.01$) Cu and Co, but did not affect ($P \geq 0.29$) Zn or Mn concentrations at feedlot arrival. Liver Cu status improved during backgrounding in steers fed the organic trace minerals in experiment 1. In conclusion, for calves of known mineral history, providing access to mineral supplements during grazing, prior to weaning, had no impacts on subsequent gain or intake during growing and finishing. Providing organic forms of trace minerals tended to improve growth early in the feeding period.

Key words: beef calves, feedlot performance, liver, trace minerals

Introduction
Basal diet alone may not supply sufficient amounts of trace minerals; making supplementation a necessary practice to optimize health and performance of livestock.[11] Mineral supplementation practices vary greatly between producers, even though inadequate intake of trace minerals can lead to suboptimal reproduction, health, or growth.[11,12] Research evaluating life-long production outcomes including growth, carcass quality and animal health of beef calves resulting from dams fed various trace mineral regimens are limited. The purpose of this experiment was to evaluate changes in feedlot calf performance and liver trace mineral concentrations due to pre-weaning access to mineral supplements, as well as to evaluate the impacts of source of trace minerals (chelate versus sulfate or chloride) on the performance and changes in trace mineral concentrations in calves during backgrounding.

With many post-weaning feeding studies, the effects of mineral supplementation have been variable and are likely affected by pre-weaning nutritional status. However, this area of research has not received sufficient attention to be fully understood. Our primary objective was to evaluate growth performance and accumulation of Co, Cu, Mn and Zn in liver tissue of calves that were previously exposed or not exposed to mineral supplements prior to weaning in both experiments. Our secondary objective was to evaluate the performance of pen-fed calves provided either organic or inorganic sources of Co, Cu, Mn and Zn during finishing in experiment 1. Our primary hypothesis was that pre-weaning exposure to mineral supplements will result in improved performance and greater liver Cu and Zn concentrations at feedlot arrival. The secondary hypothesis for the current project was that post-weaning supplementation of organic trace minerals will improve steer performance during backgrounding compared to calves fed inorganic sources of minerals.

Materials and methods
This study was approved by the North Dakota State University Institutional Animal Care and Use Committee prior to the start of the experiments.

Experiment 1
Two groups of steers were utilized in this experiment. Group 1 consisted of 120 beef steers (584 ± 62.4 lb initial BW) of multiple breeds and consigned as part of the Dakota Feeder Calf Show, with unknown previous mineral history prior to feedlot arrival. Group 2 consisted of 48 beef steers (564 ± 26.7 lb initial BW) from Central Grassland Research Extension Center having previous exposure to (or not) mineral supplements while suckling dams. Treatments for Group 2 were applied to cow-calf pairs on pasture as previously described.[5] Mineral

supplement provided to cow-calf pairs, with access to mineral in Group 2 contained: 14.4-17% Ca, 7.7-9.2% NaCl, and a minimum of 8.0% P, 0.6% Mg, 0.18% K, 5,500ppm Mn, 65ppm Co, 2,400ppm Cu, 130ppm I, 34ppm Se, 7,820ppm Zn, 215,000 IU/lb Vitamin A, 53,500 IU/lb Vitamin D, and 2,667 IU/lb Vitamin E[a].

Upon arrival, steers from Group 1 were randomly assigned to one of 16 pens (7-8 steers per pen) with pen being assigned to treatments (n = 4). Steers of known mineral history (group 2) were split in groups of 3 steers, with sub-groups either having previous exposure to (or not) mineral supplements prior to weaning. Respective groups of 3 steers were placed in pens where the remaining steers had an unknown mineral exposure history. Comingled groups were then stratified by previous mineral exposure (of group 2 calves) and assigned to one of the 2 post-weaning treatments; 1) steers received an Co, Cu, Mn and Zn in sulfate or chloride forms (inorganic; n = 8 pens); or 2) steers received Co, Cu, Mn and Zn in chelated forms (organic; n = 8 pens). Supplements for the inorganic and organic treatments had equal concentrations of Co, Cu, Mn and Zn.

