

Effects of Dietary Zinc Oxide and Chlortetracycline on Nursery Pig Growth Performance¹

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Summary

A total of 240 weaned pigs (PIC 1050; initially 13.4 lb) were used in a 47-d study to compare the effects of added Zn from zinc oxide (ZnO), alone or in combination with a low or high dose of chlortetracycline (CTC), on nursery pig performance. Pigs were allotted to pens at weaning (d 0) and fed a common starter diet with no antimicrobial for 5 d before the start of the experiment. On d 5, pens of 5 pigs were allotted to 1 of 6 dietary treatments in a randomized complete block design with 8 replications per treatment. Dietary treatments were arranged in a 2 × 3 factorial with main effects of added ZnO (0 vs. 2,500 ppm of Zn) and CTC (0, 50, or 400 g/ton). Pigs were fed experimental diets from d 5 to 26 after weaning followed by a common corn-soybean meal-based diet without antimicrobial from d 26 to 47. Pigs on the 50 g/ton treatment received CTC continuously from d 5 to 26; however, to comply with FDA guidelines, CTC was removed on d 15 from the diets of pigs fed 400 g/ton CTC, then added again from d 16 to 26. All diets contained 110 ppm of Zn from ZnO in the trace mineral premix. No ZnO × CTC interactions were observed. Pigs fed added ZnO had increased ($P = 0.001$) ADG, ADFI, and ending BW during the treatment period but increased F/G ($P = 0.03$) from d 26 to 47 when a common diet was fed. Pigs fed CTC had increased (linear, $P < 0.05$) ADG, ADFI, and ending BW during the treatment period as well as a tendency (quadratic, $P = 0.08$) for improved F/G. Overall (d 5 to 47), pigs fed added ZnO had increased ($P < 0.05$) ADG and ADFI. Overall, pigs fed CTC tended to have increased (linear, $P = 0.06$) ADG and ADFI, but F/G tended (quadratic, $P = 0.07$) to decrease then increase as CTC increased. In summary, when ZnO or CTC were added to the diets, increased ADG and ADFI were observed, but additional carryover benefits were not evident after these feed additives were removed from the diets. The benefits of added Zn from ZnO and CTC are additive and could be included together in diets to get the maximum benefit in growth performance of weaned pigs.

Key words: growth, nursery pig, chlortetracycline, zinc

Introduction

It is well established that feeding pharmacological levels of Zn from zinc oxide (ZnO) consistently improves the growth rate of nursery pigs despite having mixed effects on feed intake and efficiency. Since feed-grade antibiotics became available in the 1950s,

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research has also demonstrated that chlortetracycline (CTC) improves both the growth rate and the feed efficiency of nursery pigs. Although no study has directly examined the effects of concurrent inclusion of both pharmacological Zn and CTC concentrations in nursery pig diets, previous research suggests that the growth benefits are additive. Therefore, the objective of this experiment was to compare the performance of nursery pigs fed diets containing pharmacological levels of Zn, alone or in combination with high or low doses of chlortetracycline.

Procedures

This trial was conducted in collaboration with Kansas State University College of Veterinary Medicine Department of Diagnostic Medicine/Pathology with the primary objective of evaluating the potential association of high levels of dietary Zn supplementation and dietary sub-therapeutic or therapeutic CTC on the prevalence of methicillin resistant *Staphylococcus aureus* (MRSA) in pigs. This report describes the growth performance of these same pigs; the influence on MRSA will be reported elsewhere.

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted at the K-State Segregated Early Weaning Facility in Manhattan, KS.

A total of 240 nursery pigs (PIC 1050; initially 13.4 lb BW) were used in a 47-d study with 5 pigs per pen and 8 replications per treatment. Each pen had metal tri-bar flooring, one 4-hole self-feeder, and a cup waterer to provide *ad libitum* access to feed and water. Pigs were weaned at approximately 21 d of age (study d 0) and allotted to pens based on initial BW to achieve equal average pen weights across all pens. For the first 5 d after weaning, pigs were fed a common pelleted starter diet that contained neither antimicrobial nor added Zn above that contained in the trace mineral premix (Table 1). On d 5, pens of pigs were weighed and allotted to 1 of 6 dietary treatments in a randomized complete block design with location within barn serving as a blocking factor as adjacent pens alternated among the treatment groups to facilitate equal bacteria exposure. The 6 dietary treatments consisted of a corn-soybean meal-based diet and were arranged in a 2 × 3 factorial with main effects of added Zn from ZnO (0 vs. 2,500 ppm of added Zn) and CTC (0, 50, or 400 g/ton). The ZnO and CTC were substituted for an equivalent amount of corn to form the experimental treatments.

