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Chad B. Paulk

Michael D. Tokach

Jim L. Nelssen

See next page for additional authors

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Authors

Chad B. Paulk, Michael D. Tokach, Jim L. Nelssen, Steven S. Dritz, John M. Gonzalez, Joel M. DeRouchey, Robert D. Goodband, G M. Hill, and K D. Haydon

Effects of Added Zinc in Diets with Ractopamine HCl on Growth Performance, Carcass Characteristics, and Zinc Concentrations in Plasma, Loin, and Liver of Finishing Pigs[1,2]

C.B. Paulk, M.D. Tokach, J.L. Nelssen, S.S. Dritz[3], J.M. Gonzalez, J.M. DeRouchey, R.D. Goodband, G.M. Hill[4], and K.D. Haydon[5]

Summary

Two experiments were conducted to determine the effects of added Zn from zinc oxide (ZnO) or Availa-Zn (AZ; Zinpro, Eden Prairie, MN) on growth performance and carcass characteristics of finishing pigs fed ractopamine HCl (RAC; Paylean; Elanco Animal Health, Greenfield, IN). In Exp. 1, a total of 320 pigs (PIC 327 × 1050, initially 215.9 lb) were used in a 35-d study. Pens of pigs were randomly allotted to 1 of 8 dietary treatments, with either 2 barrows or 2 gilts per pen and 20 pens per treatment. Dietary treatments included: a corn-soybean meal–based negative control (0.66% standardized ileal digestible [SID] lysine); a positive control diet (0.92% SID lysine) containing 10 ppm of RAC; and the RAC diet plus 75, 150, or 225 ppm added Zn from ZnO or AZ. The trace mineral premix provided a basal level of 55 ppm Zn from Zn Sulfate ($ZnSO_4$) in all diets. In Exp. 1, overall (d 0 to 35), pigs fed RAC had improved ($P < 0.04$) ADG, F/G, d-35 BW, caloric efficiency on an ME and NE basis, HCW, carcass ADG and F/G, loin depth, percentage lean, and carcass caloric efficiency on an ME and NE basis, and reduced ($P < 0.01$) ADFI and backfat thickness compared with pigs fed the control diet. No evidence of a Zn effect or an interaction between Zn source and level was observed. Performance and IOFC did not differ in pigs fed diets with added Zn from either source.

In Exp. 2, a total of 1,234 pigs (PIC 337 × 1050; initially 228.6 lb) were used in a 28-d study. Pens contained 23 to 28 pigs with either all barrow, all gilt, or mixed-sex allotments. Pens of pigs were blocked by BW, feeder type, and gender and were randomly assigned to diets. The 4 dietary treatments consisted of (1) a corn-soybean meal–based negative control diet (0.70% SID lysine); (2) a positive control diet (0.92% SID lysine) containing 10 ppm RAC; or the RAC diet plus 50 ppm added Zn from ZnO (3) or AZ (4). All diets contained 80 ppm Zn from ZnO provided by the trace mineral premix. On d 14, the 6 heaviest pigs from each pen (determined visually) were individually tattooed by pen and harvested to allow for carcass data collection, and on d 28, the remaining pigs were individually tattooed by pen and harvested to allow for carcass data

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[3] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

[4] Department of Animal Science, College of Agriculture and Natural Resources, Michigan State University.

[5] Elanco Animal Health, Greenfield, IN.

collection. Overall (d 0 to 28), pigs fed RAC had improved ($P < 0.001$) ADG, F/G, final BW, and caloric efficiency on an ME and NE basis. Added Zn or Zn source did not affect ($P > 0.20$) growth performance. For pigs harvested on d 14, pigs fed RAC had improved ($P < 0.001$) carcass ADG, F/G, income over feed cost (IOFC), and carcass caloric efficiency on an ME and NE basis and a tendency for increased HCW, loin depth, and percentage lean compared with those fed the negative control diet. No differences were observed in carcass characteristics ($P > 0.11$) between pigs fed RAC diets and diets containing added Zn; however, pigs fed diets with added Zn from ZnO had increased ($P < 0.05$) carcass F/G, carcass yield, carcass IOFC, and carcass caloric efficiency on an ME and NE basis compared with those fed Zn from AZ. For pigs harvested on d 28, pigs fed RAC had improved ($P < 0.01$) HCW, carcass ADG and F/G, backfat thickness, loin depth, percentage lean, carcass IOFC, and carcass caloric efficiency on an ME and NE basis. No differences were observed in carcass characteristics between pigs fed RAC, and no additional Zn and diets containing added Zn from either source. Carcass characteristics did not differ in pigs fed diets with added Zn from ZnO vs. AZ.

