Effects of Increasing Zn from Zinc Sulfate or Zinc Hydroxychloride on Finishing Pig Growth Performance, Carcass Characteristics, and Economic Return[1]

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Summary

A total of 1,008 pigs [TR4 (Fast × L02 PIC; initially 70.6 lb BW)] were used in a 103-d growth study to determine the effects of Zn source and level on finishing pig growth performance, carcass characteristics, and economic return. The 6 dietary treatments were arranged as a 2 × 3 factorial with main effects of Zn source ($ZnSO_4$; Agrium Advance Technology, Loveland, CO, or Zn hydroxychloride; Intellibond-Z; Micronutrients, Indianapolis, IN) and level (50, 100, or 150 ppm added Zn). The trace mineral premix was formulated to contain no added Zn. There were 21 pigs per pen and 8 pens per treatment.

Overall, there was no effect of Zn source for growth performance criteria observed. Increasing added Zn maximized (quadratic, $P = 0.007$) ADG when diets contained 100 ppm Zn; however, F/G tended to worsen (source × level, linear, $P = 0.068$) as Zn from Zn hydroxychloride increased, but was relatively unchanged when pigs were fed increasing Zn from $ZnSO_4$. Carcass yield increased (linear, $P = 0.027$) as Zn level increased. Pigs fed diets with Zn hydroxychloride had heavier ($P = 0.041$) HCW, and increased HCW ADG ($P = 0.036$) than those fed $ZnSO_4$. Hot carcass weight and HCW ADG were maximized (quadratic, $P \leq 0.006$) when diets contained 100 ppm Zn. There was a tendency for income over feed cost (IOFC) to be maximized when pigs were fed diets with 100 ppm Zn when economic analysis was calculated on both a constant day (quadratic, $P = 0.059$) and constant carcass weight (quadratic, $P = 0.070$) basis, respectively.

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In summary, these results suggest that a total of 100 ppm added Zn is adequate to maximize ADG, HCW, HCW ADG, and IOFC, but F/G worsened as Zn level increased. Zinc source did not affect growth performance; however, pigs fed Zn hydroxychloride had increased HCW and HCW ADG compared to those fed $ZnSO_4$.

Key words: finishing pig, zinc hydroxychloride, zinc sulfate

Introduction

Historically, increasing Zn above that provided from the trace mineral premix [generally around 50 ppm (NRC, 2012)[5]] has not been added in finishing pig diets. However, some recent research suggests improvements in growth performance with increasing levels of added Zn (75 ppm), especially during the finisher period when ractopamine HCl is fed (Paulk et al., 2014)[6]. These studies suggest that further research is necessary to re-examine the Zn requirement of grow-finish pigs. Furthermore, while some nursery pig data are available to compare Zn sources, no data are available to compare the effects of Zn hydroxychloride, a unique form of inorganic Zn, to other more commonly used forms of Zn ($ZnSO_4$) in the finisher phase. Therefore, our study was designed to investigate the effects of increasing Zn from two different sources on growth performance, carcass characteristics, and economic return of finishing pigs housed in a commercial environment.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocols used in these experiments. This study was conducted at New Fashion Pork in a commercial research facility in Round Lake, MN. The research barn was double-curtain-sided with completely slatted flooring and deep pits for manure storage. Pigs had approximately 7.4 ft^2/pig and each pen was equipped with a 5-hole stainless steel dry self-feeder (Thorp Equipment, Inc., Thorp, WI) 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). Research diets were manufactured in a commercial feed mill located in Estherville, IA.