Steers were progressively adapted from a moderate-concentrate to high-concentrate finishing record over the course of 53 days. The final finishing diet consisted of 59.3% dry-rolled corn, 22% modified distillers grains with solubles, 11% corn silage, 5% wheat straw, and 2.7% vitamin and mineral supplement (DM basis). The supplement contained a minimum of 10% CP, 1.5% crude fat, 17.5% Ca, 0.1% P, 6.5% salt, 1.1% Mg, 0.1% K, 400ppm Cu, 1400ppm Zn, 80,000 IU/lb vitamin A, 20,000 IU/lb of vitamin D, 330 IU/lb vitamin E, and contained 1000g/ton monensin. The supplement was fed to provide 250 mg of monensin per steer per day. Feed bunks were managed to be devoid of feed prior to feeding the subsequent day. Feed was delivered once daily at 0700. All calves received a growth promotant implant[b] at the initiation of the experiment, followed by a second growth promotant implant[c] on day 67 of the experiment based on anticipated marketing date. All calves received a parasiticide pour-on[d] at arrival in addition to a parasiticide pour-on[e] on day 67. Further, all calves received a vaccine for bovine respiratory disease[f] and clostridial disease[g] on day 0 and day 53.

The experiment was broken into 2 segments: a 53-day backgrounding experiment and a 149-day finishing experiment. On day 53 and 54, steers were weighed to allow for determination of body weight. Liver biopsies were performed on steers from Group 2 to assess trace mineral status upon arrival (day 0), and at the conclusion of backgrounding (day 53). Biopsies were collected by trained personnel utilizing a trochar[h] to gather a minimum of 20 mg of liver tissue to allow for mineral analysis. Steers were again weighed on 2 consecutive days prior to shipment to a commercial abattoir for harvest. Carcass data was not collected due to health concerns, and the inability of collection crews to enter facilities.

Experiment 2

Eighty-three Angus-crossbred beef steer calves (650 ± 57.3 lb initial BW) were utilized in a complete random design with a 2 × 2 factorial arrangement in this 181-day finishing experiment. Factors included exposure to (or not) mineral supplements during gestation and exposure to (or not) to mineral supplements during the subsequent lactation. Calves were generated as a result of a multi-year project. For the purposes of this experiment, treatments were defined as: Gestation – included the time from spring turnout in year 1 until weaning in the fall, and Lactation – included the time from spring turnout in year 2 until weaning. Briefly, cows in the preceding experiment were provided either access to or no access to mineral supplements in the summer of 2019. Cows were re-randomized in the summer of 2020 to these treatments resulting in calves from cows exposed to 4 distinct groups. The mineral supplement used in year 2 of the cow-calf portion of the experiment contained 12.0-14.0% Ca, 17.5-21.0% NaCl, and a minimum of 6% P, 2.75% Mg, 3,400 ppm Mn, 38 ppm Co, 3,000 ppm Cu, 300 ppm I, 36 ppm Se, and 9,000 ppm Zn, in addition to a minimum of 250,000 IU/lb Vitamin A, 25,000 IU/lb Vitamin D, and 250 IU/lb Vitamin E.[i] More information on beef cow management can be found in the following publication.[5]

Calves were adapted from a moderate-concentrate to a high-concentrate diet in 5 equal steps over the course of 35 days. The final finishing diet consisted of 52.0% dry-rolled corn, 30% modified distillers grains with solubles, 10% corn silage, 5% grass hay, 2.5% vitamin and mineral supplement, and 0.5% calcium carbonate (DM basis). The finishing diet supplement contained a minimum of 10% CP, 1.5% crude fat, 17.5% Ca, 0.1% P, 6.5% salt, 1.1% Mg, 0.1% K, 400ppm Cu, 1400ppm Zn, 80,000 IU/lb vitamin A, 20,000 IU/lb of vitamin D, 330 IU/lb vitamin E, and contained 1000 g/ton monensin. The supplement was fed to provide 250 mg of monensin per steer per day. Copper, Zn, Mn and Co were all included as inorganic forms.

Upon arrival, steers were weighed on 2 consecutive days, sorted and assigned to a pen. All calves received a growth promotant implant[b] at the initiation of the experiment, followed by a second growth promotant implant[c] on day 84 of the experiment. Additionally, all calves received a parasiticide pour-on[d] at arrival in addition to a parasiticide pour-on[e] on day 84. All calves received a vaccine for bovine respiratory disease[f] and clostridial disease[g] on day 0. Liver biopsies were performed on a subset of steers from each pen (3 steers per pen) to assess pre-weaning trace mineral status upon arrival (d 0), and trace mineral status on day 56 after initiation of the experiment in the same manner as Experiment 1. Unfortunately, due to poor electronic identification tag reading and inability for collection crews to enter facilities, the carcass data was not collected from steers.

