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The Effects of Increasing Organic or Inorganic Zinc on Growth Performance and Carcass Characteristics of Finishing Pigs

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The Effects of Increasing Organic or Inorganic Zinc on Growth Performance and Carcass Characteristics of Finishing Pigs^{1,2}

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Summary

A total of 3,390 pigs (PIC 337 × 1050; initially 63.2 lb), housed in three replicate barns, were used in this study to determine the influence of increasing organic or inorganic Zn sources on growth performance and carcass characteristics of finishing pigs. A total of 126 pens of pigs were allotted to 1 of 7 dietary treatments, with 24 to 27 pigs per pen and 14 to 17 replications per treatment. All diets contained a trace mineral premix that provided 55 ppm of Zn from ZnSO₄. The seven experimental treatments were a control diet with no additional zinc included in the diet; the control diet with an additional 25, 50, or 75 ppm of Zn from a zinc AA complex (ZnAA; Availa®-Zn; Zinpro Corporation, Eden Prairie, MN); or the control diet with an additional 25, 50, or 75 ppm of zinc from ZnO. Diets were fed in meal form, for five dietary phases, and formulated to maintain a constant standardized ileal digestible Lys:NE ratio within phase.

Overall, a Zn × level interaction (quadratic; $P < 0.05$) was observed for ADG as pigs fed increasing ZnO had similar ADG, while pigs fed added levels of 25 and 50 ppm ZnAA had decreased performance compared to those fed the highest level of ZnAA. A Zn source × level interaction (quadratic; $P < 0.05$) was also observed for overall F/G. This was due to pigs fed diets with 25 or 50 ppm Zn from ZnAA having poorer F/G compared to pigs fed similar levels of ZnO. The interaction in ADG also led to a tendency (quadratic; $P < 0.10$) for a Zn source × level interaction for final BW. No differences were observed for ADFI. For carcass characteristics, a Zn source × level interaction ($P < 0.05$) was observed for HCW, as pigs fed diets with 25 or 50 ppm Zn from ZnAA had decreased HCW compared with those fed 75 ppm Zn from ZnAA, while increasing ZnO did not influence HCW. Loin depth and percentage lean tended to increase and then decrease (quadratic; $P < 0.10$) as added ZnAA increased; however, a similar response was not observed for increasing added ZnO. These data suggest that in fin-

¹ The authors thank Zinpro Corp., Eden Prairie, MN for providing the organic Zn and for partial financial support.

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ishing pigs, supplemental ZnO did not impact growth performance, but low inclusion levels of ZnAA increased F/G and reduced final BW.

Key words: finishing pigs, growth, zinc

Introduction

The NRC (2012)⁴ estimates the dietary Zn requirement for a growing pig weighing from 50 to 270 lb ranges from 50 to 60 ppm. Historically, the trace mineral premix is considered to be the sole source of supplemental Zn for meeting and/or exceeding the NRC requirement estimate, of growing and finishing pigs. Recently, research has reported growth performance benefits from greater concentrations of supplemental Zn when included in diets containing ractopamine (Fry et al., 2013⁵; Rambo, 2013⁶). However, Paulk et al. (2015)⁷ added either ZnO or an organic Zn source at 75, 150, or 225 ppm of the diet starting at 35 or 41 d before slaughter, in diets containing ractopamine, and observed no benefit from the supplemental Zn nor a difference between Zn sources. It is not clear if supplementing Zn at levels greater than that supplied by the trace mineral premix, and for the entire finishing period, will lead to growth or carcass performance benefits.

Previous studies with Zn additions to grow-finish diets were performed in university research settings. However, under a commercial environment, pigs have lower feed intakes and growth rates, due to higher stocking density and other detrimental environmental factors. Therefore, the objective of this study was to determine the influence of increasing Zn, from either an organic or inorganic source, on growth performance and carcass characteristics of grow-finish pigs housed in a commercial facility.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted in three barns at a commercial research-finishing facility in southwest Minnesota. The three barns were similar in design with completely slatted concrete floors, natural ventilation, and double-curtain sides. Each pen was equipped with a 4-hole stainless steel feeder and bowl waterer for ad libitum access to feed and water. Feed additions to each individual pen were made and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN).

Animals and Diets

A total of 3,390 mixed sex pigs (PIC 337 × 1050; initially 63.2 lb) were used in this study, and housed in three replicate barns. Barn 1 utilized 1,122 pigs for 112 d; barn 2

⁴ NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press, Washington, D.C.

