Impacts of Zinc, Manganese, and Copper Source on Mature Bull Sperm Quality, Trace Mineral Status, and Performance

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IMPACT STATEMENT

Hydroxychloride trace minerals may be more bioavailable and more readily stored in the liver compared with Cu and Zn sulfate. Greater Zn concentrations were correlated with less sperm acrosomal damage, but other sperm characteristics and quality were not affected by trace mineral source. However, trace minerals status was not deficient in the bulls, which may, in part, be explained by maturity.

SUMMARY

Our objective was to measure impacts of trace mineral source on liver mineral status and performance of mature bulls. Thirty-seven mature bulls of mixed breeds fed in the drylot for 71 d were blocked by length of time without trace mineral supplementation and stratified by initial liver Cu status to one of three dietary supplements (4 pens/treatment). Treatments were: 1) Supplement without Cu, Zn, and Mn (**CON**); 2) Supplement with Cu, Zn, and Mn sulfate (**SULF**); and 3) Supplement with basic Cu chloride, Zn and Mn hydroxychloride (HCTM). On d 71, liver Cu concentrations of HCTM bulls were greater ($P = 0.008$) than CON and SULF bulls. Liver Zn concentrations tended to be greater ($P = 0.08$) in HCTM bulls compared with SULF bulls. All other liver trace minerals were not different ($P \geq 0.16$) due to dietary treatments. Liver concentration of Cu increased ($P = 0.04$) from the d -24 to 71 biopsy in HCTM bulls but not CON or SULF bulls. Sperm morphology, acrosomal integrity, motility, and concentration were not different ($P \geq 0.10$) between treatments. Diets deficient in trace mineral for >170 d had no other detrimental effects on semen quality of mature bulls. We conclude that the chloride based trace minerals may be more bioavailable and more readily stored in the liver compared with Cu, Mn, and Zn sulfate.

INTRODUCTION

Trace mineral requirements are specified for growing and finishing cattle, gestating cows, and cows in early lactation, but there are no specific requirements listed for bulls (NRC, 2000). In addition, bulls at some locations often receive poorer quality feeds once the breeding season is over and impacts of poorer quality feed on bull fertility has not been assessed.

A case study conducted by Arthington et al. (2002) indicated that a greater percentage of yearling bulls failed breeding soundness exams based on sperm morphology and motility when fed Zn at 40 mg/kg compared with bulls fed at 60 mg/kg. Yearling bulls fed complexed mineral (Zn, Cu and Mn) tended to reach puberty after fewer days of supplementation than bulls fed sulfate minerals (Geary et al., 2016).

We hypothesized that mature bulls fed the chloride trace mineral supplement would have improved trace mineral status and spermatozoa quality.

MATERIALS AND METHODS

All procedures were approved by the animal care and use committee of USDA-ARS Fort Keogh LARRL.

Animals and Diets. Thirty-seven mature bulls of mixed breeds were used in a 71 d trial. Bulls were blocked by length of time without trace mineral supplementation and stratified by initial liver Cu status to one of three dietary supplements (4 pens/supplement): 1) Supplement without Cu, Zn, and Mn (**CON**); 2) Supplement with Cu, Zn, and Mn sulfate (**SULF**); and 3) Supplement with basic Cu chloride, Zn and Mn hydroxychloride (**HCTM**; IntelliBond, Micronutrients USD LLC, Indianapolis, IN). Liver biopsies were collected on d -73, -24, and 71 to determine trace mineral status. The basal diet was fed once daily ad libitum (Table 1) and top-dressed (1 lb/hd/d) with supplements containing Cu, Zn, and Mn were fed at 75% of NRC requirements for growing and finishing cattle (Table 2; NRC, 2000). Semen collection and scrotal circumference measurements were collected on d 0, 36, and 70. Ejaculates were evaluated for spermatozoa concentration, motility, and morphology as part of a standard breeding soundness examination. Acrosome integrity, sperm viability, and mitochondrial membrane potential were evaluated via flow cytometry.

Table 1. Dietary ingredients and nutrient composition of bull diet.

Ingredient	Basal Diet, % DM
Corn silage	80.0
Chopped grass hay	10.0
Straw	10.0
Nutrient Composition	
DM, %	92.0
CP, % of DM	11.5
TDN, % of DM	55.9
Mn, ppm	49.9
Cu, ppm	8.9
Zn, ppm	35.6

Statistical Analysis. The MIXED procedure of SAS was used for the statistical analysis of all data. Initial data measurements were used as covariates. Significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Initial and final BW and ADG were not different ($P \geq 0.67$; Table 3) between treatments. Similar to the current results, Arthington et al. (1992) observed similar ADG in bulls consuming a diet with 40 or 60 ppm Zn.

On d 71, liver Cu concentrations of HCTM bulls were greater ($P = 0.008$) than CON and SULF bulls. Liver Zn concentrations tended to be greater ($P = 0.08$) in HCTM bulls compared with SULF bulls. All other trace minerals were not different ($P \geq 0.16$) due to dietary treatments. Liver concentration of Cu increased ($P = 0.04$) from the d -24 to 71 biopsy in HCTM bulls. No differences ($P \geq 0.17$) were observed in any other liver trace mineral concentrations between treatments from the d -24 to 71 liver biopsies. Although there were differences observed in liver trace mineral status between bulls, none of the bulls were deficient at the time points measured as defined by Kincaid (1999). The study suggests that liver trace mineral status is extremely resilient in mature animals as some of the CON bulls were without mineral supplement for more than 170 d.