Laboratory analysis

Diet samples were dried using a forced-air oven (65 °C; The Grieve Corporation, Round Lake, IL) for a minimum of 48 h for determination of DM content. Dried samples were ground using a Wiley Mill (Arthur H. Thomas Co., Philadelphia, PA) to pass a 2-mm screen. Feed samples were analyzed for DM, ash, CP, phosphorus, calcium, (methods 934.01, 942.05, 2001.11, 965.17, and 968.08, respectively).[2] Concentrations of NDF and ADF were determined using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY).[4,17] Laboratory analysis of Co, Cu, Mn and Zn in liver tissue and feed samples was performed with ICP mass spectrometry at the Diagnostic Center for Population and Animal Health at Michigan State University.

Statistical analysis

Cattle performance data were analyzed with Mixed Procedures of SAS (SAS Ins. Inc., Cary, NC). In experiment 1, organic versus inorganic trace mineral data from comingled calves was analyzed as a completely random design with two treatments (n = 8). The subset of calves with known history was further analyzed as a complete random design with a 2 × 2 factorial arrangement with factors of pre-weaning mineral access or not, and organic versus inorganic trace mineral source (n = 4). Data from experiment 2 was analyzed as a complete random design with a 2 × 2 factorial arrangement (n = 3) with main factors including mineral access or not during either early gestation (factor 1) or subsequent lactation (factor 2). Pen served as the experimental unit. Individual animal data was averaged within pen to create pen values. The model included the respective factors, as well as the interaction of the factors within experiment.

Liver trace mineral data for Experiment 1 were analyzed using the Mixed procedure of SAS with pen as the experimental unit. The model for data representing calves from Group 2 included pre-weaning treatment (no mineral or mineral), post-weaning treatment (inorganic or organic), day of evaluation (0 or 53), and all respective interactions. Liver trace mineral data for Experiment 2 were analyzed using the Mixed Procedure of SAS with pen as the experimental unit. Model terms included early-gestation treatment (no mineral or mineral), subsequent lactation (no mineral or mineral), day of evaluation (0 or 56), and all respective interactions. Covariate structures (simple, compound symmetry, autoregressive order 1 and variance components) were tested for goodness of fit, and models yielding the lowest Akaike information criterion (AIC) were used for data presented in this manuscript. Means were separated using the PDIFF procedure with a Tukey adjustment with *P*-values ≤ 0.05 were considered significant.

Results

Experiment 1

When data was pooled for calves of unknown and known mineral history, providing an organic source of trace mineral (Co, Cu, Mn and Zn) tended to result in greater average daily gain ($P = 0.09$; 3.5 and 3.8 ± 0.11 lb/d for inorganic and organic, respectively) during the first 53 days on feed (Table 1). However, over the duration of the finishing period, there was no difference ($P = 0.60$) in average daily gain due to trace mineral treatment. There were no differences ($P \geq 0.26$) in DMI or G:F during backgrounding or over the entire project. No carcass data was collected as collection personnel were not able to enter the abattoir for safety reasons, and travel restrictions in the spring of 2020.

When examining the performance data of the subset of calves, initial weight was greater ($P = 0.06$; Table 2) for steers with mineral access prior to weaning compared to those without mineral access prior to weaning; however, there was no difference in initial body weight of calves based on post-weaning treatment in of known mineral history ($P = 0.21$). The improvement in average daily gain in the pool of calves of unknown and known history during the first 53 days on feed was not observed in the subset of known history calves ($P = 0.58$).

For the minerals presented, no pre-weaning × post-weaning × day interactions were present ($P \geq 0.49$). Concentrations of Cu were influenced by pre-weaning treatment, being greater ($P < 0.01$; Table 3) in calves having mineral access compared with calves not having access on pasture. In addition, concentrations of Cu tended to be influenced by a post-weaning treatment × day interaction ($P = 0.08$), being greater on day 53 for steers receiving organic mineral supplementation compared with baseline levels for all steers, with day 53 samples from steers receiving inorganic mineral supplements being intermediate. No effects of pre-weaning or post-weaning treatment or tested interactions ($P \geq 0.14$) were observed for concentrations of Zn, but there was a day effect with concentrations decreasing ($P < 0.01$) from day 0 to day 53. No effects of pre-weaning or post-weaning treatment or tested interactions ($P \geq 0.29$) were observed for concentrations on Mn. Concentrations of Mn increased ($P < 0.01$) from day 0 to day 53 of the backgrounding period.

