

Effects of Source and Concentration of Trace Minerals on Feedlot Performance, Immunity, Mineral Status, Carcass Characteristics and Fatty Acid Profile of the *Longissimus* Muscle of Beef Steers

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SUMMARY

Trace minerals are important components in ruminant diets. However, minerals are often fed in amounts that exceed the requirement of the animal. The excess is excreted by the animal, which results in contamination of the soil and ground water. The objective of this study was to determine if trace minerals fed at different concentrations and sources affected feedlot performance, liver mineral concentrations, carcass characteristics and fatty acid profile in the *longissimus* muscle of beef steers.

Key Words: Steer, Trace Mineral, Fatty Acid, Carcass

INTRODUCTION

Current National Research Council (NRC) recommendations for trace mineral concentrations in the ration of beef cattle are formulated on a whole diet basis (NRC, 1996). Generally, the level recommended by the NRC is supplemented to cattle diets without realizing the current trace mineral levels in the basal diet, which results in excess supplementation of minerals.

Excess minerals such as phosphorus, copper (Cu) and Zn most commonly result in excretion of the minerals by the animal, which eventually accumulates in the soil and groundwater (Jongbloed and Lenis, 1998). Different mineral sources have been fed to cattle in attempts to

achieve higher levels of absorption of the mineral into the small intestine. One source, organic minerals, have shown to be more bioavailable (Nockels *et al.*, 1993), as well as have the same availability as inorganic mineral forms (Henry *et al.*, 1992; Rojas *et al.*, 1995). The different results may be due to interactions or antagonistic effects with other minerals within the digestive system.

The supplementation of Cu at 10 and 20 ppm in the diet of finishing beef steers has been shown to reduce back fat depth and to increase the percentage of unsaturated fatty acids in the *longissimus* muscle (Engle and Spears, 2000; Engle *et al.*, 2000). The objectives of this study were to determine if initial mineral status and supplementation of minerals at: 1) different levels and 2) from alternate sources changed quantitative parameters of beef steers during feeding from receiving to harvest.

MATERIALS AND METHODS

The Colorado State University Animal Care and Use Committee approved the care, treatment, and handling of animals used in this study.

Receiving Phase

Two-hundred ninety six crossbred steers (mean BW 583 ± 70 lbs) were utilized in a research study at the Agricultural Research Development and Education Center (ARDEC) beef feedlot facility in Fort Collins, CO. Prior to arrival, calves and dams were on a native grass pasture and randomly assigned to two different mineral treatments. Treatments consisted of: 1) Cu deficient inorganic free choice mineral, or 2) Cu adequate organic free choice mineral. Mineral treatments were initially available to the cows the third trimester of gestation and to the calves from birth until shortly prior to weaning. Upon arrival, calves were weighed, bled via jugular venipuncture, vaccinated with Bovi-Shield® 4+/L5 and Cattle Master® 4 (Pfizer Animal Health, Exton, PA), dewormed with Dectomax® (Pfizer Animal Health, Exton, PA) pour-on and placed in

pens. Bleeding was continued 7, 14 and 21 days after arrival to determine antibody titer values for infectious bovine rhinotracheitis (IBR) in non-heparinized tubes (Becton Dickinson, Franklin Lakes, NJ). Steers were supplemented with 50% whole corn, 43% alfalfa hay, and 7% protein supplement (DM basis, 10.6 lbs DM/steer/d) for 8 days. Twelve steers were removed from the feedlot phase during the beginning of the study and used in a metabolic trial. Three steers were eliminated from the study due to morbidity reasons and two steers died during the trial. Data from these steers were not used for analysis after they were removed from the study.

On d 0 of the trial, steers were weighed and implanted with Ralgro® (Intervet, Millsboro, DE). Steers were then blocked by initial ranch treatment and weight, stratified by breed and assigned to pens that measured 21 x 125 ft (32 pens, 8-11 steers per pen). Pens were then randomly assigned to treatments. Treatments consisting of whole diet mineral concentrations of: 1) 2xNRC organic mineral from Availa-4, 2) NRC organic mineral from Availa-4, 3) 3xNRC inorganic mineral, or 4) 6xNRC inorganic mineral. Minerals referred to in treatment groups are Cu, Zn, Mn, and Co. Inorganic mineral sources are CuSO₄, ZnSO₄, MnSO₄, and CoCO₃. Steers were fed a step up growing ration consisting mainly of whole corn for 31d (Table 1). The basal growing diet contained 3.0 ppm of Cu; 20.1 ppm of Zn; and 9.6 ppm of Mn. Steers were weighed and three randomly selected steers per pen were bled via jugular venipuncture on d 28 of the growing phase. A liver biopsy was obtained from five randomly selected steers per pen on d 0 and d 28 to determine mineral status (Engle *et al.*, 1997). Blood and liver samples were transported on ice to the laboratory. Blood samples were centrifuged at 1,300 x g for 25 min and plasma was removed. Plasma and liver samples were frozen at -9°F until analyzed.

