Influence of feeding amino acid complexes of zinc and copper on growth performance and carcass response of finishing steers fed ractopamine hydrochloride[1]

Chanda L. Engel,[2] Gary Tibbetts,* and Mark E. Branine

Zinpro Corporation, Eden Prairie, MN 55344

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INTRODUCTION

Feeding a beta-agonist (βA) to finishing cattle prior to harvest increases muscle mass. Beta-agonists work by increasing lipolysis and increasing muscle accretion. Zinc and Cu are trace metals known to be involved in the signaling and activation of βA activity at the cellular level. Feeding 90 mg Zn/kg dry matter (DM) from zinc–amino acid complex throughout the finishing period, with a βA, has been shown to improve cattle performance (Genther-Schroder et al., 2016). Similar to Zn, research suggests Cu is also involved in the βA cascade. Feeding a supplemental source of amino acid-complexed Cu (AAC-Cu) throughout the finishing period including the time the βA was fed has shown enhanced animal performance responses (Messersmith et al., 2018). However, no information is presently available evaluating responses to feeding finishing cattle a lower level of Zn followed by an increased level of Zn or Zn with Cu, concurrently with a βA. We hypothesized feeding finishing steers both added Zn and Cu would enhance the βA response and further improve cattle finishing performance. The objectives of this research were to evaluate 1) the effects of level and timing of feeding Zn methionine (ZINPRO, Zinpro Corporation, Eden Prairie, MN) with a βA to finishing beef steers on the combined performance responses to added Zn and βA in the last ~40 d of the finishing period and 2) effects from feeding supplemental Cu from a AAC-Cu (Availa-Cu, Zinpro Corp.) in combination with higher Zn levels and βA on finishing beef cattle performance and carcass responses.

MATERIALS AND METHODS

Prior to study initiation, all cattle were fed a common finishing diet at a commercial feedlot. Steers (n = 120) were selected from two large group pens of similar cattle originating from the same source ranch. Steers were individually weighed (mean body weight [BW] = 624 kg) and sequentially assigned, as they came through the processing chute, to one of three treatment groups: 1) nasal finishing diet (Table 1) including trace minerals from inorganic sources plus 30 mg Zn/kg DM from zinc methionine (AAC-Zn; ZINPRO, Zinpro Corporation, Eden Prairie, MN; CON); 2) basal finishing diet + 90 mg Zn/kg DM from AAC-Zn (AAC-Zn90); or 3) AAC-Zn90 diet + 10 mg Cu/kg DM from copper amino acid complex (AAC-Cu; Availa-Cu, Zinpro Corp.; AAC-Zn/Cu). Cattle in all three treatment groups were fed 300 mg/hd/d ractopamine hydrochloride (RAC; Optaflexx, Elanco Animal Health Inc., Greenfield, IN) for 35 d prior to harvest. Study pens (n = 40 steers per pen) were equipped with GrowSafe Systems

*Retired.

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[2]Corresponding author: cengel@zinpro.com

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Table 1. Ingredient composition of basal finishing diet for steers fed 30 or 90 mg Zn/kg DM from Zn methionine (ZINPRO, Zinpro Corporation, Eden Prairie, MN) with or without 10 mg Cu/kg DM from Cu amino acid complex (Availa-Cu, Zinpro Corp.) concurrently with ractopamine the last 35 d of the finishing period

Ingredient	% DM
Rolled corn	63.0
Dry distillers grain	16.4
Corn silage	8.0
Beet pulp	7.0
Supplement[1]	5.6
Total	100

[1]Supplement formulated to provide monensin at 36 g/ton, tylosin at 9 g/ton, and ractopamine hydrochloride at 300 mg/hd/d.

(Calgary, AB, Canada) feed bunks to measure individual daily intakes. Cattle were acclimated to respective treatment diets and GrowSafe bunks for 7 d followed by a 35-d RAC feeding period. After 42 d, steers were group weighed by pen and shipped to a commercial packing plant for harvest. Final individual animal BW were calculated using individual animal hot carcass weight divided by overall mean dressing percentage as determined by total live weight (5% shrink adjustment) and carcass weight at the packing plant. Carcass data were collected from each individual animal. Treatment diets were sampled midway through the feeding period and tested for chemical composition at a commercial laboratory (Table 2). Intake data were summarized by animal and day. Nine steers were removed from the final data set because intake data validity could not be determined. Cook's *D* was used to further check data validity and evaluate specific animal or data points for inclusion or exclusion. Normality and homogeneity of variance were evaluated across all parameters in the final data set. Growth performance, DM intake, and carcass data were analyzed as a completely randomized design using the MIXED procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC) with individual animal within pen as the experimental unit. The statistical model included dietary treatment as a fixed effect and random effect of animal. Initial BW was evaluated and retained as a covariate in the statistical model. Categorical data, USDA quality and yield grade (YG), were analyzed using PROC GLIMMIX in SAS 9.4; treatment served as fixed effects and individual animal as random effects. For all statistical analyses, $P < 0.05$ were considered highly significant, $P \leq 0.10$ regarded as significant, and $P \leq 0.15 \geq 0.10$ denoted a statistical trend.

