Effects of Zinc Source and Dietary Concentration on Zinc Status, Growth Performance, and Wool Characteristics in Developing Rams

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IMPACT STATEMENT

Overall, Zn source and concentration affected ADG, serum Zn concentrations, staple length, and tended to increase feed efficiency. Results indicate the beneficial effects of supranutritional Zn concentrations beyond basal dietary concentrations. Although Zn retention and metabolic pathways of Zn metabolism were not investigated, results indicate that greater dietary Zn concentrations can enhance nutritional strategies in ram development. These findings might be especially applicable to producers developing white-face type rams for fall ram sales in the mountain west and northern plains regions.

SUMMARY

The objectives of this study were to evaluate the effects of dietary zinc source and concentration on Zn status, growth performance, and wool characteristics in developing rams. There were no differences in DMI (P = 0.18), BW (P = 0.45), LMD (P = 0.48), BF (P = 0.47), and AFD (P = 0.9) among treatment groups. $ZnSO_4$ had greater ($P \leq 0.03$) serum Zn concentrations compared to ZnAA and CON treatments. Rams consuming ZnAA had greater ($P \leq 0.03$) ADG than $ZnSO_4$ and CON. There tended to be differences among groups for G:F (P = 0.06), with ZnAA being greater than $ZnSO_4$ and CON. SL was greater ($P < 0.001$) in the $ZnSO_4$ treatment group and tended to be longer (P = 0.06) in ZnAA treatment group compared to CON. These results indicate that the source and concentration of a Zn supplement appears to improve ram development, specifically ADG, serum Zn concentrations, SL, with a tendency to improve G:F. Although zinc retention and metabolic pathways of zinc metabolism were not investigated, results indicate that greater dietary zinc concentrations could be beneficial to ram development. This evidence can be utilized to make sound management decisions when accounting for minerals with developing rams in Montana and other northern range lands.

INTRODUCTION

Western sheep production systems rely largely on rangeland plant communities as the primary feed source. This reliance on the rangeland plant community could lead to mineral deficiencies, which may limit the productivity of livestock operations. Mineral concentrations in forages are highly variable across rangelands (Mathis et al., 2004) with influential factors such as soil geochemistry (Smith et al., 2013) and forage stage of maturity (Jones and Tracy, 2015). Numerous studies have suggested that the chemical form of a mineral source plays an important role in bioavailability; generally with organic sources being more bioavailable than inorganic sources (Rojas et al., 1995; Spears, 2003). A survey conducted to quantify serum Zn concentrations in Montana ram lamb populations indicated that approximately 14% of ranches sampled were categorized as being deficient and 52% marginally deficient in Zn (Page et al., 2016).

Zinc is the second most abundant trace mineral in the body with important functions

involved in reproduction (Kumar et al., 2006), gene expression (Berg, 1990), immune function (Spears and Weiss, 2008), and wool growth in sheep (White et al., 1994). Cholecystokinin, an appetite regulating hormone is thought to be affected by the gene expression properties of zinc which in turn could affect growth rate (Blanchard and Cousins, 1996). Subclinical deficiencies in Zn could be more frequent than other trace minerals because the body does not sequester large amounts of available Zn in any one organ. (NRC, 2007; Herdt and Hoff, 2011). Optimal concentrations of dietary Zn are not well understood, and with such high tolerance to dietary Zn in most mammals, there is potential for higher supplementation levels than the recommended concentrations for sheep (NRC, 2007). The objective of the present study was to quantify the effects that dietary zinc source and concentration have on developing ram zinc status, growth performance, and wool characteristics.

PROCEDURES

Experimental procedures described herein were approved by the Agriculture Animal Care and Use Committees of Montana State University (#2016-AA09). All animals used in this study were provided by the Montana Agricultural Experiment Station, and the study was conducted at the Fort Ellis Research Station at Montana State University in Bozeman, MT.

Forty-four purebred Targhee rams (14 mo of age; 150 ± 40 lb BW) were utilized in an 84 d completely randomized design. Rams were stratified by BW, serum Zn concentrations and allocated to one of three pelleted dietary treatments: 1) control diet without fortified Zn (**CON**; n = 15; Table 1); 2) a diet fortified with a Zn amino acid complex (**ZnAA**, Zinpro Corp; n = 14); and 3) a diet fortified with $ZnSO_4$ (**$ZnSO_4$**; n = 15). The basal diet was formulated to meet 100% of nutrient and Zn requirements of developing rams (24 mg of Zn/kg; NRC, 2007). Zinc dietary treatments were formulated to provide 300% of Zn (72 ppm Zn) and 100% of nutrient requirements. Rams were fitted with an electronic identification tag and each pen was equipped with two GrowSafe bunks (GrowSafe Systems Ltd., Airdrie, AB, Canada) to monitor individual intake. Rams were denied access to a complete free choice granulized mineral premix d -50 to d 0 of the study to normalize trace mineral status.