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Finishing Phase

At the conclusion of the step-up receiving ration, steers were changed over to a finishing diet (Table 2), of which they remained on for the remainder of the study. The basal finishing diet contained 1.8 ppm of Cu; 19.7 ppm of Zn; and 5.9 ppm of Mn. During finishing steers remained in the same treatment groups as in the growing phase, however whole diet mineral treatments were changed to: 1) NRC organic mineral from Availa-4, 2) 1.5xNRC organic mineral from Availa-4, 3) 1.5xNRC inorganic mineral, or 4) 3xNRC inorganic mineral. The same three steers that were bled on d28 were bled again on d 56, 84, 112, 140, 168, 198, and 230 of the trial. Steers were reimplanted with Revalor-S (Intervet, Millsboro, DE) on d 84 and a liver biopsy was obtained from the same five steers on d 112 of the trial.

Harvest Phase

Equal numbers of pens from each treatment were slaughtered on two different dates, d198 and d230. Final live weights and hot carcass weights were obtained on the day of slaughter. Fat depth over the *longissimus* muscle (between the 12th and 13th ribs); estimated percentage of kidney, pelvic, and heart (KPH) fat; lean maturity; bone maturity; marbling score; quality grade (QG); and yield grade (YG) were determined by trained Colorado State University (CSU) personnel after the two slaughter dates. *Longissimus* muscle area (LMA) was determined using acetate paper being placed on the exposed ribeye area after it had been ribbed. Each ribeye blot was traced and measured using Meatscan software (version 2.11, 1998). Prior to carcass grading, *longissimus* muscle samples were obtained, placed in Whirlpack bags, transported to the laboratory and frozen at -112°F until analyzed for fatty acid profile and percent lipid.

Analytical Procedures

Serum samples were analyzed for antibody titers to IBR in the Virology

Section at the Diagnostic Laboratory (Department of Clinical Sciences; Colorado State University; Fort Collins, CO). Plasma was analyzed for ceruloplasmin content by a spectrophotometer (Spectronic Genesys 5, Rochester, NY) using the method described by Houchin (1958). Plasma samples were diluted 1:1 with 10% TCA and Cu concentrations were determined using flame atomic absorption spectrophotometry (Varian Model 1275) at the Diagnostic Laboratory (Department of Pathology; Colorado State University; Fort Collins, CO). Plasma samples were diluted 1:4 with deionized water and Zn concentration was determined using flame atomic absorption spectrophotometry on the machine described above. Liver samples were analyzed for mineral concentration by the method described by Braselton *et al.*, (1997) in the Toxicology Section of the Animal Health Diagnostic Laboratory (Michigan State University). Lipid extraction procedure was performed using the chloroform:methanol method described by Bligh and Dyer (1959). Fatty acid composition of the *longissimus* muscle was determined via gas chromatography, comparable to the method described by Engle *et al.*, 2000.

Statistical Analysis

Data were analyzed with least square ANOVA using the GLM procedures of SAS (2001). The model contained treatment x time interactions.

RESULTS

All treatment groups mentioned from here on are from the finishing phase. Average daily gain (ADG) and gain:feed were not affected by treatment, however average daily feed intake (ADFI) was reduced ($P < 0.0001$) with inorganic mineral supplementation (Table 3). Liver Cu concentrations were higher ($P < 0.05$) on d 112 in treatment groups that contained a higher level of Cu compared to the NRC organic mineral treatment group (Table 4). There was

not a statistical difference between treatments for ceruloplasmin activity or antibody titer values for IBR. Plasma Zn levels were higher ($P < 0.05$) on d 28 in steers at the 1.5xNRC level supplemented with organic mineral compared to inorganic (Table 4). Plasma Zn levels also were increased ($P < 0.01$) with inorganic mineral supplementation. Steers in the NRC organic mineral treatment group exhibited a higher ($P < 0.05$) dressing percentage than ones in the 1.5xNRC inorganic treatment group (Table 5). Organic mineral supplementation at the 1.5xNRC level resulted in a higher ($P < 0.05$) percentage of 18:3 and 18:2 *cis9 trans11* fatty acids in the *longissimus* muscle than steers supplemented with the 1.5xNRC level of inorganic mineral (Table 6). There were also marked increases ($P < 0.05$) in the percentage of 20:4 fatty acids in the *longissimus* muscle of steers supplemented at the 1.5xNRC level with inorganic mineral compared to the ones with organic mineral at NRC levels (Table 6).