In conclusion, we observed improvements in growth and carcass performance from adding RAC similar to previous studies. In contrast with our previous research, these data indicate that adding Zn to finishing pig diets containing RAC did not improve overall performance. Consistent with the earlier research, income over feed cost (IOFC) was numerically increased with the addition of Zn.

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[6]; Patience, 2011[7]; Paulk et al., 2012[8]). We designed experiments to determine the effects of adding zinc from ZnO or Availa-Zn on growth performance; carcass characteristics; plasma, loin, and liver Zn concentrations; and economics of finishing pigs supplemented with RAC.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments. Experiment 1 was conducted at the K-State Swine Teaching and Research Center in Manhattan, KS. Experiment 2 was conducted in a commercial research-finishing barn in southwestern Minnesota.

[6] Akey. 2011. Effects of Zinc Source and Level in Paylean Diets on Pig Performance and Carcass Characteristics. Akey Swine Newsletter.
[7] Patience, J. P. 2011. Impact of Zinc Source and Timing of Implementation on Grow-finish Performance, Carcass Composition, and Locomotion Score. IA St. Univ. Anim. Ind. Rep.
[8] Paulk et al., Swine Day 2012, Report of Progress 1074, pp. 348–356.

For Exp. 1, a total of 320 pigs (PIC 327 × 1050, four consecutive groups of 80 pigs) with an initial BW of 215.9 lb were used in this study. Pigs were housed in an environmentally controlled finishing building in 5-ft × 5-ft pens with totally slatted flooring. Each pen was equipped with a 2-hole dry self-feeder and a nipple waterer to provide *ad libitum* access to feed and water. Two consecutive replications of 160 pigs in the same barn were used. Within each replication, there were 80 pens with 2 pigs per pen. Within each replication, the 80 pens were divided into two 40-pen groups with 24 barrow pens and 16 gilt pens or 16 barrow pens and 24 gilt pens per group, which resulted in 4 groups of 40 pens each.

Pens of pigs were randomly allotted to 1 of 8 dietary treatments, with either 2 barrows or 2 gilts per pen and 20 pens per treatment. Dietary treatments were fed for the last 41 d prior to slaughter for group 1 and 35 d for groups 2, 3, and 4. Dietary treatments included: a corn-soybean meal–based negative control diet formulated to 0.66% SID lysine; a positive control diet formulated to contain 0.92% SID lysine and 10 ppm of RAC; and the RAC diet plus 75, 150, or 225 ppm added Zn from ZnO, or Availa-Zn (Zinpro, Eden Prairie, MN; Table 1). All diets contained 55 ppm Zn from $ZnSO_4$ provided by the trace mineral premix. Final analyzed total Zn concentrations were 66 and 74 ppm in the control diets; 134, 241, and 308 ppm in the ZnO diets; and 157, 255, and 318 ppm in Availa-Zn diets, respectively. Experimental diets were fed in meal form, and either ZnO or Availa-Zn (AZ) was added to the RAC diet at the expense of corn. Pigs and feeders were weighed on d 0 and 35 to determine ADG, ADFI, F/G, and caloric efficiency on an ME and NE basis. Caloric efficiency is a method to measure the efficiency of energy utilization and is reported as the ME or NE required per pound of gain. Metabolizable energy values of the feed ingredients were derived from the NRC (1998), and NE values of the feed ingredients were derived from INRA (2004).[9]

One pig was randomly selected from 16 pens per treatment (balanced across gender and group) for collection of blood on d 0, 8, 18, and 32 of the experiment to determine circulating Zn concentrations. Blood samples were chilled for approximately 2 h, then centrifuged at 2,000 × *g* for 15 min at 39.2°F. Plasma was then collected from each sample, frozen at -4°F, and sent to Michigan State University for mineral analysis. Zinc levels were determined by atomic absorption spectrophotometry.

On the final day of the experiment, pigs were harvested at 1 of 2 locations. One pig was randomly selected from each pen and weighed, tattooed, and shipped to the K-State Meat Laboratory for harvest. The remaining pigs were weighed, tattooed, and shipped to a commercial packing plant (Triumph Foods LLC., St. Joseph, MO) for harvest.