Feed intake was monitored daily and additional feed was added to the bunk as needed. Rams were weighed on consecutive days on d -1 and 0, 27 and 28, 55 and 56, and 83 and 84. For the consecutive days at the beginning and end of the study rams were fasted 12 h before weights were recorded. On d 27, 28, 55, and 56 rams were given free access to feed prior to BW being recorded.

Ultrasonic measurements of loin muscle depth (**LMD**) and back fat (**BF**) were taken on d 0, 28, 56, and 84 of the study. Wool side samples were collected from rams on d 0 and d 84, and wool staple length (**SL**) growth over the 84-d

Table 1. Chemical and nutrient composition of dietary treatments.

	Dietary Treatments[1]		
Item	CON	ZnAA	$ZnSO_4$
Ingredient, %			
Alfalfa, DHY-17	37.47	37.43	37.46
Corn, ground	30	30	30
Soybean hulls	15	15	15
Malt sprouts	10	10	10
Molasses, cane	4	4	4
Calcium carbonate	1.35	1.35	1.35
Ammonium chloride	1	1	1
Mineral premix	1.18	1.18	1.18
Nutrient Composition[2]			
DM, %	90.41	90.41	90.41
CP, %[3]	17.6	16.8	17.4
NDF, %	30.72	30.71	30.72
ADF, %	20.72	20.71	20.72
Ash, %	7.65	7.65	7.67
Mineral Composition[2]			
Ca, %	1.24	1.24	1.24
P, %	0.35	0.35	0.35
K, %	1.5	1.5	1.5
S, %	0.19	0.19	0.19
Mg, %	0.21	0.21	0.21
Na, %	0.39	0.39	0.39
Fe, ppm	237.37	237.2	237.31
Mn, ppm	89.14	89.13	89.14
Cu, ppm	7.87	7.86	7.87
Zn, ppm[3]	47.5	95.5	91.5
I, ppm	0.9	0.9	0.9

[11]Dietary treatments: 1) control diet without fortified zinc (CON); 2) a diet fortified with a Zn amino acid complex (ZnAA); and 3) a diet fortified with $ZnSO_4$.
[2]Calculated concentration in diets.
[3]Analyzed concentration in diets.

study was measured at 5 locations and averaged for each ram. Wool side samples were prepared and analyzed for fiber diameter (**AFD**) and other wool traits by the Montana State Wool Lab utilizing the OFDA 2000 optical scanning device.

Blood samples were collected via jugular venipuncture into trace mineral royal blue top vacutainer tubes (Covidien, Mansfield, MA) without additives for blood serum analysis. The first blood sample was obtained on d -16 of the study for the purpose of stratifying groups by serum Zn status. Blood samples were then collected on d 28, 56, and 84 of the study. Serum Zn concentrations were determined by a commercial laboratory (Michigan State University Diagnostic Center for Population and Animal Health, East Lansing).

Data were analyzed as a completely randomized design with individual ram as experimental unit. Growth performance and intake data were analyzed as repeated measures using the MIXED procedure of SAS (version 9.4; SAS Inst. Inc., Cary, NC).

RESULTS AND DISCUSSION

Effects of Zn source and dietary concentration on ADG, DMI, G:F, and BW are presented in Tables 2 and 3. There was no difference ($P = 0.18$) among treatments for DMI. Overall, there was no difference ($P = 0.45$) among treatments in BW. Rams consuming ZnAA had greater ($P \leq 0.03$) ADG than $ZnSO_4$ and CON rams. Similar results were found in lambs supplemented with Zn-methionine and ZnO, with a tendency of Zn-methionine to increase growth performance (Spears, 1989). There tended to be differences among groups for G:F ($P = 0.06$) with ZnAA being greater than $ZnSO_4$ and CON. Although Zn deficiency is less of a clinical problem in ruminant animals (Herdt and Hoff, 2011), some of the initial signs of deficiency include poor feed intake and reduced growth rates (Herdt and Hoff, 2011). Zinc's effects on growth and intake performance may be in part modulated by its relationship with cholecystokinin. Cholecystokinin secretion is increased in Zn-deficient intestinal tissues and serves roles in endocrine and neurocrine functions regulating gall bladder contraction, pancreatic secretion, gastric emptying, and satiety mechanisms (Blanchard and Cousins, 1996).

Effects of Zn on ultrasound measurements of LMD and BF are presented in Table 3. There were no differences in LMD ($P = 0.48$) and BF ($P = 0.47$) among treatments.

Wool traits for rams measured in the study are presented in Table 3. Average wool fiber diameter (AFD) did not differ ($P = 0.96$) among treatments regardless of Zn source or concentration. Staple length (SL) was greatest ($P < 0.001$) in rams consuming fortified $ZnSO_4$ diets compared to CON; whereas ZnAA tended ($P = 0.06$) to have longer staple length over the 84-d study than CON. Zinc is a major constituent in wool (NRC, 2007), and Zn plays a critical role in the keratinization process through structural and regulatory factors (Tomlinson et al., 2004), which could provide a reasonable explanation for rams consuming greater concentrations of Zn, despite different sources, tended to have longer SL. Zinc deficiencies reduce wool growth and impair keratinization in wool through a specific mechanism, perhaps involving protein synthesis (White et al., 1994).