A total of 1,008 pigs (TR4 (Fast × L02 PIC); initially 70.6 lb BW) were used in a 103-d growth experiment to determine the effects of increasing Zn from two different sources on finishing pig growth performance, carcass characteristics, and economic return. Pigs were allotted to pen based on initial body weight with 8 pens per treatment and 21 pigs per pen (mixed gender) and pens were randomly allotted to 1 of the 6 dietary treatments. The 6 dietary treatments were arranged as a 2 × 3 factorial with main effects of Zn source ($ZnSO_4$ or Zn hydroxychloride; Intellibond Z; Micronutrients, Indianapolis, IN) and Zn level (50, 100, or 150 ppm). All diets were corn- soybean meal-DDGS based and were fed in 5 phases (approximately 70 to 100, 100 to 140, 140 to 180, 180 to 230, and 230 to 280 lb) with ractopamine HCl included in the final phase (Table 1). The trace mineral premix added to all diets contained no added Zn.

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

[6] Paulk et al., Swine Day 2014, Report of Progress 1110, pp. 164-171. Kansas Agricultural Experiment Station, Manhattan, KS.

Complete diet samples were collected from a minimum of 6 feeders per phase and combined to make 1 composite sample per treatment and phase. Each sample was split and ground then sent to Cumberland Valley Analytical Services (Hagerstown, MD) and Ward Laboratories Inc. (Kearney, NE) for analysis of DM, CP, ADF, crude fiber, Ca, P, ether extract, ash, starch and Zn concentrations. Final Zn concentrations were determined by averaging a total of 3 values; 1 analyzed value from Ward Laboratories Inc. and 2 analyzed values from Cumberland Valley Analytical Services.

Pigs were weighed and feed disappearance was measured approximately every 2 weeks to calculate ADG, ADFI, and F/G. On d 89 of the trial, pens were weighed and the 6 heaviest pigs from each pen were removed and transported 350 miles to Triumph Foods (St. Joseph, MO) for harvest. The remaining pigs were transported to Triumph Foods on d 103 for harvest. Carcass yield was calculated using HCW at the plant divided by live weight at the farm on an individual pig basis. Standard carcass measurements of backfat and loin depth were measured with pen as experimental unit and carcass as the observational unit. Percentage lean was calculated using equations from the National Pork Producers Council (2000). Hot carcass weight ADG was calculated by subtracting initial HCW from the final HCW obtained at the plant, then divided by 103 d on test. An assumed carcass yield of 75% was used to calculate initial HCW at the beginning of the experiment. Hot carcass weight F/G was calculated by dividing the pen total feed intake divided by pen total carcass weight gain.

Economical comparisons were made based on both a constant ending weight and a constant day basis. For both, total feed cost per pig, cost per pound of gain, carcass ADG and F/G, value and income over feed cost (IOFC) were calculated. Feed cost was calculated by multiplying total feed intake per pig by a weighted mean diet cost on a per pen basis. Prices used for corn, soybean meal, and DDGS at the time of the experiment were $0.05, 0.14, and 0.04/lb, respectively. Prices used for the Zn hydroxychloride and $ZnSO_4$ were $2.80 and 0.69/lb, respectively. Carcass price at time of slaughter was calculated at $0.82 per pound. Cost per pound of gain was calculated by dividing the total feed cost per pig by the total carcass pounds gained overall. The value of the carcass weight gained during the experiment (gain value) was calculated by multiplying the carcass value by the product of the pen final carcass weight yield. Income over feed cost was calculated by subtracting total feed cost from gain value. The income over feed and facilities cost (IOFFC) was calculated for the constant market weight evaluation because pigs with faster growth rates will reach a 210 lb carcass sooner, therefore decreasing housing costs. Facility cost was calculated by multiplying the number of overall days the pigs need to reach a 210 lb carcass based on their respective growth rate by $0.10 per head per day facility cost.

Data were analyzed as a randomized complete block design using PROC GLIMMIX (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Hot carcass weight was used as a covariate for carcass characteristics including percentage lean, loin depth, and backfat. Both linear and quadratic effects of source and level were analyzed with significance defined as $P < 0.05$ and a tendency as $P < 0.10$ and ≥ 0.05.