Pigs harvested at the commercial packing plant were tattooed to allow individual identification for 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, carcass IOFC, and carcass caloric efficiency on an ME and NE basis were calculated. Percentage carcass yield was calculated by dividing HCW at the packing plant by the

[9] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

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[10]):

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

To calculate carcass ADG, the percentage yield was multiplied by ADG. Carcass F/G was calculated by dividing ADFI by carcass ADG. Income over feed cost, a method to measure economic value, was also calculated assuming that other costs, such as utilities and labor, are equal across treatments, and the only variables are carcass ADG and feed usage for the experimental period. Corn was valued at $242/ton, soybean meal at $515/ton, L-lysine at $0.70/lb, phytase at $2.65/lb, RAC at $35.26/lb, zinc oxide at $0.86/lb, Availa-Zn at $1.50/lb; live weight was priced at $75.15/cwt, and carcass price was set at $100.20/cwt.

Pigs harvested at the K-State Meat Laboratory were tattooed to allow for individual carcass data collection. Immediately following evisceration, HCW and liver weight were collected. After a 24-h chilling period, the left side of each carcass was ribbed between the 10th- and 11th-rib interface. At this time, backfat and loin depth were measured with a ruler to mimic data collected at the commercial packing plant. All economic comparisons were calculated as previously described. Liver and loin samples were collected, frozen, and sent to Michigan State University for Zn analysis.

For Exp. 2, the barns were naturally ventilated and double-curtain-sided with completely slatted flooring and deep pits for manure storage. The barn was equipped with two types of Thorp feeders (Thorp Equipment, Inc, Thorp, WI). Both feeder types were a 4-hole stainless steel dry self-feeder (56 in. wide). Pigs were provided 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 1,234 pigs (PIC 337 × 1050; initially 228.6 lb) were used in the 28-d study. Pens consisted of 23 to 28 pigs per pen with either all barrow, all gilt, or mixed-sex pens. Pens of pigs were blocked by BW, feeder type, and gender and were randomly assigned to diets with 12 pens per treatment. Dietary treatments consisted of (1) a corn-soybean meal–based negative control diet (0.70% SID lysine); (2) a positive control diet (0.92% SID lysine) containing 10 ppm RAC; (3) treatment 2 plus 50 ppm added Zn from ZnO, and (4) treatment 2 plus 50 ppm added Zn from AZ. All diets contained 80 ppm Zn from ZnO provided by the trace mineral premix.

Pigs and feeders were weighed on d 0 and 28 to determine ADG, ADFI, F/G, and caloric efficiency on an ME and NE basis. On d 14, the 6 heaviest pigs from each pen (determined visually), and on d 28, the remaining pigs, were sold according to the normal marketing procedures of the farm. Pigs were tattooed by pen and used for collection of carcass measurements. Pigs were transported to JBS Swift and Company

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

(Worthington, MN) for processing and carcass data collection. Carcass data were collected as described in the previous experiment. Additionally, IOFC was calculated including dried distillers grains with solubles valued at \$220/ton and bakery meal at \$232/ton.

For both experiments, all data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Statistical significance was determined at $P < 0.05$, and P-values falling within $P > 0.05$ and $P < 0.10$ will be termed trends or tendencies. For Exp. 1, data were analyzed as a generalized randomized complete block design. Dietary treatment served as the fixed effect, and gender within group within barn were random effects. Hot carcass weight was used as a covariate for analyses of backfat thickness, loin depth, and percentage lean. Contrast statements consisted of: (1) negative control vs. positive control RAC diet, (2) interaction between increasing Zn level and Zn source, (3) increasing Zn linear and quadratic polynomials, and (4) added Zn from ZnO vs. Availa-Zn. For Exp. 2, data were analyzed as a randomized complete block design. In addition to dietary treatment, the effects of gender (barrow, gilt, or mixed gender) were included as fixed effects in the model. Average initial pen weight and feeder type were included as random factors. Hot carcass weight was used as a covariate for analyses of backfat thickness, loin depth, and percentage lean. Contrast statements consisted of: (1) negative control vs. positive control RAC diet, (2) RAC vs. added Zn, and (3) added Zn from ZnO vs. Availa-Zn.

