Effects of Added Zinc During the Grower and/or Finisher Phase on Growth Performance and Carcass Characteristics of Finishing Pigs Fed Diets With or Without Ractopamine HCl[1]

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Summary

A total of 1,197 pigs (PIC 337 × 1050) were used in a 72-d study to determine the effects of added zinc from zinc oxide (ZnO) fed in grower (d 0 to 45; initially 129.6 lb) and finisher (d 45 to 72; initially 218.3 lb) pig diets with or without ractopamine HCl (RAC; Paylean; Elanco Animal Health, Greenfield, IN) on growth performance and carcass characteristics. Pens were randomly assigned to a 2 × 2 × 2 factorial arrangement in a split-plot design. The whole plot consisted of diets with or without 75 ppm added Zn from d 0 to 45, and the subplots were diets with or without 75 ppm added Zn and with or without 10 ppm RAC from d 45 to 72. All diets contained 50 ppm Zn supplied from the premix. No interactions were observed. Addition of 75 ppm Zn during either period or both periods did not influence overall pig growth performance or carcass characteristics. Pigs fed RAC had improved ($P < 0.03$) ADG, F/G, final BW, HCW, loin depth, and fat-free lean index compared with pigs fed the control diet. In conclusion, feeding RAC improved the performance of growing-finishing pigs, but additional Zn did not.

Key words: finishing pig, ractopamine HCl, zinc

Introduction

Ractopamine HCl (RAC; Paylean; Elanco Animal Health, Greenfield, IN) is frequently added to finishing pig diets to improve growth performance and carcass leanness. Previous research suggests that when adding RAC to finishing diets, amino acid concentrations need to be increased approximately 30% to maximize growth and carcass leanness, but little research has been conducted to determine if other nutrients (such as trace minerals) also should be increased. Some recent studies have indicated that added Zn above that contained in the standard trace mineral premix can further increase the response of RAC (Akey, 2011[3]; Paulk et al., 2012[4]).

One consequence of feeding higher levels of zinc if not utilized by the pig is increased excretion and the associated environmental impact. Increasing dietary Zn levels above

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[3] Akey. 2011. Effects of zinc source and level in Paylean diets on pig performance and carcass characteristics. Akey Swine Newsletter.

[4] Paulk et al., Swine Day 2012, Report of Progress 1074, pp. 348–356.

the requirement results in increased Zn excreted in swine waste (Creech et al., 2004[5]), so it is important to define the duration of feeding added Zn to maximize performance while minimizing Zn excretion.

The objective of this study was to determine if added Zn had to be fed throughout the grower period, and with or without RAC in the finishing period, to achieve an improvement in growth performance, and the influence of added Zn on plasma and fecal Zn concentrations.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The experiment was conducted at a commercial research-finishing barn. The barn was naturally ventilated and double-curtain-sided with completely slatted flooring and a deep pit for manure storage. Each pen was equipped with a 4-hole stainless steel dry self-feeder and a cup waterer for ad libitum access to feed and water. Daily feed additions to each pen were accomplished through a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of providing and measuring feed amounts for individual pens.

A total of 1,197 pigs (Line 337 × 1050: PIC Hendersonville, TN; initially 129.6 lb) were used in a 72-d study to determine the effects of added Zn from ZnO fed during the grower (d 0 to 45) and finisher (d 45 to 72) phase in diets with or without RAC on growth performance, carcass characteristics, and plasma and fecal Zn concentrations. Pens were randomly assigned to a 2 × 2 × 2 factorial arrangement in a split-plot design. The whole plot consisted of diets with or without 75 ppm added Zn from ZnO from d 0 to 45, and the subplots were diets with or without 75 ppm added Zn from ZnO and with or without 10 ppm RAC from d 45 to 72. All diets contained 50 ppm Zn supplied from the premix. All experimental diets were in meal form and were prepared at a commercial feed mill. A subsample of experimental diets was collected and analyzed for dietary Zn (Ward Laboratories, Inc., Kearney, NE). There were 25 pigs per a pen and a total of 24 pens per treatment for the whole plot and 12 pens per treatment for the subplot.