Table 2. Chemical analysis of treatment diets (DM basis) for steers fed 30 or 90 mg Zn/kg DM from Zn methionine with or without 10 mg Cu/kg DM from Cu amino acid complex concurrently with ractopamine the last 35 d of the finishing period

	Treatments[1]		
Item	CON	AAC-Zn90	AAC-ZN/Cu
Dry matter	61.6	58.4	56.6
Crude protein, %	15.5	15.2	15.5
Acid detergent fiber, %	9.1	10.1	9.6
Total digestible nutrients, %	89.7	88.5	89.2
Net energy, maintenance, Mcal/kg	2.23	2.21	2.23
Net energy gain, Mcal/kg	1.54	1.52	1.52
Metabolizable energy, Mcal/kg	3.24	3.20	3.22
Calcium, %	0.60	0.61	0.65
Phosphorus, %	0.37	0.37	0.39
Zinc, mg/kg	108	179	169
Copper, mg/kg	16	16	26

[1]CON = basal finishing diet + 30 mg/kg DM supplemental Zn from ZINPRO zinc methionine (Zinpro Corporation, Eden Prairie, MN; AAC-ZN) + 300 mg/hd/d ractopamine hydrochloride (RAC) for 35 d; AAC-Zn90 = basal finishing diet + 90 mg/kg DM supplemental Zn from AAC-Zn + 300 mg/hd/d RAC for 35 d; AAC-Zn/Cu = AAC-Zn90 diet + 10 mg/kg DM supplemental Cu from copper amino acid complex (Availa-Cu, Zinpro Corp.) + 300 mg/hd/d RAC for 35 d.

RESULTS

Chemical and ingredient composition of experimental diets are shown in Tables 1 and 2, respectively. Analyzed values for Cu in the CON and AAC-Zn90 treatments were lower than the formulated value; however, analyzed Cu level in the AAC-Zn/Cu treatment was approximately 10 mg/kg greater than the formulated value. Similarly, for Zn, analyzed concentrations in the AAC-Zn90 and AAC-Zn/Cu were substantially greater than the formulated value for these treatment diets. Based on the measured DM intake and analyzed feed values, total Cu and Zn intakes were 179 and 1,208, 175 and 1,942, and 285 and 1,856 mg/d for CON, AAC-Zn90, and AAC-Zn/Cu treatments, respectively. No significant differences ($P \geq 0.10$) in growth parameters were apparent among treatment groups (Table 3). Numerically, the AAC-Zn fed cattle had heavier calculated final BW than CON and AAC-Zn/Cu, respectively.

No significant difference ($P \geq 0.10$) was measured among treatments for hot carcass weight (HCW; Table 4), although, numerically, HCW for cattle fed AAC-Zn90 was greater than cattle fed CON and AAC-Zn/Cu, respectively. The primary response of interest observed in this experiment was the apparent effect from feeding added Cu from AAC-Cu on carcass fatness measures. Marbling

Table 3. Effect of feeding 30 or 90 mg Zn/kg DM from Zn methionine with or without 10 mg Cu/kg DM from Cu amino acid complex concurrently with ractopamine the last 35 d of the finishing period on DM intake and calculated growth performance in finishing beef steers

	Treatment[1]				Probability[3]			
						Contrast[4]		
Item	CON	AAC-Zn90	AAC-Zn/Cu	SEM[2]	Overall	1	2	Covariate[5]
Initial *n*	40	40	40	—	—	—	—	—
Final *n*	38	35	38	—	—	—	—	—
Initial BW, kg	622	626	624	5.8	0.91	0.66	0.83	—
DM intake, kg	11.5	11.2	11.3	0.19	0.44	0.21	0.73	<0.01
Calculated values								
Final BW, kg[6]	657	661	657	3.6	0.55	0.58	0.34	<0.001
Total gain, kg[7]	58	63	58	3.6	0.55	0.58	0.34	0.34
Daily gain, kg	1.4	1.5	1.4	0.09	0.55	0.58	0.34	0.34
Gain/feed	0.12	0.13	0.12	0.01	0.31	0.34	0.22	0.06