Results and Discussion

In Exp. 1, overall (d 0 to 35), pigs fed RAC had improved ($P < 0.01$) ADG, F/G, d-35 BW, and caloric efficiency on an ME and NE basis and reduced ($P < 0.01$) ADFI compared with pigs fed the control diet (Table 3). Adding increasing levels of Zn to RAC diets did not affect ($P > 0.25$) growth performance and IOCF, and no differences ($P > 0.17$) were observed between Zn sources.

For carcass measurements, pigs fed RAC had improved ($P < 0.04$) HCW, carcass ADG and F/G, backfat thickness, loin depth, percentage lean, and carcass caloric efficiency on an ME and NE basis compared with those fed the control diet (Table 4). No differences were observed in carcass characteristics ($P > 0.3$) between pigs fed the RAC diet and diets containing added Zn. Carcass characteristics did not differ ($P > 0.25$) in pigs fed diets with added Zn from ZnO vs. Availa-Zn.

Pigs fed the RAC diets had increased ($P = 0.04$) liver weights compared with those fed the control diet. No evidence for a Zn-level effect, or an interaction between Zn source and level ($P > 0.18$) for liver weights (Table 5), was observed. Pigs fed RAC diets with added Zn from ZnO had numerically heavier ($P = 0.09$) liver weights than pigs fed the RAC diet with added Zn from AZ. No difference ($P > 0.29$) was observed in Zn concentrations in liver or loin from pigs fed either the RAC or control diet. A Zn level × source interaction (quadratic, $P = 0.02$) was observed in liver Zn concentrations on both a DM and as-is basis, resulting from liver Zn concentrations plateauing at 150 ppm of added Zn from ZnO but continuing to increase to 225 ppm added Zn from AZ. Zinc concentrations in the loin did not differ ($P > 0.25$) due to Zn source.

There was no plasma Zn interaction between dietary treatment and day (*P* > 0.17), no difference between pigs fed the RAC vs. control diet, no difference in Zn source, and no interaction between Zn source and level (*P* > 0.16) on any of the collection days (Table 6). Pigs fed RAC diets with up to 225 ppm added Zn had increased (*P* < 0.02) plasma Zn levels on day 18 and 32.

In Exp. 2, overall (d 0 to 28), pigs fed RAC had improved (*P* < 0.001) ADG, F/G, final BW, and caloric efficiency on an ME and NE basis (Table 7). No differences were observed in performance (*P* > 0.33) between pigs fed RAC and diets containing added Zn. Performance did not differ (*P* > 0.20) between pigs fed diets with added Zn from ZnO vs. AZ.

For carcass measurements on d 14, pigs fed RAC had improved (*P* < 0.001) carcass ADG, F/G, IOFC, and carcass caloric efficiency on an ME and NE basis and a tendency for increased HCW, loin depth, and percentage lean compared with those fed the diet without RAC (Table 8). No differences were observed in carcass characteristics (*P* > 0.11) between pigs fed RAC diets and diets containing added Zn; however, pigs fed diets with added Zn from ZnO had increased (*P* < 0.05) carcass F/G, carcass yield, carcass IOFC, and carcass caloric efficiency on an ME and NE basis.

For carcass measurements on d 28, pigs fed RAC had improved (*P* < 0.01) HCW, carcass ADG and F/G, backfat thickness, loin depth, percentage lean, carcass IOFC, and carcass caloric efficiency on an ME and NE basis (Table 8). No differences were observed in carcass characteristics (*P* > 0.21) between pigs fed RAC and diets containing added Zn and carcass characteristics did not differ (*P* > 0.14) between Zn sources.

In conclusion, additional Zn did not significantly improve the performance of pigs fed diets containing RAC, but pigs fed 50 to 75 ppm of added Zn from ZnO had a 3% reduction in F/G. This numeric improvement in F/G resulted in a numeric increase in IOFC of $1.30 to $1.45 when pigs in a commercial environment were fed 50 ppm of added Zn from ZnO and $1.26 on a live weight basis (35 d) and $0.54 on a carcass basis when pigs in K-State research facilities were fed 75 ppm added Zn from ZnO. Although these values were not significant, the numerical increase in IOFC was consistent with previous data conducted in our lab (Paulk et al., 2012a[11]; Paulk et al., 2012b[12]). The response to added Zn is not consistent, but only small improvements in performance are needed to overcome the cost of inclusion when adding Zn from ZnO.