Results and Discussion

The chemical analyses of the complete diets were similar to the intended formulation (Table 2, 3, and 4). Total Ca and P concentrations were similar among diets across each dietary phase. The total analyzed Zn concentrations for diets formulated to 50, 100, and 150 ppm added zinc from $ZnSO_4$ ranged from; 83 to 202, 150 to 200, and 183 to 225 ppm, respectively. Total analyzed Zn levels for diets formulated to 50, 100, and 150 ppm added zinc from Zn hydroxychloride ranged from; 101 to 121, 128 to 176, and 178 to 226 ppm, respectively.

From d 0 to 33, neither Zn source nor level influenced growth performance. From d 33 to 66, there were no Zn source × level interactions for ADG or ADFI; however, F/G worsened when 150 ppm of Zn from $ZnSO_4$ was added, whereas, poorer F/G was first observed when 100 ppm of Zn from Zn hydroxychloride was added (source × level, quadratic, $P = 0.007$; Table 5). There was a tendency for ADG to increase then decrease (quadratic, $P = 0.092$) and ADFI increased (linear, $P = 0.042$) with increasing Zn. This resulted in poorer (linear, $P = 0.001$) F/G with increasing added Zn. Pigs fed $ZnSO_4$ tended to have better F/G ($P = 0.096$) compared with those fed Zn hydroxychloride.

From d 66 to 103, there were no Zn source × level interactions observed for ADG or ADFI; however, as Zn from Zn hydroxychloride increased, F/G became poorer (source × level, linear, $P = 0.007$). Increasing Zn increased ADG (quadratic, $P = 0.001$) and tended to increase ADFI (quadratic, $P = 0.051$) through 100 ppm, but when 150 ppm was included performance returned to levels similar to those fed 50 ppm. Pigs fed Zn from Zn hydroxychloride had greater ADFI ($P = 0.026$) than those fed $ZnSO_4$. Feed efficiency improved (quadratic, $P = 0.011$) and was maximized when pigs were fed 100 ppm of Zn compared with those fed 50 or 150 ppm which had similar F/G.

Overall, (d 0 to 103), there were no Zn source × level interactions observed for ADG or ADFI; however, F/G tended to worsen (source × level, linear, $P = 0.068$) as Zn from Zn hydroxychloride increased, but was relatively unchanged when pigs were fed increasing Zn from $ZnSO_4$. Final BW and ADG were maximized (quadratic, $P \leq 0.011$) when pigs were fed 100 ppm of Zn. Carcass yield increased (linear, $P = 0.027$; Table 6) with increasing added Zn. Pigs fed Zn hydroxychloride had heavier ($P = 0.041$) HCW than those fed added $ZnSO_4$. Hot carcass weight increased (quadratic, $P = 0.006$) then decreased and was maximized when diets contained 100 ppm of added Zn. Similarly, pigs fed Zn hydroxychloride had increased ($P = 0.036$) HCW ADG. Hot carcass weight ADG increased (quadratic, $P = 0.005$) then decreased with increasing Zn and was maximized when diets contained 100 ppm of added Zn.

For the economic analysis when reported on a constant time basis, there were no source × level interactions observed for feed cost, carcass gain value or IOFC. However, cost per pound of carcass gain increased (source × level, linear, $P = 0.002$; Table 7) as Zn from Zn hydroxychloride increased, which may be attributed to the poorer (source × level, linear, $P = 0.005$) carcass F/G at the 150 ppm level. Increasing added Zn tended (quadratic, $P = 0.098$) to increase then decrease feed cost and was highest when diets contained 100 ppm of added Zn. Carcass gain value was maximized (quadratic, $P = 0.011$) when pigs were fed 100 ppm of Zn, which resulted in the greatest (quadrat-

ic, P = 0.007) IOFC. Because of the improved HCW ADG, carcass gain value increased (P = 0.039) for pigs fed Zn hydroxychloride compared with pigs fed $ZnSO_4$.

