Kansas Agricultural Experiment Station Research Reports

Volume 3
Issue 7 *Swine Day*

Article 29

2017

Effect of Zinc Oxide, Zinc Hydroxychloride, and Tri-basic Copper Chloride on Nursery Pig Performance

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Recommended Citation

Cemin, H. S.; Woodworth, J. C.; Tokach, M. D.; Dritz, S. S.; DeRouchey, J. M.; and Goodband, R. D. (2017) "Effect of Zinc Oxide, Zinc Hydroxychloride, and Tri-basic Copper Chloride on Nursery Pig Performance," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 7. https://doi.org/10.4148/2378-5977.7482

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Abstract

A total of 1,215 pigs (PIC 1050 × 280; initially 11.7 lb BW) were used in a 42-d growth trial to determine the effects of ZnO, Zn hydroxychloride (IntelliBond Z; IBZ), and tri-basic copper chloride (IntelliBond C; IBC) on growth performance of nursery pigs. Pigs were allotted by pen weight and assigned to 1 of 5 dietary treatments. Treatments consisted of added Zn as ZnO (3,000 ppm in phase 1 and 2,000 ppm in phase 2); Zn hydroxychloride (IBZ; 1,000 ppm in phase 1 and phase 2); and Cu as tri-basic copper chloride (200 ppm), alone or in combination, as follows: 1) Cu only; 2) ZnO only; 3) ZnO and Cu; 4) IBZ only; and 5) IBZ and Cu. Experimental diets were fed from d 0 to 21. From d 21 to 42, pigs were fed a common diet that contained 200 ppm Cu from tri-basic copper chloride but no additional Zn other than that provided by the trace mineral premix.

From d 0 to 21, there was a tendency ($P = 0.073$) for interaction between Zn source and Cu for ADG, where the addition of Cu to ZnO diets increased ADG; whereas, adding Cu to IBZ diets decreased ADG. Pigs fed added ZnO had greater ADFI ($P = 0.018$), ADG ($P = 0.033$), and BW on d 21 ($P = 0.042$) than those fed added IBZ.

From d 21 to 42, pigs previously fed diets with ZnO had greater ADFI ($P = 0.040$) and a tendency ($P = 0.071$) for poorer F/G than those previously fed Cu only. Overall, feeding diets with ZnO resulted in greater ADFI ($P = 0.026$) compared to feeding the diet with Cu only. There was a tendency ($P = 0.053$) for decreased removal rate when IBZ was added to the diet compared to only adding Cu. Overall, pigs fed diets with ZnO had greater ADFI ($P = 0.048$) and a tendency ($P = 0.074$) for increased ADG compared to pigs fed diets with added IBZ.

Feed cost marginally increased ($P = 0.064$) with the addition of ZnO compared to IBZ. Diets with ZnO resulted in greater feed cost ($P = 0.018$) and a tendency for higher revenue ($P = 0.062$) compared to the diet with Cu only. Similarly, diets with added IBZ resulted in tendencies for greater feed cost ($P = 0.070$), revenue ($P = 0.052$), and income over feed cost (IOFC) ($P = 0.071$) compared to the diet with Cu only.

The results suggest that there are no additive effects of Zn and Cu and no major differences in performance between pigs fed diets with added Zn or Cu. Pigs fed diets with higher levels of ZnO had improved performance compared to those fed added IBZ.

Keywords

Zn, Cu, nursery pig, growth performance

Cover Page Footnote

Appreciation is expressed to Micronutrients (Indianapolis, IN) for financial support and New Horizon Farms (Pipestone, MN) for providing research facilities.

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Effect of Zinc Oxide, Zinc Hydroxychloride, and Tri-basic Copper Chloride on Nursery Pig Performance[1]

H.S. Cemin, J.C. Woodworth, M.D. Tokach, S.S. Dritz,[2] J.M. DeRouchey, and R.D. Goodband