⁵ Fry, S., W. Hu, N. Paton, and D. Cook. 2013. Effect of dietary zinc level and source and ractopamine level on performance and carcass traits of finishing pigs. *J. Anim. Sci.* 91(Suppl.2):O231 (Abstr.).

⁶ Rambo, Z. J. 2013. Effects of supplemental zinc and ractopamine on growth performance, carcass composition, and skeletal muscle synthesis and gene expression in finishing pigs. PhD Diss. Purdue Univ., West Lafayette, IN.

⁷ Paulk, C. B., D. D. Burnett, M. D. Tokach, J. L. Nelssen, S. S. Dritz, J. M. DeRouchey, R. D. Goodband, G. M. Hill, K. D. Haydon, and J. M. Gonzalez. 2015. Effect of added zinc in diets with ractopamine hydrochloride on growth performance, carcass characteristics and ileal mucosal inflammation mRNA expression of finishing pigs. *J. Anim. Sci.* 93:185-196.

used 1,159 pigs for 114 d; while barn 3 included 1,109 pigs fed for 120 d. On d 0 within each barn, pens of pigs (24 to 27 pigs per pen) were ranked by average pig weight and randomly assigned within weight blocks to 1 of 7 dietary treatments, resulting in six replicates per barn in a randomized complete block design. All diets contained a trace mineral premix that provided 55 ppm of Zn from ZnSO_4 . The treatments were arranged as a $2 \times 3 + 1$ factorial with two Zn sources and three levels of Zn added at the expense of corn. The seven experimental treatments were a control diet with no additional Zn included in the diet; the control diet with an additional 25, 50, or 75 ppm of Zn from ZnAA (Availa®-Zn; Zinpro Corporation; Eden Prairie, MN); or the control diet with an additional 25, 50, or 75 ppm of Zn from ZnO. Diets were fed in meal form for five dietary phases (60 to 100, 100 to 135, 135 to 170, 170 to 230, and 230 to 280 lb; Table 1). Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN) was included at 5 ppm in all diets, in the final phase. Diets were formulated to maintain a constant standardized ileal digestible Lys:NE ratio within phase, based on previous research conducted in the same research facility.

Due to a malfunction of the robotic feeding system that resulted in interrupted feed delivery, six pens from replicate barn 1 and eight pens from barn 2 were removed from the study. Additionally, two pens were removed from the dataset in barn 3 due to a broken gate, which allowed pigs from two pens to come in. For pens removed from the data set, data for all phases were eliminated. This resulted in 14 replicates for pigs fed the control diet; 17 replicates per treatment for pigs fed either 25, 50, or 75 ppm Zn from ZnAA; and 17, 14, and 14 replicates for pens of pigs fed either 25, 50, or 75 ppm Zn from ZnO, respectively.

Sample Collection

Samples from each diet and group were collected for each phase. Samples were then combined for a composite and analyzed for DM, CP, crude fiber, ether extract, ash, ADF, NDF, and Zn (Ward Laboratories, Inc., Kearney, NE; Tables 2, 3, and 4). An additional Zn analysis was also conducted at Cumberland Valley Analytical Services (Hagerstown, MD). Results of Zn analyses from both labs were combined, and the mean analytical values are reported.

Pens of pigs were weighed, and feeder measurements recorded approximately every 2 to 3 wk to calculate ADG, ADFI, and F/G. On d 99, 97, and 103, the 4, 3, or 4 heaviest pigs in barns 1, 2 and 3, respectively, were marketed according to standard farm procedures. Prior to marketing, pigs were individually tattooed with a pen ID number to allow for recording of carcass measurements on a pen basis. On d 112, 114, and 120 for barns 1, 2, and 3, respectively, final pen weights were taken, and pigs were transported approximately 58 miles to a commercial packing plant (JBS Swift and Company, Worthington, MN) for processing and carcass data collection. Carcass measurements taken at the plant included HCW, 10th rib loin depth, backfat, and percentage lean. Percentage carcass yield was also calculated by dividing individual HCW at the plant, by average final live weight of pen at the farm. Fat depth and loin depth were measured with an optical probe inserted between the third and fourth last rib (counting from the ham end of the carcass), at a distance approximately 2.75 in from the dorsal midline.