Pigs and feeders were weighed on d 0, 23, 45, 52, 57, 65, and 72 to determine ADG, ADFI, and F/G. Subsamples of 1, 2, 4, and 4 pigs were bled from each pen on d 0, 45, 52, and 63, respectively. On d 0, the median weight barrow from each pen was ear tagged to allow for bleeding on subsequent collection dates. On day 52 and 63, four median weight barrows, including the previously selected pig, were selected from each pen for blood collection. Samples were collected via jugular venipuncture into heparinized (143 USP units of NA heparin) vacutainer tubes (Tyco Healthcare Group LP, Mansfield, MA), inverted, and immediately placed on ice until samples were processed. On d 45 and 63, fecal grab samples were collected on 3 random pigs per pen for determination of Zn concentrations. On d 57, the 6 heaviest pigs from each pen (determined visually), and on d 72, the remaining pigs were tattooed by pen and transported 1 h to a USDA-inspected processing plant (JBS Swift and Company, Worthington, MN)

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[5] Creech, B.L., J.W. Spears, W.L. Flowers, G.M. Hill, K.E. Lloyd, T.A. Armstrong, and T.E. Engle. Effect of dietary trace mineral concentration and source (inorganic vs. chelated) on performance, mineral status, and fecal mineral excretion in pigs from weaning through finishing. J. Anim. Sci. 82:2140–2147.

for processing and carcass data collection. Hot carcass weight was collected immediately following evisceration, and carcass measurements including backfat depth and loin depth were collected using a Fat-O-Meter probe (SFK, Herlev, Denmark). Using the data collected at the farm and commercial abattoir, carcass yield, percentage lean, and carcass IOFC were calculated. Percentage carcass yield was calculated by dividing HCW at the packing plant by the live weight obtained at the farm. Percentage lean was calculated by dividing the standardized fat-free lean (SFFL) by HCW. The following equation was used for calculation of SFFL (NPPC, 2001[6]):

$$\text{SFFL, lb} = 15.31 - (31.277 \times \text{backfat depth, in.}) + (3.813 \times \text{loin muscle depth, in.}) + (0.51 \times \text{HCW, lb})$$

Income over feed cost, a method to measure economic value, was also calculated assuming that other costs, such as utility and labor, are equal across treatments, and the only variables are carcass ADG and feed usage for the experimental period. Corn was valued at \$152/ton, soybean meal at \$420/ton, dried distillers grains with solubles at \$164/ton, L-lysine sulfate at \$0.61/lb, phytase at \$1.65/lb, RAC at \$35.26/lb, ZnO at \$0.86/lb, and live and carcass weight were priced at \$84.24/cwt and \$115.40/cwt, respectively.

For plasma Zn analysis, whole blood was centrifuged (2000 × *g*, 15 min, 4°C), plasma was removed, and blood was frozen at -20°C. Plasma was deproteinized by diluting 1:4 in 12.5% trichloroacetic acid followed by centrifugation at 2,000 × *g* for 15 min (GS-6KR, Beckman-Coulter, Brea, CA) and collection of the supernatant for analysis. The ashed fecal samples were placed in 10 mL of 6N HCl and boiled for 10 min (AOAC, 1995[7]). Zinc concentrations were determined by flame atomic absorption spectrophotometry (Perkin Elmer 3110 AA Spectrometer, PerkinElmer, Waltham, MA).

Data were analyzed as a split-plot design using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC), with dietary grower treatment (0 or 75 ppm added Zn from d 0 to 45) as the whole plot and dietary finisher treatment (diets with or without RAC × 0 or 75 ppm added Zn from d 45 to 72) as the subplot. Pen served as the experimental unit. For plasma Zn concentration analysis, the statistical structure was the same except day of bleeding, and treatment × day of bleeding served as a fixed effects in addition to dietary treatment. Day of bleeding also served as the repeated measure, with animal as the subject. The covariance structure compound symmetry was used. Hot carcass weight was used as a covariate for analyses of backfat thickness, loin depth, and percentage lean. Statistical significance was determined at $P < 0.05$ and trends at $P < 0.10$.