Summary

A total of 1,215 pigs (PIC 1050 × 280; initially 11.7 lb BW) were used in a 42-d growth trial to determine the effects of ZnO, Zn hydroxychloride (IntelliBond Z; IBZ), and tri-basic copper chloride (IntelliBond C; IBC) on growth performance of nursery pigs. Pigs were allotted by pen weight and assigned to 1 of 5 dietary treatments. Treatments consisted of added Zn as ZnO (3,000 ppm in phase 1 and 2,000 ppm in phase 2); Zn hydroxychloride (IBZ; 1,000 ppm in phase 1 and phase 2); and Cu as tri-basic copper chloride (200 ppm), alone or in combination, as follows: 1) Cu only; 2) ZnO only; 3) ZnO and Cu; 4) IBZ only; and 5) IBZ and Cu. Experimental diets were fed from d 0 to 21. From d 21 to 42, pigs were fed a common diet that contained 200 ppm Cu from tri-basic copper chloride but no additional Zn other than that provided by the trace mineral premix.

From d 0 to 21, there was a tendency ($P = 0.073$) for interaction between Zn source and Cu for ADG, where the addition of Cu to ZnO diets increased ADG; whereas, adding Cu to IBZ diets decreased ADG. Pigs fed added ZnO had greater ADFI ($P = 0.018$), ADG ($P = 0.033$), and BW on d 21 ($P = 0.042$) than those fed added IBZ.

From d 21 to 42, pigs previously fed diets with ZnO had greater ADFI ($P = 0.040$) and a tendency ($P = 0.071$) for poorer F/G than those previously fed Cu only. Overall, feeding diets with ZnO resulted in greater ADFI ($P = 0.026$) compared to feeding the diet with Cu only. There was a tendency ($P = 0.053$) for decreased removal rate when IBZ was added to the diet compared to only adding Cu. Overall, pigs fed diets with ZnO had greater ADFI ($P = 0.048$) and a tendency ($P = 0.074$) for increased ADG compared to pigs fed diets with added IBZ.

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[1] Appreciation is expressed to Micronutrients (Indianapolis, IN) for financial support and New Horizon Farms (Pipestone, MN) for providing research facilities.
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IBZ resulted in tendencies for greater feed cost ($P = 0.070$), revenue ($P = 0.052$), and income over feed cost (IOFC) ($P = 0.071$) compared to the diet with Cu only.

The results suggest that there are no additive effects of Zn and Cu and no major differences in performance between pigs fed diets with added Zn or Cu. Pigs fed diets with higher levels of ZnO had improved performance compared to those fed added IBZ.

Introduction

The positive effects of pharmacological concentrations of Zn and Cu on growth performance of nursery pigs are well described with the concentrations required to produce optimal responses have been reported as 3,000 ppm of Zn from ZnO[3] and 250 ppm of Cu from $CuSO_4$.[4] The additive effects of supplementation of Zn and Cu are controversial. Hill et al. (2000)[5] did not observe additive effects, while Pérez et al.[3] observed improved growth performance when both minerals were added to nursery pig diets. However, adding pharmacological concentrations of Zn and Cu have raised environmental concerns. The minerals are inert and non-degradable in the manure and in the environment, posing risks to long term soil quality by impairing essential ecosystems.[6] Therefore, different strategies and sources should be considered as alternatives to traditional supplementation of Zn and Cu.

Zinc hydroxychloride and tri-basic copper chloride (Micronutrients, Indianapolis, IN) are manufactured using a patented process reacting high purity forms of the desired trace metal with water and hydrochloric acid. This process forms hydroxychloride crystals that contain the trace metal covalently bonded to hydroxyl groups and to chloride.[7] The covalent bonds are expected to reduce reactiveness with other components of the diet and to improve bioavailability. There is not a lot of research that compares the effect of supplementing Zn as ZnO or Zn hydroxychloride and/or Cu as tri-basic copper chloride on growth performance of nursery pigs. Therefore, the objective of this study was to determine the impact of Zn as ZnO or Zn hydroxychloride and Cu as tri-basic copper chloride, added alone or in combination, on growth performance of nursery pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research

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[3] Shelton, N.W., M.D. Tokach, J.L. Nelssen, R.D. Goodband, S.S. Dritz, J.M. DeRouchey, and G.M. Hill. 2011. Effects of copper sulfate, tri-basic copper chloride, and zinc oxide on weanling pig performance. J. Anim. Sci. 89:2240-2451.