Serum Zn concentrations were greatest ($P \leq 0.03$) in $ZnSO_4$ (Table 3; Figure 1); whereas, serum Zn concentration did not differ ($P = 0.12$) between ZnAA and CON. Zinc homeostasis is tightly regulated in the body (Herdt and Hoff,

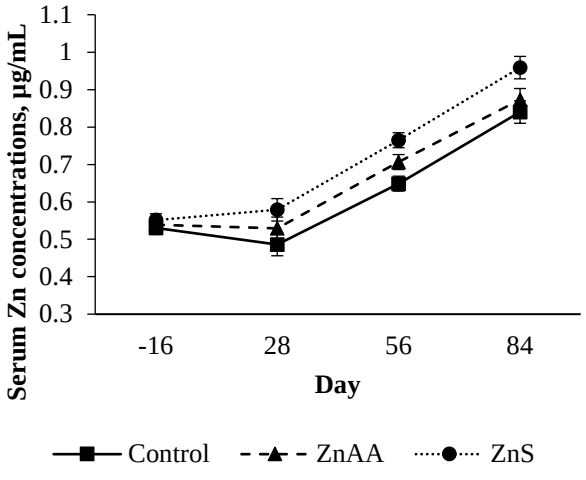

Figure 1. Effects of Zn source on serum Zn concentrations in rams. Treatment x day: $P = 0.22$; dietary treatment: $P = 0.002$; and day: $P < 0.0001$.

2011), and resultant Zn tissue concentrations remain relatively constant over a wide range of Zn intakes. There is no clear site of accumulation of Zn throughout the body and Zn absorption is reduced under conditions of ample Zn intake (NRC, 2007; Herdt and Hoff, 2011), which could offer a reasonable explanation for not having observed an increase in serum Zn levels in ZnAA, with this study. In a similar study, Zn absorption did not differ between Zn sources, but retention was greater in lambs treated with Zn Methionine than with a ZnO source, indicating difference in metabolism post-absorption or tissue retention (Spears, 1989).

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Table 2. Effects of dietary Zn source and period on the performance of rams, carcass traits, serum Zn concentrations, and wool traits

	Treatment[1]					Period				
Item	CON	ZnAA	$ZnSO_4$	SEM[2]	*P* – value	d 0 to 28	d 29 to 56	d 57 to 84	SEM[2]	*P* – value
ADG, lb/d	0.73[b]	0.88[a]	0.75[b]	0.40	0.03	0.97[a]	0.88[a]	0.51[b]	0.44	<0.001
DMI, lb/d	6.86	7.32	7.01	1.79	0.18	6.19[a]	7.56[b]	7.43[b]	1.27	<0.001
G:F	0.109[b]	0.124[a]	0.109[b]	0.005	0.06	0.158[a]	0.115[b]	0.068[c]	0.005	<0.001

[1]Dietary treatments: 1) control diet without fortified zinc (CON; Table 1); 2) a diet fortified with a Zn amino acid complex (ZnAA, Zinpro Corp); and 3) a diet fortified with $ZnSO_4$.
[2]Greatest SEM presented (n = 15).
[a-c] LS means, within a row, lacking common superscripts differ (P < 0.05).

Table 3. Effects of dietary Zn source and day on the performance of rams, carcass traits, serum Zn concentrations, and wool traits

	Treatment[1]					Day					
Item[3]	CON	ZnAA	$ZnSO_4$	SEM[2]	*P* – value	0	28	56	84	SEM[2]	*P* – value
BW, lb	184.5	191.8	185.4	4.45	0.45	150.8[a]	178.1[b]	203.0[c]	216.9[d]	2.87	<0.001
LMD, mm	30.02	29.80	29.13	0.55	0.48	25.30[a]	28.34[b]	30.56[c]	34.41[d]	0.50	<0.001
BF, mm	4.45	4.70	4.70	0.17	0.47	2.98[a]	4.28[b]	5.25[c]	5.96[d]	0.15	<0.001
Serum Zn, µg/mL[4]	0.63[b]	0.66[b]	0.71[a]	0.16	0.002	0.54[a]	0.53[a]	0.71[b]	0.89[c]	0.02	<0.001
SL, mm	23.37[b]	25.91[b]	26.67[a]	1.02	0.003	—	—	—	—	—	—
AFD, micron	22.1	22.1	22.0	0.34	0.96	—	—	—	—	—	—

[1]Dietary treatments: 1) control diet without fortified zinc (CON; Table 1); 2) a diet fortified with a Zn amino acid complex (ZnAA, Zinpro Corp); and 3) a diet fortified with $ZnSO_4$.
[2]Greatest SEM presented (n = 15).
[3]LMD: loin muscle depth; BF: back fat; SL: wool staple length; AFD: average fiber diameter.
[4]d 0 measurements were collected d -16.
[a-d] LS means, within a row, lacking common superscripts differ (P < 0.05).