IMPLICATIONS

Excess mineral supplementation above NRC requirements does not improve growth performance in beef feedlot steers. However, organic mineral supplementation, particularly at the 1.5xNRC level increased the levels of unsaturated fatty acids in the *longissimus* muscle. This increase would make beef a more appealing item for consumption by health conscious people, thus stimulating demand and sales for beef products.

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Table 1. Step-Up Ration % DM

Ingredient	Ration Number				
	1	2	3	4	5
Feedlot Phase	Growing	Growing	Growing	Growing	Finishing
Days Fed	16	7	8	9	199
Whole Corn	50.4	61.8	72.3	79.4	86.3
Alfalfa Hay	42.7	31.4	20.9	13.8	7.0
Supplement	6.9	6.8	6.8	6.8	6.7

Table 2. Composition of Ration

Item	Growing	% ^a	Finishing
Whole Corn	66.00		86.30
Alfalfa Hay	27.20		7.00
Supplement	6.80		6.70
Supplement Constituents:			
Sunflower Meal 32%	77.30		-
Ground Corn	-		45.50
Limestone	6.97		12.30
Urea	6.00		15.80
Feather Meal	3.87		-
Salt	2.07		2.10
Biofos	1.12		7.80
Wheat Midds	-		7.50
Dyna-mate	0.57		1.38
Dyna-K	-		6.00
Niacin 98%	0.27		0.25
Tylan 40	0.22		0.16
Rumensin	0.22		0.24
Selenium (0.16)	0.06		0.08
Vitamin premix ^b	0.23		0.06
Mineral premix ^c	1.03		0.75

^aDry matter basis.

^bContained per pound of supplement: Growing Supplement: 194216 IU of Vitamin A and 581 IU of Vitamin E.
Finishing Supplement: 133008 IU of Vitamin A and 535 IU of Vitamin E.

^cContained per pound of supplement:

Growing Ration: Treatments: 1) 442 ppm of Cu from Availa®-4, 1421 ppm of Zn from Availa®-4, 849 ppm of Mn from Availa®-4 and 39 ppm of Co as CoCO₃. 2) 295 ppm of Cu from Availa®-4, 933 ppm of Zn from Availa®-4, 526 ppm of Mn from Availa®-4 and 23 ppm of Co as CoCO₃. 3) 851 ppm of Cu as CuSO₄, 2103 ppm of Zn as ZnSO₄, 1797 ppm of Mn as MnSO₄ and 65.6 ppm of Co as CoCO₃. 4) 1646 ppm of Cu as CuSO₄, 4488 ppm of Zn as ZnSO₄, 3234 ppm of Mn as MnSO₄ and 150 ppm of Co as CoCO₃.

Finishing Ration: Treatments: 1) 363 ppm of Cu from Availa®-4, 651 ppm of Zn from Availa®-4, 706 ppm of Mn from Availa®-4 and 25.5 ppm of Co as CoCO₃. 2) 576 ppm of Cu from Availa®-4, 1001 ppm of Zn from Availa®-4, 1091 ppm of Mn from Availa®-4 and 24.4 ppm of Co as CoCO₃. 3) 735 ppm of Cu as CuSO₄, 1069 ppm of Zn as ZnSO₄, 1313 ppm of Mn as MnSO₄ and 16.7 ppm of Co as CoCO₃. 4) 1354 ppm of Cu as CuSO₄, 1683 ppm of Zn as ZnSO₄, 2046 ppm of Mn as MnSO₄ and 12.3 ppm of Co as CoCO₃.