Results and Discussion

From d 0 to 45, there were no differences in ADG or ADFI but a tendency for increased ($P < 0.10$) F/G and caloric efficiency on both an ME and NE basis in pigs fed diets containing added Zn compared with pigs fed the control diet (Table 2). For the finisher phase (d 45 to 72), there were no interactive effects of Zn grower × Zn finisher × RAC or Zn grower × Zn finisher for growth performance and carcass characteristics. There

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[6] NPPC. 2001. Procedures for Estimating Pork Carcass Composition. Natl. Pork Prod. Counc., Des Moines, IA.

[7] AOAC. 1995. Official methods of analysis. 16th ed. Assoc. Off. Anal. Chem., Gaithersburg, MD.

was an added Zn during the grower phase × RAC interaction ($P = 0.034$) for ADG of finishing pigs. This resulted from pigs fed RAC and diets with added Zn during the grower phase having increased ADG compared with pigs fed RAC diets without added Zn during the grower phase. Added Zn during the grower phase did not influence ADG of pigs fed the control diet without RAC during the finisher phase. There was a tendency for an added Zn during the finisher phase × RAC interaction ($P = 0.066$) for ADG of finishing pigs. This resulted from pigs fed control diets with added Zn during the finisher phase having decreased ADG compared with pigs fed control diets without added Zn. Pigs fed RAC diets with or without added Zn had similar ADG. There was an added Zn during the finisher phase × RAC interaction ($P = 0.025$) for ADFI. Pigs fed RAC diets with added Zn during the finisher phase had increased ADFI compared with those fed added Zn diets without RAC; however, pigs fed RAC diets without added Zn during the finishing phase had ADFI similar to pigs fed control diets without added Zn. Pigs fed RAC diets had improved ($P < 0.05$) ADG, F/G, IOFC, and caloric efficiency on both an ME and NE basis compared with those fed diets without RAC for the 27-d finishing period. Pigs fed diets with added Zn during the finisher phase had poorer ($P < 0.05$) ADG, F/G, IOFC, and caloric efficiency on both an ME and NE basis compared with those fed diets without. Overall (d 0 to 72), there were no dietary treatment interactions for growth performance and carcass characteristics. Pigs fed RAC for the last 27 d of the experiment had improved ($P < 0.05$) ADG, F/G, IOFC, caloric efficiency on an ME and NE basis, final BW, HCW, loin depth, and percentage lean; a tendency for improved ($P = 0.064$) IOFC on a carcass basis; and reduced ($P = 0.001$) backfat thickness compared with pigs fed diets without RAC. Added Zn did not influence overall growth performance or carcass characteristics of pigs.

From d 0 to 45, pigs fed diets with added Zn had increased ($P = 0.001$) average daily Zn intake (Table 3). From d 45 to 72, there was an added Zn during the finisher phase × RAC interaction ($P = 0.004$). Either added Zn during the finishing period or RAC caused an increase in average daily Zn intake; however, average daily Zn intakes were further increased when both added Zn during the finisher period and RAC were fed to pigs.

For plasma Zn concentrations, there were no 4, 3, or 2-way interactions among dietary treatment and day. Added Zn during the grower phase did not influence plasma Zn concentrations on d 45, but pigs fed diets with 75 ppm added Zn during the finisher phase had increased ($P < 0.05$) plasma Zn levels on d 52 and 63 compared with those fed diets without added Zn during the finisher phase. There was no effect of the RAC diet on plasma Zn concentration. For fecal analysis, pigs fed added Zn during the grower period had increased ($P < 0.05$) fecal Zn concentrations on d 45 compared with those fed diets without added Zn. For d-63 fecal Zn concentrations, there was an added Zn during the finishing period × RAC interaction ($P = 0.032$). Either added Zn during the finishing period or RAC caused an increase in d-63 fecal Zn concentration; however, concentrations were further increased when both added Zn during the finisher period and RAC were fed to pigs.