[4] Pérez, V.G., A.M. Waguespack, T.D. Bidner, L.L. Southern, T.M. Fakler, T.L. Ward, M. Steidinger, and J.E. Pettigrew. 2011. Additivity of effects from dietary copper and zinc on growth performance and fecal microbiota of pigs after weaning. J. Anim. Sci. 89:414-425.

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[6] Jensen, J., M.M. Larsen, and J. Bak. 2016. National monitoring study in Denmark finds increased and critical levels of copper and zinc in arable soils fertilized with pig slurry. Environ. Pollut. 214:334-340.

[7] Leisure, N.J., C.C. Jackson, M. Huang, T.B. Moore, and F.A. Steward. 2014. Micronutrient supplement. US Pat. No. 8,802,180 B2.

nursery barn in southwestern MN. The facility was totally enclosed, environmentally controlled, and mechanically ventilated. Each pen was equipped with a 6-hole dry self-feeder (SDI Industries, Alexandria, SD) and a pan waterer for ad libitum access to feed and water.

A total of 1,215 weanling pigs (PIC 1050 × 280; initial BW of 11.7 ± 0.18 lb) were used in a 42-d growth trial. There were 9 pens per treatment and 27 pigs per pen. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) capable of recording feed deliveries for individual pens.

Pens were blocked by weight and randomly assigned to dietary treatment within weight blocks. Five treatments were created consisting of supplementation of Zn as ZnO (3,000 ppm in phase 1 and 2,000 ppm in phase 2); Zn hydroxychloride (IntelliBond Z; IBZ; 1,000 ppm in phase 1 and phase 2), and Cu as tri-basic copper chloride (IntelliBond C; 200 ppm), alone or in combination, as follows: 1) Cu only; 2) ZnO only; 3) ZnO and Cu; 4) IBZ only; and 5) IBZ and Cu. Dietary treatments (Table 1) were offered during phases 1 (d 0 to 7) and 2 (d 7 to 21). From d 21 to 42, pigs were fed a common diet that contained 200 ppm Cu from tri-basic copper chloride but no additional Zn other than that provided by the trace mineral premix. All diets contained a trace mineral premix that contributed 111 ppm Zn from zinc sulfate and 17 ppm Cu from copper sulfate. Pen BW and feed disappearance were measured on d 0, 7, 15, 21, 28, 35, and 42 to calculate ADG, ADFI, and F/G.

Feed cost, revenue, and IOFC were calculated on a pen basis. Feed cost was calculated by multiplying pen feed intake by diet cost. The basal diet cost was \$639.20/ton for phase 1 and \$533.43/ton for phase 2. Treatments IBZ, IBC, and ZnO were valued at \$2.95/lb, \$3.68/lb, and \$1.10/lb, respectively. Phase 3 common diet was valued at \$389.87. Revenue was calculated by multiplying 42 d pen weight by an assumed live price of \$0.42/lb. To calculate IOFC, feed cost was subtracted from revenue. The IOFC per pig placed was calculated by dividing pen IOFC by number of pigs placed.

Data were analyzed using the GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. The statistical model included treatment as a fixed effect and block as a random effect. Results were considered significant at $P \leq 0.05$ and marginally significance at $0.05 < P \leq 0.10$.

Results and Discussion

Chemical analysis of complete diets are presented in Table 2. Crude protein, total Ca, and total P levels were similar among treatments. The total analyzed Zn levels of diets formulated to 3,000, 2,000, or 1,000 ppm Zn were in general agreement with calculated values. However, diets formulated without supplemental Zn had higher analyzed values than expected.

Interactive effects of Zn and Cu are shown in Table 3 and main effects of Zn and Cu are shown in Table 4. There was a marginally significant interaction ($P = 0.073$) for ADG from d 0 to 21. The addition of Cu to diets containing ZnO resulted in greater ADG; however, adding Cu to IBZ diets decreased ADG. From d 0 to 21, pigs fed added ZnO had increased ADFI ($P = 0.020$), ADG ($P = 0.023$), and d 21 BW ($P = 0.035$)

compared with those fed added IBZ. From d 21 to 42, pigs fed diets with ZnO had greater ADFI ($P = 0.040$) and marginally significant poorer ($P = 0.071$) F/G than those fed diets containing Cu only.