[11] Paulk et al., Swine Day 2012, Report of Progress 1074, pp. 348–355.
[12] Paulk et al., Swine Day 2012, Report of Progress 1074, pp. 356–364.

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

Item	Control	RAC
Ingredient, %		
Corn	83.06	74.24
Soybean meal, (46.5% CP)	15.22	23.97
Monocalcium P, (21% P)	0.25	0.20
Limestone	0.75	0.78
Salt	0.35	0.35
Vitamin premix	0.075	0.075
Trace mineral premix[3]	0.075	0.075
L-lysine HCl	0.15	0.15
DL-methionine	---	0.015
L-threonine	---	0.025
Phytase[4]	0.075	0.075
Ractopamine HCl[5]	---	0.05
Total	100	100
Calculated analysis, %		
Standardized ileal digestible (SID) amino acids, %		
Lysine	0.70	0.92
Isoleucine:lysine	71	70
Leucine:lysine	179	158
Methionine:lysine	31	30
Met & Cys:lysine	65	60
Threonine:lysine	63	64
Tryptophan:lysine	19	19
Valine:lysine	84	79
Total lysine, %	0.79	1.03
CP, %	14.3	17.6
ME, kcal/lb[6]	1,525	1,523
NE, kcal/lb[7]	1,044	1,029
SID lysine: ME, g/Mcal	2.08	2.74
Ca, %	0.41	0.44
P, %	0.39	0.42
Available P, %	0.21	0.21

[1] Diets were fed in meal form during the experiment.
[2] Dietary treatments were obtained by replacing corn in the ractopamine HCl diet to achieve 75, 150, and 225 ppm added Zn from ZnO (Zinc Nacional S.A., Monterrey, Mexico) or Availa-Zn (Zinpro, Eden Prairie, MN).
[3] Trace mineral premix provided 55 ppm Zn from $ZnSO_4$.
[4] Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 204 phytase units (FTU)/lb, with a release of 0.10% available P.
[5] Provided 9 g/lb (10 ppm) of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).
[6] ME values for ingredients were derived from NRC (1998).
[7] NE values for all ingredients were derived from INRA (2004).

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

Item	Control	RAC
Ingredient, %		
Corn	54.68	45.83
Soybean meal, (46.5% CP)	13.63	22.39
Bakery meal	15.00	15.00
DDGS[3]	15.00	15.00
Limestone	1.03	1.08
Salt	0.35	0.35
Vitamin trace mineral premix[4]	0.08	0.08
L-lysine[5]	0.23	0.23
Phytase[6]	0.005	0.005
Ractopamine HCl[7]	---	0.05
Total	100	100
Calculated analysis, %		
Standardized ileal digestible (SID) amino acids, %		
Lysine	0.70	0.92
Isoleucine:lysine	80	77
Leucine:lysine	207	180
Methionine:lysine	38	33
Met & Cys:lysine	73	65
Threonine:lysine	72	68
Tryptophan:lysine	20.3	20.5
Valine:lysine	96	89
Total lysine, %	0.83	1.07
CP, %	16.9	20.2
ME, kcal/lb[8]	1,546	1,543
NE, kcal/lb[9]	1,129	1,102
SID lysine: ME, g/Mcal	2.05	2.70
Ca, %	0.48	0.52
P, %	0.39	0.43
Available P, %	0.21	0.21

[1] Diets were fed in meal form for the final 28 d prior to slaughter.
[2] Dietary treatments were obtained by replacing corn in the ractopamine HCl diet to achieve 50 ppm of added Zn from ZnO or from Availa-Zn (Zinpro, Eden Prairie, MN).
[3] Dried distillers grains with solubles.
[4] Provided 80 ppm Zn from ZnO.
[5] Biolys (50.7% L-lysine; Evonik Degussa Corporation, Kennesaw, GA)
[6] OptiPhos 2000 (Enzyvla LLC, Sheridan, NJ) provided 113.5 phytase units (FTU)/lb, with a release of 0.08% available phosphorus.
[7] Provided 9 g/lb (10 ppm) of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).
[8] ME values for ingredients were derived from NRC (1998).
[9] NE values for all ingredients were derived from INRA (2004).