Table 1: Impacts of organic or inorganic Cu, Zn, Mn and Co mineral supplements on backgrounding and finishing performance of steers of both known and unknown mineral history prior to feedlot arrival (Experiment 1).

	Inorganic*	Organic*	SE	*P*-value
Observations	n = 8	n = 8		
Backgrounding (d 0 - 53)				
Initial BW, lb	579.5	579.3	3.64	0.98
Final BW, lb	759.4	772.0	5.23	0.11
ADG, lb/d	3.5	3.8	0.11	0.09
DMI, lb/d	14.1	14.3	0.22	0.40
G:F2	0.25	0.26	0.007	0.26
Overall				
BW, lb	1411.6	1402.8	12.90	0.63
ADG, lb/d	4.2	4.2	0.07	0.60
DMI, lb/d	20.7	21.2	0.51	0.56
G:F†	0.20	0.19	0.005	0.38

* Inorganic mineral was supplied via sulfate forms of Co, Cu, Mn and Zn, while organic mineral was supplied via commercially available chelated Co, Cu, Mn and Zn.

† G:F = lb of weight gain:lb of dry feed intake

Concentrations of Co at feedlot arrival were greater in calves with mineral access on pasture ($P = 0.01$) compared to calves not having access to mineral on pasture. In addition, concentrations of Co were influenced by post-weaning treatment × day interaction ($P < 0.01$), being greater ($P < 0.001$) on day 53 for steers receiving organic mineral supplementation compared with steers receiving inorganic minerals on day 53, which were greater ($P \leq 0.01$) than baseline concentrations for both post-weaning treatments.

Experiment 2

Steer body weight, ADG, DMI and G:F during the backgrounding and finishing periods were unaffected by maternal exposure or not to mineral supplements during either early gestation ($P \geq 0.47$) or subsequent lactation ($P \geq 0.14$), or the interaction of the 2 time points ($P > 0.33$; Table 4).

For all minerals evaluated, no gestation × lactation × day interactions were present ($P \geq 0.20$). Concentrations of Cu tended to be lesser ($P = 0.08$; Table 5) in calves from dams receiving mineral supplementation during early gestation compared

Table 2: Impacts of pre- and post-weaning trace mineral programs on steer performance in feedlot of calves with known trace mineral supplementation history (Experiment 1).

	Pre-weaning		Post-Weaning			*P*-values		
	Min	No-Min	Inorganic*	Organic*	SE	Pre-Weaning	Post-Weaning	Interaction
Observations	n = 4	n = 4	n = 4	n = 4				
Backgrounding (d 0 -53)								
Initial BW, lb	570.4	562.5	564.0	568.9	2.69	0.06	0.21	0.07
Final BW, lb	760.9	745.3	750.4	757.0	8.82	0.26	0.59	0.84
ADG, lb/d	3.7	3.5	3.7	3.7	0.15	0.58	0.87	0.66
Overall								
Final BW, lb	1418.5	1390.5	1406.1	1402.8	21.37	0.37	0.91	0.94
Final ADG, lb/d	4.2	4.2	4.2	4.2	0.11	0.52	0.79	0.74

* Inorganic mineral was supplied via sulfate forms of Co, Cu, Mn and Zn, while organic mineral was supplied via commercially available chelated Co, Cu, Mn and Zn. Pre-weaning treatment was established by calves having access to a commercial trace mineral source or not during the grazing season prior to weaning.

Table 3: Effect of pre-weaning mineral access during the grazing period and postweaning mineral type on concentrations of liver mineral in backgrounding steers (Experiment 1).