Statistical Analysis

The experimental data were analyzed as a randomized incomplete block design using the GLIMMIX procedure of SAS (SAS Institute, Cary, NC) with pen as the experimental unit. Data from barns 1, 2, and 3 were analyzed as a combined data set, and the statistical model included the fixed effect of dietary treatment, and the random effects of barn and block within barn. Studentized residuals were evaluated, and no evidence of departure from normality was observed. Also, data were evaluated for heterogeneity of variance, and no evidence for heterogeneity of variation was found across replicate barn, blocks, or treatments. Orthogonal contrasts were constructed to test the linear and quadratic effects of Zn, Zn source, and Zn source $\times$ dose interactions. Backfat, loin depth, and lean percentage were adjusted to a common carcass weight for analysis. Significant differences were recognized at $P < 0.05$ while a tendency was recorded between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

A calculated concentration for Zn in diets was determined by using book values provided by NRC (2012)⁴ for ingredients used in this study. The control diets for phase 1, 2, 3, 4, and 5 were calculated to contain 85, 84, 82, 81, and 81 ppm, respectively. Analyzed Zn concentrations for the control diets were slightly greater than the estimated concentrations. Although some variation in analyzed levels of Zn existed, analyzed Zn content still increased with increasing Zn treatments.

For the grower period (phases 1 to 3), there were no Zn source $\times$ level interactions. A Zn source effect was observed as pigs fed added ZnO had better F/G ($P = 0.046$), compared to pigs fed ZnAA (Table 5). A Zn level effect was also observed (quadratic; $P = 0.020$) as pigs fed 25 and 50 ppm added Zn had poorer F/G than pigs fed 75 ppm added Zn. This was driven by a F/G response (quadratic; $P = 0.006$) that was observed for pigs fed supplemental ZnAA, with pigs being fed 25 and 50 ppm Zn from ZnAA having poorer F/G, compared with pigs fed a diet containing 75 ppm Zn from ZnAA. No treatment differences were observed for ADG, ADFI, or BW during the grower period.

Within the finishing period (phases 4 to 5), a Zn source $\times$ level interaction was observed (quadratic; $P < 0.05$) for ADG, as pigs fed increasing ZnO had similar performance; however, pigs fed 25 and 50 ppm Zn from ZnAA had poorer ADG than pigs fed 75 ppm Zn from ZnAA, which had ADG similar to pigs fed the control diet. A tendency (quadratic; $P < 0.10$) for a Zn source $\times$ level interaction was also observed for final BW, as pigs fed increasing ZnO had similar BW; however, pigs fed 25 or 50 ppm Zn from ZnAA weighed less than pigs fed 75 ppm Zn from ZnAA. A tendency for a Zn source $\times$ level interaction (quadratic; $P < 0.10$) was also observed for F/G, as pigs fed increasing levels of ZnAA were observed to have poorer F/G at lower inclusion levels of Zn, in comparison to pigs fed increasing ZnO. A Zn level effect was observed ($P = 0.017$) for ADFI, as pigs fed diets with 25 or 50 ppm added Zn had decreased feed intake, compared to pigs fed diets with 75 ppm added Zn. An ADFI effect was also observed (quadratic; $P = 0.014$) for pigs fed ZnAA. Similar to the Zn level effect, a reduction in ADFI was observed for pigs fed diets with 25 and 50 ppm Zn from ZnAA.

Overall, Zn source $\times$ level interactions (quadratic; $P < 0.05$) were observed for ADG and F/G. The ADG response was due to pigs fed increasing ZnO having consistent ADG across treatments, while pigs fed 25 or 50 ppm of added Zn from ZnAA had reduced ADG compared to pigs fed 75 ppm Zn from ZnAA. The interaction for F/G was due to pigs fed 25 or 50 ppm Zn from ZnAA having poorer F/G than those fed 75 ppm Zn from ZnAA, while pigs fed supplemental ZnO had similar feed efficiency as Zn concentration increased. No differences were observed for overall ADFI.

Similar to overall ADG and final BW, a Zn source $\times$ level interaction (quadratic; $P < 0.05$) was observed for HCW. The response was observed because there were no differences in HCW among ZnO treatments; however, pigs fed 25 or 50 ppm Zn from ZnAA had lower HCW than pigs fed the diet with 75 ppm Zn from ZnAA. Tendencies (quadratic; $P < 0.10$) for increases in loin depth and percentage lean were also observed for pigs fed increasing ZnAA, with values peaking at 25 and 50 ppm supplemental Zn from ZnAA, respectively. No differences ($P > 0.10$) were observed for carcass yield and backfat.