The experimental diets were fed from d 5 to 26. Food and Drug Administration regulations prohibit the continuous feeding of therapeutic levels of CTC longer than 14 d.³ Thus, on study d 15, the feeders from pens assigned to the 400 g/ton CTC diets were emptied and pigs were fed the control diet with or without the 2,500 ppm of added Zn. The normal treatment diet containing CTC at 400 g/ton was then re-added to the feeders on d 16 and fed for the remainder of the 21-d period. From d 26 to 47, a common corn-soybean meal-based diet with no added ZnO and no CTC was fed to all pigs to evaluate any carryover effects from the treatment diets.

All diets were prepared at the K-State O.H. Kruse Feed Technology Innovation Center and contained 110 ppm of Zn from the trace mineral premix. Diet samples

³ Code of Federal Regulations. Title 21; Volume 6; Sec. 558.128. Accessed at: <http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=558.128> on August 14, 2014.

were collected periodically throughout the study, and pooled samples of each diet were submitted to Ward Laboratories, Inc. (Kearney, NE) for near-infrared reflectance (NIR) spectrometry analysis of Cu and Zn (Table 2). As determined by analysis, the Phase 1 common diet contained 166 ppm Zn and 29 ppm Cu, whereas the Phase 3 common diet contained 160 ppm Zn and 21 ppm Cu. Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 5, 26, and 47.

Growth data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS (v9.3, SAS Institute Inc., Cary, NC) with pen as the experimental unit and barn location as a blocking factor. The main effects of ZnO and CTC, as well as their interactions, were tested. Within the CTC treatments, linear and quadratic contrasts were determined. Differences between treatments were determined by using least squares means with results considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

Results and Discussion

No ZnO \times CTC interactions were observed for any response criteria in any period (Table 3). Growth rates of pigs did not differ during the first 5 d when the common starter diet was fed. During the d 5 to 26 treatment period, pigs fed added Zn had increased ($P \leq 0.001$) ADG, ADFI, and BW on d 26. Similarly, increasing CTC increased ($P < 0.02$) ADG, ADFI, and BW on d 26. Although ZnO had no effect on F/G during the period when treatments were fed from d 5 to 26, increasing CTC level had a tendency to improve (quadratic, $P = 0.08$) F/G and caloric efficiency with pigs fed CTC at 50 g/ton having the lowest F/G.

From d 26 to 47 when the common diet was fed, there were no effects on growth rate or feed intake of pigs that had previously been fed ZnO or CTC in their diets; however, pigs previously fed pharmacological Zn had a significant ($P = 0.04$) but small increase in F/G. Overall, across both the 21-d treatment period and the subsequent 21-d common period (d 5 to 47), added Zn from ZnO increased ($P < 0.05$) ADG and ADFI but had no effect on feed efficiency. Added CTC tended to increase (linear, $P = 0.06$) ADG and ADFI from d 5 to 47. Feed efficiency and caloric efficiency of pigs fed CTC tended to improve (quadratic, $P = 0.08$) as 50 g of CTC was added to the diet, with no further improvement at the 400 g/ton level.

In summary, added Zn from ZnO and CTC increased ADG and ADFI but had a minimal effect on feed efficiency. This study illustrates the value of feeding pharmacological concentrations of Zn and other antimicrobials to newly weaned pigs to promote growth. However, neither ZnO nor CTC had a beneficial effect on subsequent nursery pig performance after ZnO and CTC were removed from the diets. Furthermore, our results agree with previous research findings with the data collectively suggesting that the benefits of feeding CTC and heavy metal micronutrients such as added Zn are additive for nursery pigs.