When reported on a constant weight basis, there were no source × level interactions observed for facility costs, but a source × level interaction (P < 0.011) was found for all other response criteria. The interaction occurred because carcass F/G, feed cost, cost/lb of carcass gain, IOFC, and IOFFC were improved for pigs fed 50 or 100 ppm Zn, but poorer for pigs fed 150 ppm Zn from Zn hydroxychloride compared with pigs fed Zn from $ZnSO_4$.

It is currently recommended (NRC, 2012) that finishing pigs are fed diets containing 50 ppm of Zn. From our study, it appears that there may be growth promoting benefits to supplementing diets with Zn beyond 50 ppm. The current study suggests 100 ppm of Zn maximizes overall ADG and BW for growing pigs from 70 to 280 lb of BW.

Previous literature suggests there may be performance benefits of added Zn during the earliest stages of finishing, but without any impact on overall growth performance (Paulk et al., 2014)[7]. In their study, the basal diet contained 55 ppm Zn from the trace mineral premix. An addition of 75 ppm of Zn for a total Zn level of 130 ppm did not improve overall performance. These results are not consistent with the findings of the current study which suggest 100 ppm of Zn maximizes overall BW and ADG. Our study also indicates HCW, HCW ADG, and IOFC were maximized when diets contained 100 ppm of Zn. However, Paulk et al. (2014) observed carcass characteristics and economics were not influenced by adding more than 55 ppm of Zn fed to pigs in the early finishing period, late finishing period, or throughout the overall finishing period.

In similar studies that evaluated increasing levels of added Zn from ZnO, a trend for improved feed efficiency was observed (Paulk et al., 2015)[8]. The same authors suggest pigs fed added Zn from ZnO have increased ADG and increased ADFI during the first growth period of their study, compared with those fed added Zn from ZnAA, but with no overall differences in growth performance. In this study, Paulk et al. (2015) used analyzed Zn concentrations ranging from 83 ppm (basal diet) to 267 ppm with the added Zn as ZnAA or ZnO. Although this range of Zn concentration is larger than that of the current study, the ADFI results between the studies are similar. Similar to our study, which suggests differences in ADFI for pigs fed different Zn sources during intermediate growth periods, these differences did not translate into the overall data. Interestingly, our data suggest overall F/G becomes poorer when pigs are fed increasing levels of added Zn; however Paulk et al. (2015) suggests increasing Zn tended to improve feed efficiency. Although the data are mixed on whether or not increasing Zn improves feed efficiency, the studies do agree that F/G is similar when pigs are fed diets containing different Zn sources.

[7] Paulk et al., Swine Day 2014, Report of Progress 1110, pp. 164-171. Kansas Agricultural Experiment Station, Manhattan, KS.

[8] 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.

In summary, our study suggests little overall differences between Zn sources on growth performance; however, pigs fed diets with Zn hydroxychloride had greater HCW compared to those fed $ZnSO_4$. These results suggest 100 ppm of Zn maximizes ADG, HCW, HCW ADG, and IOFC when reported on a constant day or weight basis with a greater response in the later phases (d 66 to 103) of the study. This might suggest that duration of feeding elevated levels of Zn might influence the magnitude of response observed. As a result, more research should be conducted to determine if duration of feeding different levels or sources of Zn influences the magnitude of growth performance response observed.

Table 1. Diet composition (as-fed basis)

Item	Phase[1,2]				
	1	2	3	4	5
Ingredient, %					
Corn	48.08	52.13	55.70	58.31	69.00
Soybean meal, 47.5% CP	19.56	15.69	12.24	9.66	18.66
Corn DDGS	30.00	30.00	30.00	30.00	10.00
Monocalcium P, 21% P	0.15	---	---	---	0.30
Limestone	1.35	1.35	1.25	1.25	0.95
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys-HCl	0.35	0.33	0.30	0.28	0.35
L-Thr	---	---	---	---	0.09
L-Trp	0.01	0.01	0.01	---	0.02
Methionine[3]	---	---	---	---	0.10
Ractopamine HCl, 9 g/lb	---	---	---	---	0.03
Vitamin/trace mineral premix[4]	0.15	0.15	0.15	0.15	0.15
Zn source[5]	---	---	---	---	---
Total	100	100	100	100	100