Table 3. Effects of level and source of added Zn on growth performance of finishing pigs fed ractopamine HCl (RAC; Exp. 1)[1]

			Zn from ZnO[2], ppm			Zn from Availa-Zn[2], ppm				Probability, $P <$[3]			
	Control	RAC[2]	75	150	225	75	150	225	SEM	Control vs. RAC	Zn Linear	Zn Quadratic	Source
d 0 to 35													
ADG, lb	2.29	2.54	2.55	2.57	2.56	2.54	2.51	2.47	0.06	0.01	0.7	0.71	0.19
ADFI, lb	7.38	7.03	6.88	6.99	7.02	6.84	6.92	6.76	0.22	0.05	0.49	0.59	0.23
F/G	3.25	2.80	2.71	2.74	2.76	2.71	2.78	2.75	0.11	0.001	0.67	0.25	0.79
IOFC,[4] $/pig	21.16	22.74	24.00	23.83	23.56	23.65	22.09	21.78	2.04	0.33	0.80	0.44	0.17
Caloric efficiency[5]													
ME	5,021	4,266	4,123	4,164	4,184	4,122	4,225	4,179	174	0.01	0.56	0.32	0.78
NE	3,750	3,118	3,013	3,040	3,057	3,012	3,087	3,054	128	0.01	0.56	0.31	0.78
BW, lb													
d 0	215.9	215.5	216.0	215.8	216.1	216.3	215.9	215.9	3.6	0.87	0.85	0.87	0.94
d 35	289.3	302.9	304.4	304.8	305.3	304.2	301.9	301.3	5.4	0.01	0.97	0.77	0.45

[1] A total of 320 pigs (PIC 327 × 1050) were used with 2 pigs per pen and 20 pens per treatment.
[2] Diets contained 10 ppm of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).
[3] No interactive effects ($P > 0.16$) of Zn level × source.
[4] Income over feed cost. Corn was valued at $242/ton, soybean meal at $515/ton, L-lysine at $0.70/lb, phytase at $2.65/lb, and RAC at $35.26/lb, zinc oxide at $0.86/lb, Availa-Zn at $1.50/lb, and live weight was priced at $75.15/cwt.
[5] Caloric efficiency is expressed as kcal/lb gain.

Table 4. Effects of level and source of added Zn on carcass characteristics, economic return, and liver weights of finishing pigs fed ractopamine HCl (RAC; Exp. 1)[1]

			Zn from ZnO[2], ppm			Zn from Availa-Zn[2], ppm				Probability, $P <$[3]			
Item	Control	RAC[2]	75	150	225	75	150	225	SEM	Control vs RAC	Zn Linear	Zn Quadratic	Source
Final wt, lb	300.4	306.1	307.1	307.4	308.5	308.6	304.9	304.6	4.1	0.15	0.97	0.76	0.48
HCW, lb	218.1	223.9	225.7	224.1	226.4	224.5	223.9	222.4	3.1	0.04	0.97	0.81	0.28
Carcass yield, %[4]	72.92	73.27	73.21	72.96	73.58	72.68	73.34	72.89	0.28	0.31	0.92	0.30	0.16
Carcass ADG, lb[5]	1.66	1.84	1.84	1.84	1.86	1.84	1.81	1.78	0.04	0.001	0.60	0.93	0.22
Carcass F/G, lb[6]	4.57	3.86	3.78	3.83	3.79	3.75	3.85	3.83	0.14	0.001	0.79	0.54	0.87
Back fat, in.[7]	0.83	0.69	0.67	0.69	0.73	0.68	0.69	0.67	0.03	0.001	0.68	0.59	0.54
Loin depth, in.[7]	2.64	2.79	2.81	2.88	2.81	2.84	2.81	2.80	0.05	0.02	0.71	0.3	0.67
SFFL, %[7,8]	50.51	52.63	52.90	52.72	52.18	52.77	52.63	52.84	0.47	0.001	0.74	0.56	0.65
Carcass IOFC, $/pig[9]	19.69	21.34	21.88	21.46	22.17	22.07	20.39	19.87	2.02	0.28	0.62	0.75	0.23
Carcass caloric efficiency[10]													
ME	6,963	5,879	5,749	5,828	5,772	5,703	5,855	5,812	208	0.001	0.73	0.56	0.94
NE	5,201	4,296	4,201	4,255	4,217	4,167	4,277	4,247	153	0.001	0.73	0.55	0.93
Liver, lb[10]	4.19	4.50	4.54	4.44	4.40	4.31	4.30	4.34	0.13	0.04	0.28	0.66	0.09

