Kansas Agricultural Experiment Station Research Reports

Volume 0
Issue 10 *Swine Day (1968-2014)*

Article 588

1994

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EFFECTS OF INTERACTION BETWEEN ZINC OXIDE AND COPPER SULFATE ON STARTER PIG PERFORMANCE[1]

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Summary

Two experiments were conducted to examine the effects of supplementing starter pig diets with zinc oxide and (or) copper sulfate on starter pig performance. In experiment 1, two hundred forty pigs were used in a 28-day growth assay. Four dietary treatments were used: 1) control (165 ppm zinc and 16.5 ppm copper), 2) 3,000 ppm zinc, 3) 250 ppm copper, and 4) 3,000 ppm zinc + 250 ppm copper. The pigs were blocked by weight and allotted to each of the four dietary treatments in a 2 × 2 factorial design with 9, 10, or 11 pigs per pen and 6 replicate pens per treatment. Diets were formulated in two phases: Phase I (d 0 to 14 postweaning) and Phase II (d 14 to 28 postweaning) with 1.6 and 1.25% lysine, respectively. Pigs were fed the same experimental mineral level during the entire 28-d growth assay. During Phase I, feeding 3,000 ppm zinc from zinc oxide, with or without 250 ppm copper, improved average daily gain (ADG) and feed efficiency (F/G) compared with pigs fed the control or added-copper diets. Surprisingly, no improvement occurred in ADG or F/G for pigs fed the diet with 250 ppm copper from copper sulfate as compared with pigs fed the control diet. In Phase II, a zinc × copper interaction occurred. Pigs fed the diet with only added zinc grew faster, ate more, and were more efficient than pigs fed the control diet. Pigs fed diets with added copper had intermediate ADG and average daily feed intake (ADFI). Pigs fed diets with added zinc and (or) copper had similar F/G. For the entire 28-day trial, pigs fed the diets with added zinc had improved ADG, ADFI, and F/G compared to pigs fed the control diet. In the second experiment, pigs were fed a common Phase I diet supplemented with zinc oxide (3000 ppm zinc). On d 14, pigs were switched to the diets containing experimental mineral levels. Phase II experimental diets were identical to those of the first experiment. Similar to Phase II in Exp. 1, a zinc × copper interaction occurred for ADG. Zinc oxide improved ADG when added to the control diet, but not when added to the copper diet. Feeding high levels of zinc oxide in the Phase I diets may have had a carryover effect in Phase II, because we found no improvement in pig performance when high levels of copper were added to the Phase II diet. The results from these experiments indicate that feeding 3,000 ppm of zinc from zinc oxide is a viable means of increasing starter pig performance, but optimum response occurs when the diet does not contain supplemental copper from copper sulfate.

(Key Words: Starter, Performance, Zinc Oxide, Copper Sulfate.)

Introduction

Recently, researchers at Kansas State University, University of Illinois, and other institutions have investigated the use of supplemental zinc in starter pig diets. The research at Kansas State University showed no advantage to feeding 3,000 ppm of zinc in combination with 250 ppm of copper. How-

[1]The authors wish to thank Steve Eichman; Ellen Johncock; and Eichman Brothers, St. George, KS, for use of facilities and animals in this experiment.

ever, research at the University of Illinois demonstrated a positive effect of feeding 3,000 ppm zinc from zinc oxide over a control diet that did not contain growth promoting levels of copper sulfate. Therefore, the objectives of these experiments were to evaluate the effects of supplementing starter pig diets with high levels of zinc and (or) copper on performance and to determine whether the presence of high levels of copper in the diet influenced the response to zinc oxide.