In conclusion, these data suggest that increasing Zn beyond the level recommended by NRC (2012)⁴ did not improve growth performance or carcass composition. Unexpectedly, our study indicates that adding lower concentrations of an organic Zn source could worsen performance compared to a higher level of organic Zn, or similar levels of inorganic Zn. This response does not agree with previously published research, and it is unclear why such a response was observed. More research should be conducted to better understand how low levels of added organic Zn impact performance of pigs housed in a commercial environment.

Table 1. Basal diet composition (as-fed basis)¹

Item	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Ingredient, %					
Corn	56.04	61.52	65.84	69.51	67.28
Soybean meal, 46.5% CP	21.65	16.30	12.00	8.35	20.65
DDGS ²	20.00	20.00	20.00	20.00	10.00
Calcium carbonate	1.25	1.28	1.23	1.20	1.03
Monocalcium P, 21% P	0.15	-	-	-	0.10
Sodium chloride	0.35	0.35	0.35	0.35	0.35
L-lysine HCl	0.36	0.37	0.39	0.39	0.28
DL-methionine	0.01	-	-	-	0.03
L-threonine	0.05	0.04	0.05	0.06	0.07
Phytase ³	0.01	0.01	0.01	0.01	0.01
Trace mineral premix ⁴	0.05	0.05	0.05	0.05	0.05
Vitamin premix ⁵	0.08	0.08	0.08	0.08	0.05
Ractopamine HCl	-	-	-	-	0.10
Total	100.0	100.0	100.0	100.0	100.0
Calculated analysis					
Standard ileal digestible (SID) amino acids, %					
Lys	1.02	0.91	0.82	0.74	0.90
Ile:Lys	63	62	60	59	64
Leu:Lys	152	159	164	172	150
Met:Lys	29	29	30	31	31
Met+Cys:Lys	55	56	57	60	58
Thr:Lys	61	61	61	63	65
Trp:Lys	18.4	17.6	16.6	15.8	19.0
Val:Lys	70	70	70	70	71
Lys:ME, g/Mcal	3.08	2.72	2.47	2.21	2.71
ME, kcal/kg	1,503	1,507	1,510	1,512	1,506
CP, %	20.0	18.0	16.4	15.0	17.6
Ca, %	0.61	0.57	0.54	0.52	0.50
P, %	0.45	0.40	0.38	0.36	0.40
Available P, %	0.29	0.26	0.25	0.25	0.24
Standard digestible P, %	0.33	0.29	0.28	0.27	0.29

¹ Phase 1, 2, 3, 4, and 5 diets were fed from 60 to 100, 100 to 135, 135 to 170, 170 to 230, and 230 to 280 lb, respectively.

² Dried distillers grain with solubles.

³ Optiphos 2000 (Enzyvia LLC, Sheridan, IN) provided 227 phytase units (FTU)/lb of diet, with an assumed release of 0.07% available P.

⁴ Trace mineral premix provided: 33 ppm Mn from manganese oxide, 110 ppm Fe from iron sulfate, 110 ppm Zn from zinc oxide, 16.5 ppm Cu from copper sulfate, 0.33 ppm I from ethylenediamin dihydroiodide, and 0.30 ppm Se from sodium selenite.

⁵ Vitamin premix provided per lb of diet: 2,400 IU vitamin A; 375 IU vitamin D₃; 12.0 IU vitamin E; 1.20 mg vitamin K; 7.5 mg pantothenic acid; 13.5 mg niacin; 2.1 mg riboflavin and 9 µg vitamin B₁₂.

Table 2. Proximate analysis of diets (as-fed basis)¹

Item ³	Phase 1							Phase 2						
	Control	ZnAA ² , ppm			ZnO, ppm			Control	ZnAA, ppm			ZnO, ppm		
		25	50	75	25	50	75		25	50	75	25	50	75
DM, %	88.8	88.6	89.0	88.8	89.0	88.9	89.2	88.9	88.9	88.8	88.7	88.9	89.0	88.6
CP, %	19.6	18.6	19.6	20.3	20.1	19.7	20.4	19.0	18.3	18.4	19.4	17.6	18.4	19.1
ADF, %	4.5	4.3	4.8	4.5	5.2	4.6	4.2	4.5	5.2	5.0	5.0	5.3	5.5	5.3
NDF, %	13.4	13.1	12.2	11.9	12.6	11.8	11.0	13.4	13.0	12.3	12.1	12.1	12.3	13.0
Crude fiber, %	3.1	3.5	3.4	3.3	3.5	3.3	3.2	4.0	3.7	4.0	3.4	3.2	3.6	3.7
NFE ⁴ , %	58.3	59.0	58.5	57.4	57.4	58.0	57.7	58.0	59.1	58.3	57.7	60.1	59.0	57.6
Ether extract, %	4.1	3.8	3.8	4.0	4.0	3.9	3.9	4.5	4.3	4.3	4.0	4.1	4.2	4.3
Ash, %	4.02	4.22	4.17	4.14	4.34	4.22	4.37	3.85	3.81	3.94	4.07	3.84	3.86	4.00
Zinc, ppm	114.5	133.7	145.6	164.2	96.2	122.9	124.9	94.9	123.4	135.5	156.9	101.5	110.6	132.6