As expected, pigs fed RAC diets had improved growth performance and carcass characteristics, but added Zn with RAC did not. However, additional Zn in diets of growing pigs may increase the ADG response to RAC fed during the finishing phase. In addition, pigs fed diets with 75 ppm added Zn during the finisher phase had increased plasma Zn levels. Pigs fed added Zn during the grower and finisher period and pigs fed RAC diets during the finisher phase had increased fecal Zn concentrations, but concentrations were further increased when both added Zn during the finisher period and RAC were fed to pigs.

Table 1. Diet composition (as-fed basis)[1,2]

	Phase 1	Phase 2	Phase 3	
Item	Control	Control	Control	RAC[3]
Ingredient, %				
Corn	54.60	58.10	72.50	62.76
Soybean meal, 46.5% CP	12.95	9.78	10.58	20.26
DDGS[4]	30.00	30.00	15.00	15.00
Monocalcium phosphate, 21 % P	0.20	---	0.05	---
Limestone	1.33	1.25	1.08	1.03
Salt	0.35	0.35	0.35	0.35
Vitamin premix	0.08	0.08	0.05	0.05
Trace mineral premix[5]	0.05	0.05	0.05	0.05
L-lysine sulfate	0.44	0.40	0.33	0.33
Methionine hydroxy	---	---	---	0.09
L-threonine	---	---	---	0.03
Phytase[6]	0.005	0.004	0.010	0.010
Ractopamine HCl[7]	---	---	---	0.05
Total	100	100	100	100
Calculated analysis, %				
ME, kcal/lb	1,505	1,510	1,512	1,509
NE, kcal/lb	1,087	1,096	1,110	1,119
Standardized ileal digestible (SID) lysine, %	0.83	0.73	0.66	0.90
Total lysine, %	1.01	0.90	0.79	1.06
SID lysine:ME, g/Mcal	2.50	2.19	1.98	2.70
Ca, %	0.59	0.52	0.46	0.46
Total P, %	0.46	0.40	0.37	0.40
Available P, %	0.28	0.22	0.21	0.21

[1] Diets were fed in meal form from d 0 to 72. Basal diets for all 3 phases contained 55 ppm zinc from zinc oxide provided by the trace mineral premix.

[2] Dietary treatments were obtained by replacing corn to achieve 75 ppm of added Zn from ZnO. Analyzed total Zn concentrations were 88 and 131 ppm in the phase 2 control and added Zn diet diets, respectively, and 96, 155, 117, and 180 for the control, control + added Zn, RAC, and RAC + added Zn diets, respectively.

[3] Ractopamine HCl (RAC; Paylean; Elanco Animal Health, Greenfield, IN).

[4] Dried distillers grains with solubles.

[5] Trace mineral premix provided 50 ppm Zn from ZnO.

[6] OptiPhos 2000 (Enzyvla LLC, Sheridan, NJ) provided 250, 200, and 500 phytase units (FTU) per kilogram of diet for phases 1, 2, and 3, respectively.

[7] Provided 10 ppm of ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).

Table 2. Effects of added zinc during the grower and/or finisher phase on growth performance and carcass characteristics of finishing pigs fed diets with or without ractopamine HCl (RAC)[1]