Table 1. Diet composition (as-fed basis)

Item	Phase[1,2] 1	2	3	4	5
Calculated analysis					
Standardized ileal digestible (SID) AA, %					
Lys	0.97	0.86	0.76	0.68	0.9
Ile:lys	71	73	75	77	63
Leu:lys	178	191	207	223	155
Met:lys	29	30	33	35	34
Met + Cys:lys	57	61	65	70	60
Thr:lys	63	65	67	70	65
Trp:lys	18.6	18.7	18.6	18.5	18.6
Val:lys	79	82	86	90	70
Total lys, %	1.11	0.99	0.88	0.8	1
ME, kcal/lb	1,510	1,512	1,514	1,514	1,514
NE, kcal/lb	1,108	1,120	1,118	1,124	1,133
SID Lys:ME, g/Mcal	2.91	2.58	2.28	2.04	2.7
CP, %	20.76	19.18	17.77	16.7	16.73
Ca, %	0.63	0.58	0.53	0.52	0.52
P, %	0.55	0.51	0.49	0.49	0.46
Available P, %	0.41	0.37	0.37	0.36	0.32

[1]Phases 1, 2, 3, 4, and 5 were fed from d 0 to 17, 17 to 33, 33 to 48, 48 to 66, and 66 to 103, respectively.

[2]Dietary treatments were formed by adding 50, 100, 150 ppm of Zn from either $ZnSO_4$ or Zn hydroxychloride at the expense of corn. All diets were manufactured using a Zn-free trace mineral premix.

[3]MHA, Novus International, Saint Charles, MO.

[4]The vitamin and Zn free trace mineral premix supplied; vitamin A 1,867,000 I.U, vitamin D3 267,000 I.U., vitamin E 12,000 I.U, vitamin B12 7.334 mg, riboflavin (B2) 2,667 mg, niacin 8,000 mg, d-panthothenic acid 5,334 mg, menidione 667 mg, selenium 0.020, copper 10.8, iron 5.07, manganese 1.9. Vitamin concentrations are expressed on a per lb of product basis; whereas mineral concentrations are expressed on a total percentage of premix basis.

[5]$ZnSO_4$ (Zinc sulfate) (Agrium Advance Technology, Loveland, CO) or Intellibond-Z, Zinc hydroxychloride, (Micronutrients, Indianapolis, IN).

Table 2. Chemical analysis of diets (as-fed basis)[1]

Item	Phase 1						Phase 2					
	$ZnSO_4$[2], ppm			Zn hydroxychloride[3], ppm			$ZnSO_4$[2], ppm			Zn hydroxychloride[3], ppm		
	50	100	150	50	100	150	50	100	150	50	100	150
DM, %	88.10	87.60	88.30	87.60	87.40	87.70	86.60	86.90	86.90	87.10	86.90	86.70
CP, %	22.50	23.00	22.40	21.00	20.90	22.20	20.20	21.60	23.00	21.20	22.20	21.60
Crude fiber, %	4.40	4.60	4.20	4.10	3.90	4.70	3.90	4.30	4.80	4.20	4.30	4.30
Ether extract, %	5.99	5.38	5.54	4.97	4.89	5.22	4.60	4.32	4.51	5.57	4.88	4.18
Ash, %	5.85	5.82	5.87	5.54	5.53	6.21	5.89	6.68	6.64	5.60	6.17	6.25
Ca, %	0.83	0.96	0.98	0.85	0.78	1.02	0.85	0.99	0.86	0.98	0.90	0.96
P, %	0.61	0.64	0.65	0.60	0.56	0.64	0.58	0.59	0.64	0.59	0.64	0.59
Zn, ppm[4]	122	205	194	110	131	193	120	150	183	112	176	226

[1]Multiple samples of each diet were collected, blended and sub sampled, and analyzed (Cumberland Valley Analytical Services, Hagerstown, MD).
[2]Zinc sulfate (Agrium Advance Technology, Loveland, CO).
[3]Intellibond-Z (Micronutrients, Indianapolis, IN).
[4]Zinc values represent means from 1 sample at Ward Laboratories Inc., Kearney, NE, and 2 samples at Cumberland Valley Analytical Services, Hagerstown, MD.