		Treatment*								
Pre-weaning		No min		Min			*P*-values			
Post-weaning		Inorganic	Organic	Inorganic	Organic	SE	Pre-weaning	Post-weaning	Day	Post-weaning × day
Item, ppm	Day									
Cu	0	69.4	58.6	105.8	99.7	13.09	< 0.01	0.36	< 0.01	0.08
	53	98.3	112.7	130.7	167.7					
Zn	0	200.9	224.6	190.1	210.2	11.61	0.97	0.27	< 0.01	0.14
	53	129.1	132.7	149.2	139.2					
Mn	0	8.6	9.0	8.6	9.2	0.54	0.29	0.68	< 0.01	0.38
	53	10.5	10.6	11.5	11.0					
Co	0	0.09	0.09	0.18	0.16	0.026	0.01	< 0.01	< 0.01	< 0.01
	53	0.22	0.54	0.27	0.54					

* Inorganic mineral was supplied via sulfate forms of Co, Cu, Mn and Zn, while organic mineral was supplied via commercially available chelated Co, Cu, Mn and Zn. Pre-weaning treatment was established by calves having access to a commercial trace mineral source or not during the grazing season prior to weaning.

with calves from dams that did not receive mineral supplementation during early gestation. In addition, calves receiving mineral access while suckling dams had greater ($P < 0.01$) concentrations of Cu than calves not receiving mineral access during lactation. Concentrations of Cu also tended to increase ($P = 0.08$) as the backgrounding period progressed.

Concentrations of Zn were not affected by mineral access during gestation, lactation, day, or any interactions tested ($P \geq 0.28$). Concentrations of Co were not influenced by mineral access during gestation, or any interactions tested ($P \geq 0.22$). Calves receiving mineral supplement while suckling dams had greater ($P = 0.03$) concentrations of Co compared with calves that did not have access to a mineral supplement, and concentrations of cobalt increased ($P < 0.01$) through the backgrounding period.

Discussion

Unlike previous data, steers supplemented with organic forms of trace minerals in the current experiment tended to have better average daily gain during the growing or backgrounding phase of the experiment.[1,14,16] Steers fed organic trace mineral sources had 0.24 lb/d greater ADG when compared to those fed inorganic sources of trace minerals, which is similar to the difference (0.22 lb/d) improvement in ADG seen in the present experiment with steers of unknown trace mineral history.[6] However, we did not observe a difference in ADG in steers of known trace mineral history when fed either organic or inorganic trace minerals post-weaning. It is possible that diet composition, region in which cattle originated from, in addition to breed could result in calves with differing responses to mineral programs. These factors could potentially explain the differences observed between the present and

Table 4: Impacts of maternal mineral access or not during early gestation and lactation on offspring performance during finishing (Experiment 2).

	Gestation*		Lactation*			*P*-values†	
	Mineral	No mineral	Mineral	No mineral	SEM	Gestation	Lactation
Observations	n = 3	n = 3	n = 3	n = 3			
Initial BW, lb	651.6	651.1	648.0	654.9	2.95	0.94	0.14
Final BW, lb	1427.3	1433.9	1423.6	1428.4	6.75	0.52	0.67
ADG, lb/d	4.4	4.4	4.4	4.4	0.04	0.47	0.32
DMI, lb/d	26.2	26.2	26.2	26.2	0.71	0.92	0.97
G:F‡	0.16	0.17	0.17	0.16	0.009	0.77	0.68

* Treatments established by dams having access to a commercial trace mineral source or not during either early gestation and/or lactation the following year with treatments applied from time of turnout to weaning.

† Interaction $P > 0.33$

‡ G:F = lb of weight gain:lb of dry feed intake

Table 5: Effect of mineral supplementation during either gestation and/or lactation on concentrations of liver mineral during the backgrounding period in crossbred beef calves (Experiment 2).

		Treatment*							
Gestation		No mineral		Mineral			*P*-values		
Lactation		No mineral	Mineral	No mineral	Mineral	SE	Gestation	Lactation	Day
Item, ppm	Day								
Cu	0	65.7	123.5	38.9	81.6	18.2	0.08	< 0.01	0.08
	56	101.1	116.4	71.4	119.2				
Zn	0	141.8	141.9	130.4	118.5	16.5	0.71	0.84	0.83
	56	122.0	130.8	128.6	141.5				
Mn	0	9.0	9.1	8.9	8.7	0.49	0.60	0.65	< 0.01
	56	10.6	9.6	9.7	10.3				
Co	0	0.13	0.18	0.14	0.15	0.015	0.75	0.03	< 0.01
	56	0.22	0.23	0.22	0.25				

* Treatments established by dams having access to a commercial trace mineral source or not during either early gestation and/or lactation the following year with treatments applied from turnout until weaning.

previous studies. Previous researchers offered that it was unknown whether performance responses to organic trace minerals are related to the source of mineral or increased mineral intake.[14] In the present experiment, dry matter intake was not different, lending credibility to the concept that mineral source (organic vs. inorganic) rather than intake was responsible for differences in steer performance, at least early in the feeding period. However, given that access to mineral does not necessarily indicate trace mineral intake, more detailed experiments evaluating mineral intake and subsequent performance are needed to fully understand the complexities of these interactions.