[1]CON = basal finishing diet + 30 mg/kg DM supplemental Zn from ZINPRO zinc methionine (Zinpro Corporation, Eden Prairie, MN; AAC-ZN) + 300 mg/hd/d ractopamine hydrochloride (RAC) for 35 d; AAC-Zn90 = basal finishing diet + 90 mg/kg DM supplemental Zn from AAC-Zn + 300 mg/hd/d RAC for 35 d; AAC-Zn/Cu = AAC-Zn90 diet + 10 mg/kg DM supplemental Cu from copper amino acid complex (Availa-Cu, Zinpro Corp.) + 300 mg/hd/d RAC for 35 d.

[2]Standard error of least squares means based on the largest value resulting from unequal numbers within each treatment.

[3]Probability based on *F*-statistic.

[4]Contrast 1 = CON vs. AAC-Zn90; Contrast 2 = AAC-Zn90 vs. AAC-Zn/Cu.

[5]Initial body weight used as covariate in statistical model.

[6]Hot carcass weight divided by overall mean dressing percentage.

[7]Calculated final BW minus initial BW.

Table 4. Effect of feeding 30 or 90 mg Zn/kg DM from Zn methionine with or without 10 mg Cu/kg DM from Cu amino acid complex concurrently with ractopamine the last 35 d of the finishing period on carcass parameters in finishing beef steers

	Treatment[1]				Probability[3]			
						Contrast[4]		
Item	CON	AAC-Zn90	AAC-Zn/Cu	SEM[2]	Overall	1	2	Covariate[5]
Initial hd.	40	40	40	—	—	—	—	—
Final hd.	38	38	35	—	—	—	—	—
Hot carcass wt, kg	424	427	424	2.3	0.55	0.58	0.34	<0.001
Marbling score[6]	464[z]	479[z]	436[y]	13.4	0.06	0.45	0.02	0.09
USDA quality grade								
Total choice, %	81.58[z]	88.24[z]	62.16[y]	0.08	0.03	0.66	0.02	—
Total select, %	18.42[y]	11.76[y]	37.84[z]	0.08	0.03	0.66	0.02	—
Backfat thickness, cm	1.5[z]	1.4[y]	1.3[y]	0.1	0.05	0.02	0.48	0.40
Ribeye area, cm^2	98.7	97.0	99.9	1.42	0.33	0.90	0.14	<0.01
Yield grade[7]	3.0	3.0	2.8	0.09	0.11	0.23	0.08	0.15
HCW:REA	4.3	4.4	4.2	1.63	0.18	0.66	0.07	<0.01

[1]CON = basal finishing diet + 30 mg/kg DM supplemental Zn from ZINPRO zinc methionine (Zinpro Corporation, Eden Prairie, MN; AAC-ZN) + 300 mg/hd/d ractopamine hydrochloride (RAC) for 35 d; AAC-Zn90 = basal finishing diet + 90 mg/kg DM supplemental Zn from AAC-Zn + 300 mg/hd/d RAC for 35 d; AAC-Zn/Cu = AAC-Zn90 diet + 10 mg/kg DM supplemental Cu from copper amino acid complex (Availa-Cu, Zinpro Corp.) + 300 mg/hd/d RAC for 35 d.

[2]Standard error of least squares means based on the largest value resulting from unequal numbers within each treatment.

[3]Probability based on *F*-statistic.

[4]Contrast 1 = CON vs. AAC-Zn90; Contrast 2 = AAC-Zn90 vs. AAC-Zn/Cu.

[5]Initial body weight used as covariate in statistical model.

[6]Select = 300–399; choice$^-$ = 400 to 499; choice^0 = 500 to 599; choice$^+$ = 600 to 699.

[7]Calculated USDA yield grade.