Procedures

Experiment 1: A 28-day growth assay used a total of 240 pigs (initially 9.8 lb and 15 d of age) to examine the effect of supplementing starter pig diets with zinc oxide and (or) copper sulfate. Each pen contained 9, 10, or 11 pigs with six replicate pens per treatment. The pigs were blocked by weight and assigned to one of four dietary treatments in a 2 × 2 factorial design. Pigs were fed the same experimental mineral treatments throughout the entire 28-day trial, and the treatments were as follows: 1) control (165 ppm zinc and 16.5 ppm copper), 2) 3,000 ppm zinc, 3) 250 ppm copper, and 4) 3,000 ppm zinc + 250 ppm copper. Diets were formulated to contain 1.6 and 1.25% dietary lysine and .44 and .35% dietary methionine from d 0 to 14 postweaning (Phase I) and d 14 to 28 postweaning (Phase II), respectively. Both the Phase I and II diets were corn-soybean meal-based. The Phase I diets were pelleted and contained 25% dried whey, 7.5% spray-dried porcine plasma, 1.75% spray-dried blood meal, and 5% soy oil (Table 1). The Phase II diets were fed in a meal form and contained 10% dried whey, 2.5% spray-dried blood meal, and 3% soy oil. Zinc oxide and (or) copper sulfate were added to achieve the appropriate levels of zinc and copper. The zinc oxide used contained 72% zinc; therefore, .393% (7.9 lb/ton) was added to the diets with 3000 ppm zinc, and .093% copper sulfate (1.86 lb/ton) was added to the diets containing 250 ppm copper. Feed samples were collected and analyzed for crude protein (CP), zinc, copper, iron, and manganese.

The pigs were housed in an environmentally controlled nursery in 5 ft × 5 ft pens with a self-feeder and two nipple waterers to allow ad libitum access to feed and water. The pigs were weighed and feed disappearance was measured weekly to calculate ADG, ADFI, and F/G.

Experiment 2: Two hundred sixty four pigs were used in another 28-d growth assay to evaluate the effects of supplementing Phase II starter pig diets with zinc oxide and (or) copper sulfate on pig performance after all pigs received a common Phase I diet containing 3000 ppm zinc from zinc oxide. This experiment used 10, 11, or 12 pigs per pen. Procedures for this experiment were the same as those used in Exp.1. Phase I and II diets were formulated to the same nutrient contents as those used in the first experiment; however, the duration of mineral supplementation was different. Pigs were fed a common Phase I diet that contained 3000 ppm zinc from zinc oxide. On d 14, pigs were allotted randomly to one of the four dietary treatments, which were the same Phase II diets used in Exp. 1.

Results and Discussion

Experiment 1: Mineral analysis confirmed that zinc and copper levels were similar to the values the diets were formulated to contain, except for the zinc content in the copper-supplemented diet (Table 2). The zinc level was considerably higher than the formulated amount, especially in the Phase II diet. The high zinc analysis may have been due to sampling error or possible carryover in diet manufacturing. The potential for carryover in diet manufacturing must be analyzed further.

In this trial, feeding 3,000 ppm zinc from zinc oxide, with or without copper, increased growth performance and feed utilization in the Phase I period (Table 3). Surprisingly, no improvement occurred in performance for pigs fed the diet supplemented with 250 ppm copper from copper sulfate. This is in direct contrast to data collected in previous research with starter pigs. This lack of response may have been due to an age-related response to

copper. Very young pigs were used in this trial (14 d) compared to 28-d-old pigs in most of the previous experiments that have demonstrated a response to copper sulfate.

In the Phase II portion of this trial, zinc × copper interactions were detected for ADG, and F/G ($P<.01$ and .05, respectively). A tendency for a zinc × copper interaction also was detected for ADFI ($P<.08$). Pigs fed the diet with only added zinc grew faster, ate more, and were more efficient than pigs fed the control diet. Unlike Phase I, the pigs fed the copper and zinc + copper diets performed more similarly, with intermediate values for ADG, ADFI, and F/G. The response to copper supplementation agrees with previous research and provides further support for an age-related response to copper, because the pigs were 28 d of age at the initiation of Phase II.

For the entire 28-day growth assay, zinc × copper interactions were found for ADG and F/G ($P<.01$ and .05, respectively). Adding high levels of zinc oxide to the diet improved performance when growth-promoting levels of copper sulfate were not included in the diet. Also, the pigs maintained on the zinc and zinc + copper diets had higher ADFI ($P<.01$) than the pigs fed the control diet. Even though the Phase I performance of the pigs fed the copper diet was similar to that of the pigs fed the control diet, their overall performance was higher than that of the pigs fed the control diet. The increased performance of the pigs fed the zinc and zinc + copper diets can be explained in part by the increased ADFI.

The performance of the pigs fed the zinc + copper diet explains previous research conducted with zinc oxide at Kansas State University. In that research, both experimental diets contained 250 ppm copper. The pigs fed the diet with supplemental zinc oxide performed the same as the pigs fed the control diet with 250 ppm copper. This is the same response found during Phase II of the current trial when zinc oxide was added to a diet already containing 250 ppm copper.