Added Zn, d 0 to 45:	-	-	-	-	+	+	+	+		Probability[2], $P <$				
Added Zn, d 45 to 72:	-	+	-	+	-	+	-	+		Zn grower × RAC	Zn finisher × RAC	Zn grower	Zn finisher	RAC
Added RAC, d 45 to 72:	-	-	+	+	-	-	+	+	SEM					
d 0 to 45														
ADG, lb	1.96	---	---	---	1.96	---	---	---	0.029	---	---	0.900	---	---
ADFI, lb	5.50	---	---	---	5.70	---	---	---	0.12	---	---	0.206	---	---
F/G	2.81	---	---	---	2.91	---	---	---	0.050	---	---	0.086	---	---
IOFC,[3] \$/pig	48.95	---	---	---	48.16	---	---	---	0.91	---	---	0.2450	---	---
Caloric efficiency[4]														
ME	4,243	---	---	---	4,385	---	---	---	76	---	---	0.086	---	---
NE	3,140	---	---	---	3,245	---	---	---	56	---	---	0.086	---	---
d 45 to 72														
ADG, lb	1.98	1.89	2.35	2.36	1.98	1.88	2.46	2.43	0.03	0.034	0.066	0.134	0.015	0.001
ADFI, lb	6.39	6.27	6.22	6.36	6.41	6.30	6.42	6.60	0.11	0.103	0.025	0.299	0.647	0.305
F/G	3.23	3.31	2.65	2.70	3.23	3.36	2.61	2.72	0.05	0.595	0.737	0.927	0.003	0.001
IOFC, \$/pig	27.90	26.27	31.38	31.01	27.97	25.84	33.18	31.72	0.61	0.102	0.267	0.242	0.003	0.001
Caloric efficiency														
ME	4,880	5,007	3,999	4,077	4,885	5,078	3,943	4,109	68	0.586	0.681	0.825	0.004	0.001
NE	3,689	3,785	2,965	3,024	3,693	3,839	2,924	3,047	51	0.586	0.661	0.822	0.004	0.001

continued

Table 2. Effects of added zinc during the grower and/or finisher phase on growth performance and carcass characteristics of finishing pigs fed diets with or without ractopamine HCl (RAC)[1]

Added Zn, d 0 to 45:	-	-	-	-	+	+	+	+		Probability[2], *P* <				
Added Zn, d 45 to 72:	-	+	-	+	-	+	-	+		Zn grower × RAC	Zn finisher × RAC	Zn grower	Zn finisher	
Added RAC, d 45 to 72:	-	-	+	+	-	-	+	+	SEM					RAC
d 0 to 72														
ADG, lb	1.96	1.94	2.09	2.09	1.97	1.94	2.13	2.11	0.03	0.450	0.698	0.549	0.293	0.001
ADFI, lb	5.84	5.74	5.73	5.80	5.93	5.90	5.96	5.99	0.10	0.301	0.164	0.225	0.879	0.565
F/G	2.98	2.96	2.74	2.77	3.02	3.05	2.80	2.84	0.04	0.793	0.439	0.174	0.338	0.001
IOFC, $/pig	76.29	76.00	80.39	79.79	76.19	74.61	80.94	79.22	1.22	0.669	0.895	0.682	0.229	0.001
Caloric efficiency														
ME	4,502	4,464	4,132	4,184	4,551	4,596	4,225	4,285	61	0.928	0.440	0.167	0.388	0.001
NE	3,358	3,329	3,060	3,098	3,394	3,428	3,128	3,173	45	0.934	0.443	0.168	0.390	0.001
BW, lb														
d 0	58.7	---	---	---	58.7	---	---	---	---	---	---	0.996	---	---
d 45	218.2	218.0	218.0	218.2	218.4	218.4	218.5	218.4	5.5	0.985	0.946	0.966	0.989	0.972
d 72	243.1	240.9	249.0	248.8	242.4	240.6	250.7	249.9	5.7	0.754	0.400	0.865	0.700	0.001
Carcass characteristics														
HCW, lb	189.7	189.6	194.4	198.3	188.2	192.0	195.6	197.3	4.9	0.950	0.873	0.960	0.404	0.026
Yield,[5] %	74.09	74.64	74.12	75.35	73.09	73.98	75.52	74.08	1.35	0.534	0.657	0.719	0.383	0.740
Backfat thickness,[6] in.	0.66	0.62	0.54	0.59	0.64	0.64	0.56	0.54	0.025	0.565	0.345	0.720	0.785	0.001
Loin depth,[6] in.	2.47	2.43	2.54	2.49	2.44	2.43	2.58	2.60	0.044	0.158	0.898	0.386	0.485	0.002
Lean,[6,7] %	53.13	55.13	53.69	55.13	53.52	55.01	53.33	55.94	0.57	0.644	0.697	0.737	0.375	0.001
IOFC, $/pig	75.53	75.93	78.25	79.46	73.72	75.88	78.34	77.71	2.33	0.977	0.766	0.604	0.638	0.064