¹ Phase 1 and 2 diets were fed from 60 to 100 and 100 to 135 lb, respectively.² ZnAA = Zn AA complex (Availa®-Zn; Zinpro Corporation, Eden Prairie, MN).³ Values represent the mean of samples collected from feeders during each replicate, then pooled and subsampled, and one composite sample of each diet was analyzed.⁴ Nitrogen free extract.**Table 3. Proximate analysis of diets (as-fed basis)¹**

Item ³	Phase 3							Phase 4						
	Control	ZnAA ² , ppm			ZnO, ppm			Control	ZnAA, ppm			ZnO, ppm		
		25	50	75	25	50	75		25	50	75	25	50	75
DM, %	88.6	88.7	88.8	88.8	89.1	88.7	88.9	88.8	88.8	88.7	88.6	88.9	88.7	88.5
CP, %	16.5	16.2	16.4	15.4	16.4	16.3	17.4	14.9	15.4	14.8	14.1	14.7	14.6	14.7
ADF, %	4.7	4.5	4.7	3.9	4.3	3.6	3.8	3.7	3.1	3.3	3.6	4.3	3.8	4.1
NDF, %	13.5	12.1	13.7	12.9	12.8	10.9	11.8	11.7	11.2	10.7	11.0	11.1	11.2	12.1
Crude fiber, %	3.5	4.0	4.0	3.4	3.9	4.0	3.7	3.2	3.3	3.4	3.4	3.5	3.3	3.4
NFE ⁴ , %	60.8	60.6	60.9	62.2	61.2	60.6	60.0	62.9	62.9	63.1	64.0	63.3	63.8	63.0
Ether extract, %	4.1	4.2	4.0	4.1	4.2	4.2	4.3	4.3	4.0	4.0	4.0	4.2	4.0	4.3
Ash, %	3.59	3.69	3.37	3.63	3.62	3.46	3.48	3.56	3.43	3.35	3.34	3.31	3.01	3.30
Zinc, ppm	100.4	101.8	121.9	158.1	108.3	114.1	136.1	120.3	113.9	126.2	150.1	108.3	115.3	122.2

¹ Phase 3 and 4 diets were fed from 135 to 170 and 170 to 230 lb, respectively.² ZnAA = Zn AA complex (Availa®-Zn; Zinpro Corporation, Eden Prairie, MN).³ Values represent the mean of samples collected from feeders during each replicate, then pooled and subsampled, and one composite sample of each diet was analyzed.⁴ Nitrogen free extract.

Table 4. Proximate analysis of diets (as-fed basis)¹

Item ³	Phase 5						
	Control	ZnAA ² , ppm			ZnO, ppm		
		25	50	75	25	50	75
DM, %	88.1	88.3	88.2	88.2	87.9	88.7	87.5
CP, %	17.2	16.0	17.8	16.1	16.3	16.1	19.1
ADF, %	3.9	4.3	3.7	3.5	3.3	3.7	3.8
NDF, %	11.3	10.8	10.9	9.9	9.9	12.1	11.2
Crude fiber, %	3.3	3.4	3.0	3.0	3.2	3.3	3.6
NFE ⁴ , %	60.6	61.9	60.6	62.1	61.6	62.1	57.5
Ether extract, %	3.4	3.7	3.3	3.4	3.3	3.7	3.5
Ash, %	3.52	3.39	3.59	3.64	3.62	3.54	3.76
Zinc, ppm	102.5	121.3	136.2	166.1	97.2	108.8	122.2

¹ Phase 5 diet was fed from 230 to 280 lb.

² ZnAA = Zn AA complex (Availa®-Zn; Zinpro Corporation, Eden Prairie, MN).