Overall, pigs fed diets with ZnO had greater ADFI ($P = 0.049$) and marginally better ADG ($P = 0.079$) compared to pigs fed diets with IBZ. Feeding diets with ZnO resulted in greater ADFI ($P = 0.026$) compared to diets with Cu only. There was no evidence for differences in growth performance between pigs fed diets with IBZ and Cu only ($P > 0.10$). There was a marginally ($P = 0.053$) significant decreased pig removal rate when IBZ was supplemented compared to Cu only.

There was no evidence for interactions between Zn and Cu on economic variables (Table 2). Pigs fed diets with ZnO had higher feed cost ($P = 0.018$) and had marginally significant higher revenue ($P = 0.062$) compared pigs fed diets with Cu only. Similarly, pigs fed diets supplemented with IBZ resulted in tendencies for greater feed cost (P = 0.070), revenue ($P = 0.052$), and IOFC ($P = 0.071$) compared to diets with Cu only. Pigs fed diets supplemented with ZnO had marginally significant higher feed cost compared to those fed IBZ ($P = 0.064$).

In summary, the addition of higher levels of ZnO resulted in improved performance compared to IBZ with little interactive effect observed between Zn and Cu. Overall, there was no evidence for differences in performance between pigs fed diets with Cu and pigs fed Zn from either ZnO or IBZ. In this trial, ZnO was supplemented at 3,000 ppm in phase 1 and 2,000 ppm in phase 2, whereas IBZ was supplemented at 1,000 ppm in phases 1 and 2. Therefore, the differences observed may be explained by Zn source but also by Zn level. The discrepancy between calculated and analyzed Zn values should also be acknowledged when interpreting the results of this study. Further research could evaluate the supplementation of IBZ at higher inclusion levels.

Table 1. Composition of base diets (as-fed basis)

Items	Phase 1[1]	Phase 2[1]	Common[1]
Ingredients, %			
Corn	39.50	48.28	56.98
Soybean meal (48% CP)	17.48	24.97	32.68
DDGS,[2] 6-9% oil	5.00	5.00	5.00
Fish meal	4.50	2.50	---
HP 300[3]	2.50	3.75	---
Spray-dried whey	25.00	10.00	---
Beef tallow	---	2.00	2.00
Choice white grease	3.00	---	---
Monocalcium phosphate	0.40	0.80	1.10
Limestone	0.50	---	---
Calcium carbonate	---	0.85	1.00
Salt	0.30	0.55	0.35
L-Lys HCl	0.48	0.39	0.33
DL-Met	---	0.17	0.14
Methionine hydroxy analog	0.26	---	---
L-Thr	0.20	0.15	---
L-Trp	0.05	0.02	---
L-Val	0.10	0.05	---
Choline chloride, 60%	0.04	---	---
Vitamin E, 20,000 IU	0.05	---	---
Trace mineral premix	0.13	0.15	0.15
Vitamin premix	0.05	0.10	0.10
Phytase[4]	0.04	0.02	0.02
Zinc oxide[5]	+/-	+/-	---
Zinc hydroxychloride[6]	+/-	+/-	---
Tri-basic copper chloride[7]	+/-	+/-	0.032

continued

Table 1, *continued*. Composition of base diets (as-fed basis)

Items	Phase 1[1]	Phase 2[1]	Common[1]
Calculated analysis			
SID amino acids, %			
Lys	1.40	1.37	1.25
Ile:Lys	55	60	63
Leu:Lys	111	122	132
Met:Lys	38	36	35
Met and Cys:Lys	57	57	58
Thr:Lys	63	63	64
Trp:Lys	19	19	19
Val:Lys	67	69	69
Lys:ME, g/Mcal	4.02	4.04	3.72
ME, kcal/lb	1,580	1,539	1,526
CP, %	20.9	22.7	22.1
Ca, %	0.71	0.74	0.70
Available P, %	0.59	0.51	0.44

[1] Phase 1 diets were fed from d 0 to 7, phase 2 diets were fed from d 7 to 21, and common diet was fed from d 21 to 42.

[2] DDGS = dried distillers grains with solubles.

[3] Hamlet Protein, Findlay, OH.

[4] Phase 1: Quantum Blue (AB Vista, Plantation, FL); phase 2 and common: Optiphos 2000 (Enzyvia, Sheridan, IN).

[5] Zinc oxide was added to the base diets to supply 3,000 ppm Zn in phase 1 and 2,000 ppm in phase 2 to form treatments.