[1] A total of 320 pigs (PIC 327 × 1050) were used with 2 pigs per pen and 20 pens per treatment.
[2] Diets contained 10 ppm of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).
[3] No interactive effects ($P > 0.12$) of Zn level × source.
[4] Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the packing plant.
[5] Calculated using carcass yield multiplied by ADG.
[6] Calculated by dividing ADFI by carcass ADG.
[7] Adjusted using HCW as a covariate.
[8] Percentage standardized fat-free lean (SFFL) was calculated by dividing the SFFL by HCW. The equation used for calculation of SFFL was derived from NPPC (2001).
[9] Corn was valued at $242/ton, soybean meal at $515/ton, L-lysine at $0.70/lb, phytase at $2.65/lb, RAC at $35.26/lb, zinc oxide at $0.86/lb, Availa-Zn at $1.50/lb, and carcass priced at $100.2/cwt.
[10] Caloric efficiency is expressed as kcal/lb gain.
[11] Liver weights were measured with the gallbladder intact.

Table 5. Effects of level and source of added Zn on loin and liver Zn concentrations of finishing pigs fed ractopamine HCl (RAC; Exp. 1)[1]

			Zn from ZnO[2], ppm			Zn from Availa-Zn[2], ppm				Probability, $P <$		
Item	Control	RAC[2]	75	150	225	75	150	225	SEM	Control vs. RAC	Level × source linear	Level × source quadratic
As-is basis, (µg/g)												
Liver	84.8	78.1	84.6	92.3	88.7	80.4	89.2	107.4	4.71	0.29	0.01	0.02
Loin	16.8	16.3	17.1	15.8	15.6	16.6	15.2	15.9	0.72	0.56	0.77	0.37
DM basis, (µg/g)												
Liver	306.2	292.8	314.1	345.4	329.3	289.6	326.4	394.8	17.44	0.55	0.01	0.01
Loin	61.5	59.2	62.4	58.1	56.4	60.2	55.8	58.7	2.80	0.50	0.55	0.25

[1]Values represent 160 pigs, 1 pig randomly selected from each pen, selected for harvest at the Kansas State University Meat Laboratory (Manhattan, KS).
[2] Diets contained 10 ppm of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).

Table 6. Effects of level and source of added Zn on plasma Zn concentrations of finishing pigs fed Ractopamine HCl (RAC; Exp. 1)[1]

			Zn from ZnO[2], ppm			Zn from Availa-Zn[2], ppm				Probability, $P <$[2,3]			
	Control	RAC	75	150	225	75	150	225	SEM	Control vs. RAC	Zn Linear	Zn Quadratic	Source
Plasma, µg/mL													
d 0	1.06	1.01	1.04	1.05	1.04	1.01	1.06	1.06	0.04	0.33	0.25	0.74	0.85
d 8	1.08	1.07	1.09	1.06	1.15	1.08	1.11	1.16	0.05	0.92	0.11	0.40	0.51
d 18	1.13	1.06	1.12	1.16	1.11	1.10	1.18	1.17	0.04	0.16	0.02	0.16	0.44
d 32	1.08	1.01	1.07	1.07	1.13	1.07	1.09	1.13	0.04	0.19	0.01	0.98	0.77

[1] Values represent 128 pigs, 1 pig randomly selected from 16 pens per treatment.
[2] No interactive effects ($P > 0.17$) of Zn level × source or treatment × day.
[3] There was an increase (quadratic, $P < 0.001$) in plasma Zn from day 0 to 18.

Table 7. Effects of added zinc on growth performance of finishing pigs fed ractopamine HCl (Exp. 2)[1]

						Probability, *P* <		
Item	Control	RAC[2]	ZnO[2]	AZ[2]	SEM	CON vs. RAC	RAC vs. added Zn	ZnO vs. AZ
d 0 to 28								
ADG, lb	2.03	2.42	2.46	2.45	0.030	0.001	0.33	0.78
ADFI, lb	6.44	6.39	6.32	6.44	0.087	0.58	0.93	0.26
F/G	3.19	2.64	2.57	2.63	0.035	0.001	0.33	0.20
Caloric efficiency[3]								
ME	4,931	4,076	3,967	4,060	54.5	0.001	0.32	0.21
NE	3,602	2,912	2,833	2,899	39.4	0.001	0.32	0.22
BW								
d 0	228.4	228.6	228.6	228.7	1.79	0.81	0.94	0.85
d 28	278.0	288.0	289.3	288.6	2.33	0.001	0.55	0.68

[1] A total of 1,263 pigs (PIC 337 × 1050; initially 228.6 lb) were used in a 28-d study with 25 to 27 pigs per pen and 12 pens per treatment.
[2] Diets contained 10 ppm of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).
[3] Caloric efficiency is expressed as kcal/lb gain.