Table 3. Chemical analysis of diets (as-fed basis)[1]

Item	Phase 3						Phase 4					
	$ZnSO_4$[2], ppm			Zn hydroxychloride[3], ppm			$ZnSO_4$[2], ppm			Zn hydroxychloride[3], ppm		
	50	100	150	50	100	150	50	100	150	50	100	150
DM, %	87.20	87.10	87.20	87.20	87.10	87.20	87.00	86.6	87.20	86.70	87.10	87.20
CP, %	19.70	21.20	20.30	20.10	19.50	20.40	20.20	20.70	20.20	20.20	20.30	19.90
Crude fiber, %	4.10	4.30	4.00	4.20	4.30	3.70	3.90	4.50	4.20	4.20	4.40	4.20
Ether extract, %	5.10	5.76	5.60	5.51	5.00	4.70	5.64	5.35	5.69	6.09	5.94	5.11
Ash, %	5.80	5.17	5.26	5.28	5.74	5.33	5.13	5.81	5.62	4.98	5.83	5.04
Ca, %	1.00	0.73	0.93	0.90	0.89	1.01	0.74	0.81	0.86	0.66	0.86	0.73
P, %	0.55	0.55	0.54	0.54	0.53	0.52	0.54	0.56	0.57	0.57	0.58	0.57
Zn, ppm[4]	216	178	193	114	158	183	140	178	219	131	128	178

[1]Multiple samples of each diet were collected, blended and sub sampled, and analyzed (Cumberland Valley Analytical Services, Hagerstown, MD).
[2]Zinc sulfate (Agrium Advance Technology, Loveland, CO).
[3]Intellibond-Z (Micronutrients, Indianapolis, IN).
[4]Zinc values represents means from 1 sample at Ward Laboratories Inc., Kearney, NE, and 2 samples at Cumberland Valley Analytical Services, Hagerstown, MD.

Table 4. Chemical analysis of diets (as-fed basis)[1]

Item	Phase 5					
	$ZnSO_4$[2], ppm			Zn hydroxychloride[3], ppm		
	50	100	150	50	100	150
DM, %	86.10	86.00	85.80	85.70	86.10	86.10
CP, %	19.70	19.50	19.30	18.80	19.10	19.50
Crude fiber, %	3.20	3.40	3.00	3.10	3.10	3.40
Ether extract, %	2.47	3.74	3.90	4.03	3.99	3.97
Ash, %	5.14	6.43	4.79	4.28	5.57	5.07
Ca, %	0.71	0.76	0.70	0.61	0.64	0.73
P, %	0.47	0.46	0.46	0.48	0.49	0.51
Zn, ppm[4]	83	162	225	101	137	204

[1]Multiple samples of each diet were collected, blended and sub sampled, and analyzed (Cumberland Valley Analytical Services, Hagerstown, MD).
[2]Zinc sulfate (Agrium Advance Technology, Loveland, CO).
[3]Intellibond-Z˚ (Micronutrients, Indianapolis, IN).
[4]Zinc values represents means from 1 sample at Ward Laboratories Inc., Kearney, NE, and 2 samples at Cumberland Valley Analytical Services, Hagerstown, MD.