[yz]Means within row with uncommon superscripts differ (Tukey's adjusted *P*-value).

score was reduced ($P \leq 0.06$) when 10 ppm Cu from AAC-Cu was added to the diet with 90 ppm Zn from AAC-Zn (AAC-Zn90 vs. AAC-Zn/Cu; Contrast 2) and was numerically lower than CON. Although average marbling score (MARB) across all treatment groups ranged between 436 and 479, indicating a degree of marbling within the Small category, the relative reduction in MARB for cattle fed added Cu from AAC-Cu was apparent. The reduction in carcass finish was also observed through lower backfat thickness between cattle fed CON and AAC-Zn90 (Contrast 1, $P = 0.02$) with no difference between cattle fed AAC-Zn90 and AAC-Zn/Cu (Contrast 2, $P = 0.48$). Calculated YG, although similar between steers fed CON and AAC-Zn90, tended to be lower for steers fed AAC-Zn/Cu again reflecting a lower overall measure of carcass finish. A similar response was observed where the percentage of total carcasses grading USDA Choice was reduced ($P = 0.03$) in cattle fed AAC-Zn/Cu compared with CON and AAC-Zn90 (Table 4). Conversely, the percentage of carcasses grading USDA Select was increased ($P = 0.03$) for cattle fed AAC-Zn/Cu compared with CON and AAC-Zn90.

DISCUSSION

The present study represents another link in a chain of research undertaken to better understand the relationship and response of source and feeding rate of supplemental Zn with feeding a βA, primarily RAC, to feedlot cattle. It is well documented that during the short time period a βA is fed to finishing cattle prior to harvest, protein accretion and muscle mass dramatically increase. This is accomplished through metabolic processes that increase protein synthesis and decrease protein degradation in skeletal muscle and increase lipolysis and decrease lipogenesis in adipose tissue of cattle. The βA activity depends on binding to a compatible receptor (β-AR) in the muscle cell or adipocyte. The β-AR has multiple allosteric binding sites for Zn (Mersmann et al., 1998), which affects the βA ability to bind to the receptor. Beta-agonists function by binding to the G-protein-coupled receptor causing an upsurge in cyclic adenosine monophosphate concentration, which serves to mediate the increased protein synthesis and decreased adipose tissue deposition responses (Mills, 2002). This rapid body composition repartitioning and associated metabolic processes may increase in response to an alternative source and feeding rate of a more bioavailable Zn, such as AAC-Zn, particularly in cattle with genetic capacity for higher rates of efficient BW gain (Genther-Schroder et al. 2016).

Similar to Zn, research suggests Cu is also involved in the βA cascade, inhibiting phosphodiesterase activity, thus potentiating the βA signal to maintain its activity to alter carcass composition and increase growth rates in cattle. Research evaluating the potential role of Cu status on RAC function suggested feeding 10 mg Cu/kg from AAC-Cu to RAC-fed steers quadratically increased average daily gain ($P \leq 0.002$) and tended ($P \leq 0.1$) to increase DM intake, feed efficiency, and ribeye area (Messersmith et al., 2018).

In the present study, dramatic effects were observed with feeding AAC-Cu in addition to the higher level of AAC-Zn. Assuming when cattle were randomized to treatment, relative body fat composition was similar across all animals, the observed responses in carcass fatness measures following feeding RAC and 10 mg Cu/kg DM from AAC-Cu for 35 d were dramatic, although in general agreement with previous research. A review by Engle (2011) indicated Cu is involved in beef cattle lipid metabolism. Although the consensus from this research substantiates a role for dietary Cu to modify body composition in ruminants, subsequent research has not yet determined the underlying mechanism.

In the present study, although statistical significance was not observed for growth performance and carcass parameters, the general numerical trends agree with observations in previous research studies. However, a primary difference between the present study and previous research is that both the higher feeding levels of AAC-Zn and added AAC-Cu were initiated concurrently with the feeding of RAC. In previous studies, cattle were supplemented with AAC-Zn or -Cu prior to initiation of feeding the βA. Although not conclusive, results from this study suggest that a higher feeding rate of AAC-Zn concurrently with RAC may incrementally improve growth performance, carcass weight, and ultimately total value per animal with little downside risk and at a minimal increased cost. Currently, there is too little definitive research to recommend feeding additional supplemental Cu concurrently with RAC. These results agree with previous research that have shown an effect of supplemental Cu to decrease overall fat content in finishing beef cattle. The current study and Messersmith et al. (2018) at present are the only data available where supplemental AAC-Cu was fed concurrently with a βA. It may be intriguing to speculate that the lower fat content in steers fed AAC- Zn/Cu, may stimulate lipolytic and protein accretion effects attributable to the repartitioning effect of RAC. Additional research may lead to optimizing the level and source of supplemental Cu and Zn fed during the RAC feeding phase to modify carcass yield and quality to an optimal economic end point.

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