[1] A total of 1,197 pigs (Line 337 × 1050: PIC Hendersonville, TN) were used in a 72-d study with 25 pigs per pen and 6 pens per treatment.

[2] No interactive effects ($P > 0.154$) of Zn grower × Zn finisher × RAC or Zn grower × Zn finisher.

[3] Income over feed cost. Corn was valued at $152/ton, soybean meal at $420/ton, dried distillers grains with solubles at $164/ton, L-lysine sulfate at $0.61/lb, phytase at $1.65/lb, RAC at $35.26/lb, zinc oxide at $0.86/lb, and live and carcass weights were priced at $84.24/cwt and $115.40/cwt, respectively.

[4] Caloric efficiency is expressed as kcal/lb gain.

[5] Calculated by dividing HCW by live weight obtained at the farm.

[6] Adjusted using HCW as a covariate.

[7] Calculated using NPPC (2001) equation.

Table 3. Effects of added zinc during the grower and/or finisher phase on plasma and fecal Zn concentrations of finishing pigs fed diets with or without ractopamine HCl (RAC)[1]

Added Zn, d 0 to 45:	-	-	-	-	+	+	+	+		Probability[2,3,4], $P <$			
Added Zn, d 45 to 72:	-	-	+	+	-	-	+	+					
Added RAC, d 45 to 72:	-	+	-	+	-	+	-	+	SEM	Zn finisher × RAC	Zn grower	Zn finisher	RAC
Zn intake, mg/d													
d 0 to 45	252	---	---	---	382	---	---	---	4.0	---	0.001	---	---
d 45 to 72	278	330	441	520	279	341	443	539	6.8	0.002	0.281	0.001	0.001
d 0 to 72	263	279	321	354	343	366	400	447	5.9	0.004	0.001	0.001	0.001
Plasma Zn, μg/mL													
d 0	1.33	---	---	---	1.38	---	---	---	0.043	---	0.422	---	---
d 45	1.34	---	---	---	1.34	---	---	---	0.029	---	0.980	---	---
d 52	1.23	1.29	1.36	1.31	1.22	1.25	1.25	1.33	0.038	0.571	0.254	0.013	0.204
d 63	1.25	1.34	1.37	1.34	1.34	1.32	1.39	1.41	0.037	0.428	0.269	0.011	0.560
Fecal Zn, ppm													
d 45	591	---	---	---	1,038	---	---	---	17.7	---	0.001	---	---
d 63	854	988	1,197	1,460	922	941	1,262	1,533	59.1	0.032	0.371	0.001	0.001

[1] A total of 1,197 pigs (PIC 337 × 1050) were used in a 72-d study with 25 pigs per pen and 6 pens per treatment. On d 0 and 45 the median weight barrow from each pen was ear tagged to allow for bleeding on subsequent collection dates. On day 52 and 63, four median weight barrows, including the previously selected pig were selected from each pen for blood collection. On d 45 and 63, fecal grab samples were collected on 3 random pigs per pen.

[2] For Zn intake, no interactive effects ($P > 0.073$) of Zn grower × Zn finisher × RAC, Zn grower × Zn finisher, or Zn grower × RAC.

[3] For plasma Zn, no interactive effects ($P > 0.083$) of Zn grower × Zn finisher × RAC, Zn grower × Zn finisher, or Zn grower × RAC.

[4] For fecal Zn, no interactive effects ($P > 0.477$) of Zn grower × Zn finisher × RAC, Zn grower × Zn finisher, or Zn grower × RAC.