[6] Intellibond Z (Micronutrients, Indianapolis, IN) was added to the base diets to supply 1,000 ppm Zn to form treatments.

[7] Intellibond C (Micronutrients, Indianapolis, IN) was added to the base diets to supply 200 ppm Cu to form treatments.

Table 2. Chemical analysis of phase 1, 2, and 3 diets (as-fed basis)[1]

	Phase 1				
Calculated Zn, ppm:	111	3,000	3,000	1,000	1,000
Calculated Cu, ppm:	200	17	200	17	200
DM, %	89.2	89.3	89.2	89.3	89.4
CP, %	20.3	19.7	19.8	20.5	20.4
Ca, %	0.88	0.82	0.90	0.91	0.90
P, %	0.70	0.62	0.70	0.72	0.71
Zn, ppm[3]	1,207	3,363	3,368	2,203	1,414
Cu, ppm[3]	251	53	234	115	229
	Phase 2				
DM, %	88.1	87.7	87.9	---[2]	88.3
CP, %	21.9	22.4	23.8	---	22.5
Ca, %	0.90	0.96	0.71	---	1.04
P, %	0.74	0.73	0.68	---	0.74
Zn, ppm[3]	682	1,425	1,532	---	1,139
Cu, ppm[3]	237	99	166	---	200
	Phase 3				
DM, %	86.2				
CP, %	21.6				
Ca, %	0.72				
P, %	0.60				
Zn, ppm[3]	197				
Cu, ppm[3]	228				

[1] For each treatment, samples were collected from multiple feeders, blended, subsampled, ground, and analyzed (Cumberland Valley Analytical Services, Hagerstown, MD and Midwest Laboratories Inc., Omaha, NE).

[2] Missing feed sample.

[3] Values represent means from 4 samples at Cumberland Valley Analytical Services, Hagerstown, MD, and 3 samples at Midwest Laboratories Inc., Omaha, NE.

Table 3. Interactive effects of Zn source and Cu level on growth performance of nursery pigs[1,2]

Zn source[3]:		ZnO		IBZ			Probability, $P <$				
Zn added:	0	3000	3000	1000	1000						
Cu added[4]:	200	0	200	0	200	SEM	Zn × Cu	Zn[5]	Cu[6]	ZnO vs. Cu[7]	IBZ vs. Cu[8]
BW, lb											
d 0	11.7	11.7	11.7	11.7	11.7	0.183	0.999	0.402	0.916	0.766	0.766
d 21	21.2	21.4	21.7	21.1	20.8	0.556	0.388	0.035	0.948	0.468	0.837
d 42	46.6	47.3	47.7	46.8	46.4	0.906	0.549	0.139	0.978	0.385	0.815
d 0 to 21											
ADG, lb	0.42	0.44	0.46	0.44	0.41	0.018	0.073	0.023	0.812	0.168	0.312
ADFI, lb	0.67	0.70	0.70	0.68	0.66	0.019	0.472	0.020	0.317	0.114	0.686
F/G	1.62	1.58	1.52	1.57	1.61	0.034	0.111	0.264	0.773	0.486	0.297
d 21 to 42											
ADG, lb	1.21	1.23	1.23	1.21	1.21	0.019	0.901	0.273	0.961	0.305	0.870
ADFI, lb	1.70	1.77	1.77	1.73	1.73	0.030	0.780	0.128	0.981	0.040	0.408
F/G	1.41	1.44	1.43	1.42	1.43	0.012	0.746	0.443	0.998	0.071	0.287
d 0 to 42											
ADG, lb	0.81	0.83	0.84	0.82	0.81	0.017	0.377	0.079	0.837	0.161	0.440
ADFI, lb	1.18	1.23	1.22	1.20	1.19	0.022	0.874	0.049	0.636	0.026	0.326
F/G	1.46	1.48	1.46	1.46	1.47	0.011	0.146	0.933	0.715	0.303	0.957
Removals, %	8.6 ± 1.8	5.3 ± 1.5	5.8 ± 1.5	4.1 ± 1.3	6.2 ± 1.6	-	0.549	0.728	0.386	0.166	0.053
Economics											
Pen feed cost, $	99.72	107.78	107.99	105.79	101.17	3.218	0.300	0.064	0.344	0.018	0.070
Revenue/pen,[9] $	481.93	506.94	509.74	508.01	493.36	11.042	0.346	0.408	0.521	0.062	0.052
IOFC,[10] $/pig placed	14.16	14.78	14.88	14.90	14.53	0.316	0.413	0.674	0.626	0.123	0.071

[1] A total of 1,215 pigs (PIC 1050 × 280; initial BW = 11.7 lb) were used in a nursery study with 27 pigs per pen and 9 replicates per treatment.