Table 8. Effects of added zinc on carcass characteristics of finishing pigs fed ractopamine HCl (RAC; Exp. 2)[1]

						Probability, *P* <		
Item	Control	RAC[2]	ZnO[2]	AZ[2]	SEM	CON vs. RAC	RAC vs. added Zn	ZnO vs AZ
d 14[3]								
Final weight, lb	282.3	288.3	289.9	290.5	3.22	0.16	0.60	0.89
HCW, lb	209.5	214.9	216.2	213.0	2.91	0.07	0.91	0.28
Carcass yield,[4] %	74.21	74.55	74.59	73.33	0.482	0.58	0.27	0.05
Carcass ADG,[5] lb	1.51	1.83	1.91	1.87	0.046	0.001	0.11	0.27
Carcass F/G,[6] lb	4.03	3.39	3.19	3.44	0.080	0.001	0.23	0.001
Backfat thickness,[7] in.	0.70	0.66	0.66	0.64	0.017	0.17	0.52	0.26
Loin depth,[8] in.	2.70	2.79	2.77	2.75	0.036	0.09	0.54	0.73
Lean,[7,8] %	52.81	53.46	53.42	53.78	0.279	0.09	0.63	0.30
Carcass IOFC,[9] $/pig	8.94	10.68	11.98	10.55	0.56	0.001	0.15	0.01
Carcass caloric efficiency[10]								
ME	6,227	5,223	4,927	5,303	124	0.001	0.23	0.001
NE	4,548	3,730	3,519	3,786	89	0.001	0.23	0.001
d 28								
Final weight, lb	277.7	288.3	289.3	288.5	2.38	0.001	0.73	0.72
HCW, lb	207.9	215.6	218.3	216.1	2.53	0.001	0.32	0.22
Carcass yield, %[4]	74.79	74.79	75.47	74.94	0.475	0.99	0.35	0.30
Carcass ADG, lb[5]	1.52	1.81	1.85	1.83	0.026	0.001	0.27	0.54
Carcass F/G, lb[6]	4.26	3.53	3.42	3.52	0.049	0.001	0.27	0.15
Backfat thickness, in.[7]	0.66	0.59	0.60	0.60	0.012	0.001	0.56	0.66
Loin depth, in.[8]	2.72	2.80	2.81	2.81	0.013	0.01	0.89	0.99
Lean, %[7,8]	53.40	54.49	54.34	54.43	0.192	0.001	0.61	0.70
Carcass IOFC, $/pig[9]	16.52	19.77	21.22	20.04	0.57	0.001	0.21	0.14
Carcass caloric efficiency[10]								
ME	6,586	5,448	5,269	5,420	76	0.001	0.26	0.16
NE	4,810	3,891	3,763	3,869	55	0.001	0.26	0.17

[1] 1,263 pigs (PIC 337 × 1050; initially 228.6 lb) were used in a 28-d study with 25 to 27 pigs per pen and 12 pens per treatment.
[2] Diets contained 10 ppm of Ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN).
[3] The 6 heaviest pigs from each pen (determined visually) were sold as tops.
[4] Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the packing plant.
[5] Calculated using yield multiplied by ADG.
[6] Calculated by dividing ADFI by carcass ADG.
[7] Adjusted using HCW as a covariate.
[8] Calculated using NPPC (2001) equation: (15.31 + 0.51 × (HCW, lb)-31.277 × (last rib backfat thickness,in.) + 3.813 × (loin muscle depth, in.)) / HCW × 100.
[9] Corn was valued at $242/ton, soybean meal at $515/ton, dried distillers grains with solubles at $220/ton, bakery meal at $232/ton, L-lysine at $0.70/lb, phytase at $2.65/lb, RAC at $35.26/lb, zinc oxide at $0.86/lb, Availa-Zn at $1.50/lb; carcasses priced at $100.2/cwt.
[10] Caloric efficiency is expressed as kcal/lb gain.