Table 5. Effects of increasing Zn from ZnSO$_4$ or Zn hydroxychloride on growth performance of pigs[1]

| | ZnSO$_4$ ppm[2] | | | Zn hydroxychloride, ppm[3] | | | | | Zn level | | Source × level | |
| | | | | | | | | | Probability, $P <$ | | | |
Item	50	100	150	50	100	150	SEM	Zn source	Linear	Quadratic	Linear	Quadratic
BW, lb												
d 0	70.7	70.7	70.7	70.7	70.6	70.6	0.722	0.899	0.951	0.971	0.951	0.971
d 33	139.3	139.3	140.9	139.9	140.5	138.9	1.040	0.867	0.675	0.823	0.111	0.177
d 66	207.6	208.5	208.9	207.8	209.5	206.2	1.362	0.563	0.904	0.166	0.200	0.242
d 103	278.2	282.7	277.8	280.1	285.4	278.8	2.378	0.326	0.703	0.011	0.848	0.766
d 0 to 33												
ADG, lb	2.07	2.07	2.12	2.09	2.09	2.07	0.024	0.895	0.631	0.742	0.174	0.308
ADFI, lb	4.52	4.50	4.56	4.56	4.55	4.51	0.043	0.720	0.950	0.770	0.318	0.441
F/G	2.19	2.19	2.16	2.19	2.18	2.19	0.017	0.533	0.459	0.869	0.477	0.548
d 33 to 66												
ADG, lb	2.07	2.10	2.06	2.05	2.08	2.04	0.022	0.299	0.659	0.092	0.925	0.886
ADFI, lb	5.50	5.60	5.71	5.49	5.76	5.61	0.078	0.830	0.042	0.130	0.580	0.114
F/G	2.65	2.66	2.76	2.66	2.76	2.74	0.022	0.096	0.001	0.700	0.332	0.007
d 66 to103												
ADG, lb	2.06	2.17	2.07	2.12	2.24	2.09	0.040	0.112	0.880	0.001	0.649	0.735
ADFI, lb	6.25	6.48	6.22	6.34	6.65	6.63	0.116	0.026	0.251	0.051	0.163	0.689
F/G	3.01	2.93	2.99	2.92	2.92	3.08	0.036	0.840	0.049	0.011	0.007	0.862
d 0 to 103												
ADG, lb	2.07	2.11	2.09	2.09	2.14	2.07	0.020	0.555	0.951	0.007	0.376	0.487
ADFI, lb	5.42	5.52	5.45	5.45	5.64	5.58	0.069	0.163	0.168	0.126	0.660	0.603
F/G	2.62	2.60	2.59	2.59	2.63	2.67	0.018	0.304	0.005	0.265	0.068	0.463

[1] A total of 1,008 pigs (TR4 × (Fast × L02 PIC); initially 70.6 lb) were used with 21 pigs per pen and 8 pens per treatment. The trace mineral premix contributed 1 ppm of Zn to the complete diet.
[2] Zinc sulfate (Agrium Advance Technology, Loveland, CO).
[3] Intellibond-Z (Micronutrients, Indianapolis, IN).

Table 6. Effects of increasing Zn from ZnSO$_4$ or Zn hydroxychloride on carcass characteristics of finishing pigs[1]

	ZnSO$_4$ ppm[2]			Zn hydroxychloride, ppm[3]			SEM	Zn Source	Level		Source × level	
Item	50	100	150	50	100	150			Linear	Quadratic	Linear	Quadratic
Yield, %	73.63	74.08	74.53	74.03	74.68	74.36	0.003	0.240	0.027	0.329	0.288	0.327
HCW, lb	204.2	209.5	206.5	208.0	213.6	208.4	1.95	0.041	0.494	0.006	0.618	0.696
Backfat[4], in.	0.69	0.68	0.70	0.69	0.68	0.68	0.016	0.618	0.802	0.343	0.717	0.445
Loin depth[4], in.	2.47	2.50	2.49	2.50	2.52	2.47	0.036	0.727	0.947	0.374	0.464	0.845
Lean[4], %	53.75	54.13	53.80	53.96	54.11	53.93	0.264	0.634	0.975	0.254	0.879	0.678
HCW ADG, lb	1.47	1.52	1.49	1.51	1.56	1.51	0.018	0.036	0.522	0.005	0.669	0.700