[2] Dietary treatments were fed from d 0 to 21 and a common diet supplemented with 200 ppm Cu (Intellibond C, Micronutrients, Indianapolis, IN) was fed from d 21 to 42.

[3] Zinc oxide or Intellibond Z (Micronutrients, Indianapolis, IN).

[4] Intellibond C (Micronutrients, Indianapolis, IN).

[5] Zn contrast compared 3,000 ppm ZnO vs. 1,000 ppm IBZ.

[6] Cu contrast compared Cu level (0 or 200 ppm) within Zn sources.

[7] ZnO vs. Cu contrast compared treatment with 3,000 ppm ZnO without added Cu vs. treatment with 200 ppm Cu without added Zn.

[8] IBZ vs. Cu contrast compared treatment with 1,000 ppm IBZ without added Cu vs. treatment with 200 ppm Cu without added Zn.

[9] Revenue per pen, $ = 42 d pen weight × $0.42.

[10] IOFC, $ per pig placed = IOFC, $/pen ÷ number of placed pigs (27 pigs per pen).

Table 4. Main effects of Zn and Cu on growth performance of nursery pigs[1,2]

	Zn[3]			Probability,	Cu, ppm[4]			Probability,
Item	ZnO	IBZ	SEM	*P* <	0	200	SEM	*P* <
BW, lb								
d 0	11.7	11.7	0.179	0.402	11.7	11.7	0.179	0.916
d 21	21.6	20.9	0.501	0.035	21.3	21.2	0.501	0.948
d 42	47.5	46.6	0.736	0.139	47.1	47.0	0.736	0.978
d 0 to 21								
ADG, lb	0.45	0.42	0.016	0.023	0.44	0.44	0.012	0.812
ADFI, lb	0.70	0.67	0.014	0.020	0.69	0.68	0.018	0.317
F/G	1.55	1.59	0.023	0.264	1.57	1.57	0.023	0.773
d 21 to 42								
ADG, lb	1.23	1.21	0.013	0.273	1.22	1.22	0.013	0.961
ADFI, lb	1.77	1.73	0.022	0.128	1.75	1.75	0.022	0.981
F/G	1.44	1.43	0.008	0.443	1.43	1.43	0.008	0.998
d 0 to 42								
ADG, lb	0.84	0.81	0.013	0.079	0.83	0.82	0.013	0.837
ADFI, lb	1.23	1.19	0.018	0.049	1.21	1.20	0.018	0.636
F/G	1.47	1.47	0.006	0.933	1.47	1.46	0.006	0.715
Removals, %	5.5	5.1	1.037	0.728	4.7	6.0	1.074	0.386
Economics								
Pen feed cost, $	107.88	103.48	3.036	0.064	106.78	104.58	3.035	0.344
Revenue/pen,[5] $	508.34	500.69	8.901	0.408	507.48	501.55	8.901	0.521
IOFC,[6] $/pig placed	14.83	14.71	0.232	0.674	14.84	14.70	0.232	0.626

[1] A total of 1,215 pigs (PIC 1050 × 280; initial BW = 11.7 lb) were used in a nursery study with 27 pigs per pen and 9 replicates per treatment.

[2] Dietary treatments were fed from d 0 to 21 and a common diet supplemented with 200 ppm Cu (Intellibond C, Micronutrients, Indianapolis, IN) was fed from d 21 to 42.

[3] Zinc oxide or Intellibond Z (Micronutrients, Indianapolis, IN).

[4] Intellibond C (Micronutrients, Indianapolis, IN).

[5] Revenue per pen, $ = 42 d pen weight × $0.42.

[6] IOFC, $ per pig placed = IOFC, $/pen ÷ number of placed pigs (27 pigs per pen).