It is important to note the importance of using zinc oxide to provide the supplemental zinc. Research at the University of Illinois comparing zinc methionine, zinc lysine, zinc oxide, and zinc sulfate showed that zinc oxide is needed to illicit a zinc response. However, lower levels of zinc methionine, zinc lysine, and zinc sulfate were needed to achieve the same plasma levels of zinc. The high cost of the amino acid chelates and the lower performance of the pigs fed zinc sulfate make supplementation with these products less economical than using zinc oxide.

An economic analysis was conducted for the entire 28-d trial using diet costs of \$650.63 and \$244.11 per ton for control Phase I and II diets, respectively, with \$.574 and \$.536 per lb for zinc oxide and copper sulfate, respectively (Table 5). The analysis of Phase I revealed that feeding the zinc diet cost \$.36 per lb of gain, whereas feeding the copper diet cost \$.37 per lb of gain. During Phase II, feeding the zinc diet cost \$.19 per lb of gain, and feeding the copper diet cost \$.18 per lb of gain. When analyzing the entire 4-week trial, feeding both the zinc and copper diets cost \$.25 per lb of gain; however, the pigs fed the zinc diet were more than 2 lb heavier than the pigs fed the copper diet at the end of the 28-day trial.

In conclusion, feeding zinc oxide at 3,000 ppm improves growth performance in the weanling pig. Because the pigs fed the zinc diet grew faster through the entire trial and more efficiently in the Phase II portion, the additional \$ 3.27 per ton for the zinc oxide diet compared to a diet containing copper sulfate can be justified in both Phase I and II starter pig diets.

Experiment 2: During Phase I, when a common diet was fed, pigs had an ADG of .50 lb and a F/G of 1.29. When pigs were fed the experimental mineral levels in Phase II, a zinc × copper interaction ($P>.05$) was detected for ADG (Table 4). When the control diet was supplemented with zinc oxide, ADG numerically improved; however, when zinc was added with copper, ADG was depressed, showing the importance of using zinc oxide alone and not in combination with

copper. During the same period, pigs fed the diet supplemented with only zinc oxide ate more feed, but adding copper to either the control or zinc diets reduced ADFI ($P<.05$). Overall, the pigs fed the diets with added copper, with or without zinc, had lower growth rates ($P<.01$) and depressed feed intakes ($P<.05$).

The copper response in this experiment can be explained by the excellent performance of the pigs fed the control diet. The pigs fed the control diet in this experiment grew better than the pigs fed the control diet in Exp. 1. This improved performance indicates a possible carryover or storage effect from feeding high levels of zinc in Phase I diets. Although not shown, feeding zinc in Phase II in this experiment had an economic advantage.

In conclusion, both experiments indicate that supplementing starter pig diets with 3000 ppm zinc from zinc oxide does improve growth performance during the first 4 weeks postweaning. However, further research is needed to examine possible interaction with copper in later stages of growth and to determine the optimum level of zinc supplementation. The effect of diets containing high levels of zinc oxide on feeders and flooring is another area that needs examination. Overall, adding zinc to Phase I and II diets is recommended to improve growth performance.

Table 1. Composition of Diets[a]

Ingredient, %	Phase I	Phase II
Corn	36.96	57.16
Soybean meal (48% CP)	19.30	22.49
Dried whey	25.00	10.00
Spray-dried porcine plasma	7.50	--
Spray-dried blood meal	1.75	2.50
Soybean oil	5.00	3.00
Monocalcium phosphate	1.74	1.95
Limestone	.62	.82
Antibiotic[b]	1.00	1.00
Cornstarch[c]	.49	.49
DL-methionine	.13	.04
L-Lysine HCl	.10	.15
Vitamin premix	.25	.25
Trace mineral premix	.15	.15
Total	100.00	100.00

[a]Pigs were fed the Phase I and Phase II diets from d 0 to 14 and d 14 to 28, respectively.
[b]Provided 150 g/ton apramycin in Phase I diets and 50 g/ton carbadox in Phase II diets.
[c]Zinc oxide (.393%) and copper sulfate (.093%) replaced cornstarch to form the experimental diets.