³ Values represent the mean of samples collected from feeders during each replicate, then pooled and subsampled, and one composite sample of each diet was analyzed.

⁴ Nitrogen free extract.

Table 5. The effects of increasing levels of Zn from organic or inorganic sources on finishing pig growth performance and carcass characteristics¹

									Probability, <i>P</i> <						
		ZnAA ² , ppm			ZnO, ppm			SEM	ZnAA vs ZnO	Level		ZnAA		ZnO	
Item	Control	25	50	75	25	50	75			Linear	Quad	Linear	Quad	Linear	Quad
No. of replicates ³	14	17	17	17	17	14	14								
BW, lb															
d 0	63.2	63.3	63.3	63.2	63.1	63.2	63.2	1.953	0.777	0.885	0.964	0.906	0.867	0.896	0.930
End of phase 3	169.2	169.4	169.7	170.6	170.6	170.0	170.8	2.036	0.544	0.322	0.976	0.362	0.748	0.427	0.797
Final ⁴	287.8	280.9	285.2	287.3	285.9	286.2	284.0	4.561	0.581	0.610	0.193	0.776	0.028	0.265	0.944
Grower ⁵															
ADG, lb	1.86	1.86	1.86	1.88	1.88	1.88	1.89	0.021	0.299	0.371	0.804	0.507	0.508	0.385	0.809
ADFI, lb	4.31	4.37	4.38	4.36	4.40	4.35	4.36	0.061	0.934	0.496	0.291	0.431	0.369	0.692	0.426
F/G	2.31	2.35	2.36	2.32	2.34	2.31	2.31	0.033	0.046	0.865	0.020	0.684	0.006	0.505	0.312
Finisher ⁶															
ADG ⁷ , lb	2.06	1.96	2.00	2.04	2.02	2.04	2.01	0.113	0.299	0.530	0.047	0.982	0.004	0.305	0.723
ADFI, lb	6.11	5.90	6.04	6.14	6.00	6.00	6.08	0.259	0.974	0.812	0.017	0.443	0.014	0.743	0.157
F/G ⁴	2.97	3.02	3.01	3.00	2.98	2.96	3.04	0.048	0.386	0.190	0.905	0.416	0.284	0.154	0.230
Overall															
ADG ⁷ , lb	1.96	1.91	1.93	1.96	1.95	1.96	1.95	0.059	0.140	0.987	0.070	0.708	0.006	0.744	0.869
ADFI, lb	5.20	5.12	5.20	5.23	5.18	5.16	5.20	0.124	0.951	0.617	0.222	0.348	0.183	0.958	0.521
F/G ⁷	2.65	2.68	2.69	2.67	2.66	2.64	2.67	0.031	0.055	0.425	0.544	0.400	0.067	0.591	0.422
Carcass characteristics															
HCW ⁷ , lb	214.7	211.7	213.4	216.5	215.1	214.7	213.8	2.440	0.581	0.732	0.300	0.295	0.038	0.676	0.709
Carcass yield, %	74.89	74.37	74.84	75.38	75.28	75.07	75.32	0.598	0.893	0.350	0.939	0.445	0.896	0.400	0.808
Backfat ⁸ , in	0.67	0.68	0.66	0.67	0.67	0.68	0.66	0.297	0.349	0.366	0.742	0.278	0.745	0.630	0.409
Loin depth, ⁸ in	2.75	2.80	2.75	2.72	2.75	2.75	2.74	0.055	0.470	0.392	0.242	0.208	0.075	0.816	0.919
Lean ⁸ , %	56.59	56.95	57.05	56.70	56.80	56.69	56.94	0.628	0.555	0.381	0.276	0.629	0.064	0.315	0.923

¹ A total of 3,390 mixed sex pigs (PIC 337 × 1050; initially 63.2 lb) were housed in three replicate barns. Barn 1 utilized 1,122 pigs for 112 d; barn 2 used 1,159 pigs for 114 d; while barn 3 used 1,109 pigs fed for 120 d.

² ZnAA = Zn AA complex (Availa®-Zn; Zinpro Corporation, Eden Prairie, MN).

³ Each replicate had 24 to 27 pigs per pen.

⁴ Zinc source × zinc level interaction (quadratic; *P* < 0.10).

⁵ Includes phases 1 to 3.

⁶ Includes phases 4 and 5.

⁷ Zinc source × zinc level interaction (quadratic; *P* < 0.05).

⁸ Adjusted to a common HCW for analysis.