Table 2. Supplement nutrient composition.

	Supplement[1]		
	CON	SULF	HCTM
DM, %	90.0	90.0	90.0
	% DM Basis		
CP	17.9	17.9	17.9
TDN	78.9	78.7	78.8
Fat	4.3	4.3	4.3
	parts per million		
Mn	0.048	300.0	300.0
Zn	0.159	233.3	233.3
Cu	23.75	83.3	83.3
Se	1.22	1.22	1.22

[1]Dietary supplements: CON: supplement without Cu, Zn, and Mn; SULF: supplement with Cu, Zn, and Mn sulfate; and HCTM: supplement with basic Cu chloride, Zn and Mn hydroxychloride.

Sperm morphology was not different ($P \geq 0.42$; Table 4) between treatments. Bull sperm

acrosomal integrity were not affected ($P \geq 0.26$) by dietary treatment, but liver Zn concentration on d 71 was correlated ($r = -0.39$, $P = 0.02$) with less acrosome damage and tended to be correlated with greater sperm concentration ($r = 0.31$, $P = 0.06$) in ejaculates. Sperm motility and concentration were not affected ($P \geq 0.24$) by treatment.

In conclusion, trace mineral source did not impact mature bull performance, but the hydroxychloride trace minerals did improve liver copper and zinc concentrations. Greater liver Zn concentrations were correlated with less acrosomal damage, but other sperm characteristics were not affected. Therefore, the chloride based trace minerals may be more bioavailable and more readily stored in the liver compared with Cu and Zn sulfate. Winter provision of trace minerals to mature bulls may not provide any beneficial effects on subsequent fertility measures.

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Table 3. Impacts of trace mineral source on performance and liver trace mineral status.

	Dietary Supplement				
Item	CON	SULF	HCTM	SEM	*P* - value
BW, lbs					
Initial	1563	1434	1522	128.3	0.77
Final	1733	1594	1672	109.5	0.67
ADG, lb/d	2.31	2.18	2.06	0.34	0.88
Copper, ppm					
Initial	98.1	114.2	107.3	25.94	0.91
Final	80.4	77.3	124.6	8.90	0.008
Manganese, ppm					
Initial	8.23	8.69	8.13	0.51	0.72
Final	7.34	7.83	8.95	0.62	0.22
Selenium, ppm					
Initial	0.89	0.93	0.92	0.05	0.84
Final	1.14	0.98	1.30	0.06	0.02
Zinc, ppm					
Initial	165.8	134.3	123.1	20.97	0.36
Final	114.8	107.8	135.8	7.72	0.08

Table 4. Impacts of trace mineral source on bull spermatozoa characteristics

	Dietary Supplement				
Item	CON	SULF	HCTM	SEM	*P* - value
Scrotal circumference, cm					
Initial	41.0	39.2	38.8	0.64	0.04
Final	40.0	39.8	40.4	0.59	0.74
Normal morphology, %					
Initial	76.5	78.0	74.6	4.31	0.85
Final	80.8	80.6	74.3	3.86	0.44
Progressive motility, %					
Initial	59.2	65.8	68.3	4.68	0.36
Final	58.4	55.2	69.6	5.37	0.18
Concentration, 10^6 cells/mL					
Initial	348.8	367.9	332.7	75.0	0.95
Final	715.2	662.8	861.6	91.6	0.29
Live intact sperm, %					
Initial	58.3	51.6	51.8	6.34	0.69
Final	46.2	43.7	47.8	3.65	0.74
Live damaged sperm, %					
Initial	20.6	31.3	21.6	4.12	0.14
Final	35.1	39.5	33.2	5.24	0.70
Dead intact sperm, %					
Initial	1.26	2.16	1.52	0.389	0.30
Final	1.24	1.11	1.28	0.188	0.81
Dead damaged sperm, %					
Initial	19.8	15.0	25.1	4.35	0.27
Final	17.1	17.0	16.9	3.07	1.00
	Mitochondrial Potential, %				
Polarized sperm					
Initial	30.3	15.6	25.0	8.52	0.49
Final	52.0	70.6	59.6	8.65	0.55
Depolarized sperm					
Initial	41.6	48.9	50.4	12.45	0.85
Final	45.3	30.5	33.2	8.50	1.00
Transitioning sperm					
Initial	29.8	35.6	25.2	11.69	0.82
Final	1.70	0.48	6.34	3.38	0.17
	Acrosomal Integrity, %				
Live intact sperm					
Initial	61.9	60.0	57.5	5.46	0.85
Final	49.4	48.8	50.1	4.11	0.98
Live disrupted sperm					
Initial	0.99	1.47	1.25	0.211	0.26
Final	1.16	1.50	1.50	0.301	0.66
Dead intact sperm					
Initial	18.5	14.0	22.3	4.06	0.36
Final	15.0	12.9	15.5	2.32	0.72
Dead disrupted sperm					
Initial	18.5	24.5	18.9	3.10	0.35
Final	34.5	37.3	32.6	5.70	0.85