[1] A total of 1,008 pigs (TR4 × (Fast × PIC L02); initially 70.6 lb) were used in a 103 d growth study.
[2] Zinc sulfate (Agrium Advance Technology, Loveland, CO).
[3] Intellibond-Z (Micronutrients, Indianapolis, IN).
[4] Hot carcass weight was used as a covariate.

Table 7. Effects of increasing Zn from ZnSO$_4$ or Zn hydroxychloride on economic performance[1]

| | ZnSO$_4$, ppm[2] | | | Zn hydroxychloride, ppm[3] | | | | | Zn level | | Source × level | |
Item	50	100	150	50	100	150	SEM	Zn Source	Linear	Quadratic	Linear	Quadratic
Constant day, $/pig												
Feed cost[4]	45.25	46.16	45.36	45.58	47.38	47.15	0.637	0.038	0.196	0.098	0.259	0.879
Cost/lb gain carcass wt.	0.298	0.295	0.293	0.295	0.297	0.305	0.0024	0.048	0.182	0.350	0.002	0.615
Carcass F/G	3.56	3.52	3.52	3.52	3.55	3.63	0.027	0.132	0.232	0.373	0.005	0.934
Carcass gain value[5]	169.37	172.77	170.20	172.43	177.72	171.83	1.843	0.039	0.948	0.011	0.683	0.416
IOFC	123.91	126.63	125.22	126.56	129.53	124.39	1.245	0.125	0.708	0.007	0.143	0.351
Constant carcass wt, $/pig[6]												
Adj. carcass F/G[7]	3.63	3.55	3.56	3.55	3.51	3.65	0.035	0.784	0.543	0.022	0.011	0.496
Feed cost	47.40	46.37	46.47	46.26	45.95	48.18	0.437	0.899	0.235	0.020	0.002	0.347
Cost/lb gain carcass wt.	0.301	0.295	0.296	0.296	0.293	0.306	0.0028	0.724	0.304	0.029	0.005	0.375
Carcass gain value	173.21	173.21	173.21	173.21	173.21	173.21	0.000	---	---	---	---	---
IOFC[8]	125.81	126.83	126.74	126.95	127.26	125.03	0.438	0.901	0.239	0.020	0.002	0.346
Facility cost[9]	10.61	10.35	10.55	10.36	9.97	10.42	0.144	0.038	0.972	0.013	0.667	0.448
IOFFC[10]	115.19	116.49	116.19	116.59	117.31	114.62	0.540	0.623	0.334	0.010	0.006	0.328

[1]A total of 1,008 pigs (TR4 × (Fast × L02 PIC); initially 70.6 lb) were used with 21 pigs per pen and 8 pens per treatment. The trace mineral premix contributed 1 ppm of Zn to the complete diet. Carcass price was calculated at $0.82/lb.

[2]Zinc sulfate (Agrium Advance Technology, Loveland, CO).

[3]Intellibond-Z (Micronutrients, Indianapolis, IN).

[4]Corn, soybean-meal and DDGS were calculated at $0.05, 0.14 and 0.04/lb, respectively. Test ingredients used were Zn hydroxychloride and ZnSO$_4$ and calculated at $2.80 and $1.10/lb, respectively. Grind, mix and delivery was calculated at $12.00/ton.

[5]Carcass gain value was calculated using (total carcass gain × carcass price).

[6]Adjusted to constant final carcass weight of 210 lb.

[7]Adjusted using a factor of 0.005 for 1 lb change in carcass weight.

[8]Income over feed cost = carcass gain value – feed cost.

[9]Facility cost at $0.10/hd/day.

[10]Income over feed and facility cost = IOFC – facility cost.

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