Table 3. Effects of source and concentration of trace minerals on growth performance of finishing steers

Item	Treatments				SEM
	NRC Organic	1.5xNRC Organic	1.5xNRC Inorganic	3xNRC Inorganic	
Body weight, lbs					
Initial	581	580	581	581	12.18
Final	1273	1284	1304	1304	17.23
ADG, lbs	3.0	3.1	3.1	3.1	0.075
ADFI, lbs of DM ^{a,b,c}	23.0	22.1	22.0	21.1	0.216
Gain:feed ^d	0.15	0.16	0.16	0.17	0.004

^aNRC Organic vs 1.5xNRC Organic and 1.5xNRC Inorganic ($P < 0.01$).

^bNRC Organic vs 3xNRC Inorganic ($P < 0.0001$).

^c3xNRC Inorganic vs 1.5xNRC Organic and 1.5xNRC Inorganic ($P < 0.01$).

^dNRC Organic vs 3xNRC Inorganic ($P < 0.01$).

Table 4. Effects of source and concentration of trace minerals on liver mineral concentrations in growing and finishing steers

Item	Treatments				SEM
	NRC Organic	1.5xNRC Organic	1.5xNRC Inorganic	3xNRC Inorganic	
Plasma Cu, ppm					
Growing					
d28	1.06	1.07	1.07	1.07	0.032
Finishing					
d198	1.29	1.28	1.30	1.30	0.031
Plasma Zn, ppm					
Growing					
d28 ^{de}	0.765	0.830	0.729	0.854	0.032
Finishing					
d198	1.14	1.09	1.06	1.06	0.045
Liver Cu, ppm DM					
Growing					
d0	178.3	152.6	177.3	174.6	11.01
d28 ^{ab}	223.7	190.7	343.6	374.9	12.17
Finishing					
d112 ^c	292.8	387.2	353.6	426.7	18.99
Liver Zn, ppm DM					
Growing					
d0	139.8	139.3	133.4	140.4	6.56
d28	96.2	103.6	93.1	97.2	4.96
Finishing					
d112	94.7	95.1	95.2	99.6	3.00

^aNRC Organic vs 1.5xNRC Inorganic ($P < 0.0001$).

^b1.5xNRC Organic vs 1.5xNRC Inorganic ($P < 0.0001$).

^cNRC Organic vs 1.5xNRC Organic and 1.5xNRC Inorganic ($P < 0.05$).

^d1.5xNRC Inorganic vs 1.5xNRC Organic ($P < 0.05$).

^e1.5xNRC Inorganic vs 3xNRC Inorganic ($P < 0.01$).

Yield Grade	3.24	3.21	3.22	3.37	0.090
12 th rib backfat, in	0.59	0.58	0.59	0.61	0.024
KPH, %	1.97	1.97	1.98	1.99	0.036
LMA, in ²	13.0	12.8	13.0	12.6	0.165
Hot Carcass wt., lb	794	786	794	793	8.125
Dressing Percentage ^c	61.40	60.30	60.40	61.20	0.210
Overall Maturity ^b	58.50	57.90	58.20	58.20	1.500
Marbling ^a	437	414	426	431	8.400

Table 5. Effects of source and concentration of trace minerals on carcass characteristics of finished steers

Item	Treatment				SEM
	NRC Organic	1.5xNRC Organic	1.5xNRC Inorganic	3xNRC Inorganic	

^aSelect⁺ = 350-399, Choice⁻ = 400-499, Choice^o = 500-599.

^bA = 0-100, B = 100-200.

^cNRC Organic vs 1.5xNRC Inorganic ($P < 0.01$).

Table 6. Effects of source and concentration of trace minerals on fatty acid profile of the *longissimus* muscle in beef steers

Items	Treatments				SEM
	NRC Organic	1.5xNRC Organic	1.5xNRC Inorganic	3xNRC Inorganic	
14:0	.56	.53	.52	.67	.08
16:0	20.89	20.55	20.28	20.56	.49
16:1	.35	.38	.33	.38	.03
18:0	8.67	9.25	9.56	9.49	.51
18:1 <i>trans</i>	3.46	3.72	3.18	3.44	.32
18:1 <i>cis</i>	27.12	26.67	28.71	27.44	1.02
18:1	29.60	30.40	30.61	30.77	.89
18:2	2.65	2.72	2.42	2.49	.17
18:3 ^a	.07	.08	.07	.08	.004
18:2 <i>cis9 trans11</i> ^a	.07	.08	.06	.07	.01
20:4 ^b	.02	.02	.04	.02	.01

^a1.5xNRC Organic vs 1.5xNRC Inorganic ($P < 0.05$).

^b1.5xNRC Inorganic vs NRC Organic and 3xNRC Inorganic ($P < 0.05$).