Table 2. **Mineral and Crude Protein Analysis of Experimental Diets (Exp. 1)**

Item	Control diet	Zinc diet	Copper diet	Zinc + copper diet
Phase I				
CP, %	22.8	22.8	22.9	22.2
Zinc, ppm	245	3051	406	2951
Copper, ppm	26	24	235	240
Iron, ppm	617	576	529	590
Manganese, ppm	62	77	72	70
Phase II				
CP, %	19.24	19.91	19.72	20.02
Zinc, ppm	235	2824	1396	2569
Copper, ppm	24	20	167	177
Iron, ppm	459	640	580	536
Manganese, ppm	83	85	74	75

Table 3. **Influence of Zinc Oxide and Copper Sulfate on Starter Pig Performance (Exp. 1)[a]**

Item	Control	Zn	Cu	Zn + Cu	CV
d 0 to 14					
ADG, lb[b]	.53	.58	.52	.59	14.2
ADFI, lb	.62	.63	.58	.64	10.5
F/G	1.22	1.08	1.13	1.08	10.7
d 14 to 28					
ADG, lb[c]	.65	.92	.82	.83	12.2
ADFI, lb[d]	1.15	1.38	1.21	1.29	8.3
F/G[e]	1.85	1.52	1.47	1.56	14.8
d 0 to 28					
ADG, lb[c]	.59	.75	.67	.71	10.9
ADFI, lb[b]	.86	1.01	.89	.96	10.2
F/G[e]	1.54	1.35	1.34	1.36	6.9

[a]Two hundred forty weanling pigs were used (initially 9.8 lb and 15 d of age) with 9, 10, or 11 pigs/pen and 6 pens/treatment.
[b]Zinc effect ($P<.01$).
[cde]Zinc × copper interaction ($P<.01$, .08, and .05, respectively).

Table 4. Influence of Zinc Oxide and Copper Sulfate on Starter Pig Performance (Exp. 2)[a]

Item	Control	Zn	Cu	Zn + Cu	CV
d 14 to 28					
ADG, lb[b]	.81	.87	.77	.75	5.6
ADFI, lb[c]	1.39	1.47	1.33	1.33	7.2
F/G	1.74	1.71	1.73	1.82	7.2
d 0 to 28					
ADG, lb[d]	.66	.69	.63	.62	5.4
ADFI, lb[c]	1.01	1.06	.97	.98	5.6
F/G	1.56	1.55	1.55	1.61	6.9

[a]Two hundred sixty four weanling pigs were used (initially 9.2 lb and 12 d of age) with 10, 11, or 12 pigs/pen and 6 pens/treatment. A common Phase I (d 0 to 14) diet (3000 ppm zinc) was fed to all pigs. Experimental mineral levels were fed during Phase II (d 14 to 28).
[b]Zinc × copper interaction ($P<.05$).
[cd]Copper effect ($P<.05$, and .01, respectively).

Table 5. Influence of Zinc Oxide and Copper Sulfate on Feed Cost per Pig and Feed Cost per Pound of Gain (Exp. 1)

Item	Control	Zinc	Copper	Zinc + copper
d 0 to 14				
Total feed, lb/pig	8.69	8.78	8.12	8.90
Diet cost, $/cwt[a]	$ 32.53	$ 32.74	$ 32.58	$ 32.79
Feed cost, $/pig	$ 2.83	$ 2.87	$ 2.65	$ 2.92
Total gain, lb/pig	7.46	8.12	7.23	8.32
Feed cost, $/lb gain	$ .38	$ .35	$ .37	$ .35
d 14 to 28				
Total feed, lb/pig	16.06	19.38	16.94	18.10
Diet cost, $/cwt[a]	$ 12.21	$ 12.41	$12.25	$ 12.46
Feed cost, $/pig	$ 1.96	$ 2.41	$ 2.08	$2.26
Total gain, lb/pig	9.04	12.86	11.52	11.65
Feed cost, $/lb gain	$ .22	$ .19	$ .18	$ .26
d 0 to 28				
Total feed, lb/pig	24.20	28.16	25.02	27.00
Diet cost, $/cwt[a]				
Feed cost, $/pig	$ 4.79	$ 5.29	$ 4.73	$ 5.18
Total gain, lb/pig	16.49	20.98	18.76	19.97
Feed cost, $/lb gain	$ .29	$ .25	$ .25	$ .26

[a]Diet cost based on $2.30/bu corn, $200/ton SBM, $.574/lb zinc oxide, and $.536/lb copper.