Performance of steers over the entirety of Experiment 1 was not affected by trace mineral source. This response is similar to previous data, where feedlot calves were fed either inorganic, organic or a mixture of inorganic and organic sources of trace minerals and did not have enhanced performance.[1,3,14] Therefore, the best use of organic trace minerals may be during receiving or backgrounding and the use of inorganic minerals may be sufficient to support animal production later in the feeding period.

The lack of performance differences in Experiment 2 indicates that access to free-choice trace mineral supplements during gestation or subsequent lactation do not have a long-lasting impact on steer performance post-weaning. We did not, however, quantify the impacts of trace mineral status on incidence of bovine respiratory disease, vaccine response, or carcass quality.

When feedlot heifers did not receive a mineral supplement, a steady decrease in Cu and Mn was observed over the duration of the finishing period.[9] Thus, our observations of improvements in Cu and Mn concentrations over time in current experiments with calves of known mineral history demonstrate the benefits of mineral supplementation. Our results are similar to previous results although the overall concentrations of these trace minerals appear to be greater in the present experiment.[8] Concentrations of Cu were initially marginal (33-125 ppm) in all calves upon feedlot arrival.[7] Copper status improved to adequate (128-600 ppm) by day-53 in calves with previous access to trace mineral supplements, regardless of source of trace minerals after feedlot arrival.[7] Liver Mn concentrations were considered marginal (7-15 ppm) throughout the experiment regardless of pre-weaning or post-weaning treatments.[7] A decrease in liver Zn concentration was also reported previously.[13] Previous researchers have attributed the reduction of liver Zn to use of Zn for production.[13] Regardless of this decrease, the concentrations of liver Zn would have always been considered adequate (25-200 ppm) across all treatments.[7] The observation that Co was the only mineral evaluated that was affected by physical form in the diet was unexpected. However, at no point were concentration of Co in the liver deficient (0.06 ppm) and were above heathy levels by the end of the backgrounding portion of the study.[10]

Previous researchers have reported that liver Cu concentrations of 10 mg/kg or less were associated with reduced growth.[15] Concentrations of Cu in the present studies in calves of known history were above this threshold partly explaining the lack of differences. Concentrations of Zn, Mn and Co were not different and therefore may help explain in part why there were no differences in performance.

In conclusion, providing access to mineral supplements during grazing, prior to weaning, had no impacts on subsequent gain or intake during growing and finishing. Providing organic forms of trace minerals tended to improve growth early in the feeding period. Copper status was improved for steers fed organic sources of trace mineral (Cu, Zn, Mn and Co). Future research with greater focus on health outcomes may be beneficial, especially when evaluating high-risk calves at feedlot entry.

End notes

[a] Repromune Min YC; Stockmen's Nutrition, West Fargo, ND

[b] Synovex S; Zoetis Inc., Parsippany-Troy Hills, NJ

[c] Synovex Choice; Zoetis Inc., Parsippany-Troy Hills, NJ

[d] Cydectin, Bayer Animal Health, Shawnee Mission, KS

[e] Clean-up II; Bayer Animal Health, Shawnee Mission, KS

[f] Bovi-Shield Gold One Shot; Zoetis Inc., Parsippany-Troy Hills, NJ

[g] Ultrabac 7/Somubac; Zoetis Inc., Parsippany-Troy Hills, NJ

[h] Tru-Cut Biopsy Trochar, Merit Medical, South Jordan, UT

[i] CHS 12-6+ Research Mineral; CHS Nutrition, Sioux Falls, SD

Conflict of interest

The authors declare no conflicts of interest.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

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Author contributions

Dr. Neville contributed to conception and design, collection and analysis of data, drafting of the manuscript, and approval of the final version to be published. Friederike Baumgaertner, Wayde Pickinpaugh, Dr. Menezes, Dr. McCarthy and Dr. Undi assisted with data collection, drafting of the manuscript, and approval of the final version to be published. Dr. Dahlen contributed to conception and design, collection and analysis of data, and drafting of the manuscript, and approval of the final version to be published.

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