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Table 1. Diet composition (as-fed basis)¹

	Phase 1	Phase 2	Phase 3
Ingredient, %			
Corn	37.54	54.65	63.71
Soybean meal (47.7% CP)	19.86	29.50	32.86
Spray-dried blood cells	1.25	1.25	---
Spray-dried animal plasma	4.00	---	---
Corn DDGS ² , 6–9% oil	5.00	---	---
Select menhaden fish meal	1.25	1.25	---
Spray-dried whey	25.00	10.00	---
Choice white grease	3.00	---	---
Monocalcium phosphate	0.90	0.80	1.00
Limestone	1.00	1.10	1.03
Salt	0.30	0.30	0.35
L-lysine HCL	0.225	0.300	0.300
DL-methionine	0.150	0.175	0.115
L-threonine	0.085	0.150	0.115
Trace mineral premix	0.150	0.150	0.150
Vitamin premix	0.250	0.250	0.250
Choline chloride, 60%	0.035	---	---
Phytase ³	---	0.125	0.125
Zinc oxide and CTC-50 additives ⁴	---	0 to 0.747	---
Total	100.00	100.00	100.00

continued

Table 1. Diet composition (as-fed basis)¹

	Phase 1	Phase 2	Phase 3
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lysine	1.40	1.35	1.22
Isoleucine:lysine	56	58	63
Leucine:lysine	128	125	129
Methionine:lysine	32	35	33
Met & Cys:lysine	57	58	57
Threonine:lysine	63	64	63
Tryptophan:lysine	19	18	19
Valine:lysine	71	69	69
Total lysine, %	1.57	1.50	1.37
CP, %	22.2	22.1	21.4
ME, kcal/lb	1,574	1,491	1,483
NE, kcal/lb ⁵	1,179	1,100	1,092
SID lysine:ME, g/Mcal	4.0	4.1	3.7
Ca, %	0.85	0.80	0.70
P, %	0.73	0.63	0.61
Available P, %	0.51	0.47	0.41

¹ Common Phase 1 diet was fed from d 0 to 5 after weaning, experimental Phase 2 diets were fed from d 5 to 26, and the common Phase 3 diet was fed from d 26 to 47. All diets contained 110 ppm of Zn from the trace mineral premix.

² Dried distillers grains with solubles.

³ Phytase 600 (Phyzyme; Danisco Animal Nutrition, St Louis, MO), providing 340.5 phytase units (FTU)/lb and an estimated release of 0.12% available P.

⁴ Experimental diets contained added ZnO at 0 or 0.347% to provide 0 or 2,500 ppm added Zn, respectively, and CTC-50 at 0, 0.050, or 0.400% to provide 0, 50, or 400 g/ton CTC, respectively. Addition of ZnO and CTC-50 ingredients replaced equivalent amounts of corn in the Phase 2 experimental diets.

⁵ NE values for ingredients were derived from NRC (2012).

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Table 2. Analyzed dietary mineral concentrations (as-fed basis)^{1,2}

	Phase 2 treatment diets					
Zinc oxide, ppm:	0	0	0	2,500	2,500	2,500
Chlortetracycline, g/ton:	0	50	400	0	50	400
Analyzed composition						
Zinc, ppm	148	317	186	2,918	2,946	2,823
Copper, ppm	53	24	22	23	20	27

¹ Analysis was performed by Ward Laboratories, Inc. (Kearney, NE) on pooled diet samples.

² Experimental Phase 2 diets were fed from d 5 to 26, whereas a Phase 1 common diet (166 ppm Zn and 29 ppm Cu as per analysis) was fed to all pigs from d 0 to 5 and a Phase 3 common diet (160 ppm Zn and 21 ppm Cu as per analysis) was fed to all pigs from d 26 to 47.

Table 3. Effects of zinc oxide and chlortetracycline on nursery pig growth performance^{1,2}

	ZnO, ppm:		0				2500			SEM	Probability, <i>P</i> <				
	CTC, g/ton:	0	50	400	0	50	400	ZnO x CTC			ZnO	CTC			
								Linear	Quadratic			Linear	Quadratic		
BW, lb															
d 5	14.2	14.2	14.2	14.2	14.2	14.2	14.2	0.17	0.923	0.974	0.981	0.751	0.912		
d 15	19.9	20.5	20.3	21.0	21.2	21.0	21.0	0.26	0.652	0.303	0.0001	0.857	0.119		
d 26	30.7	31.9	32.1	32.6	32.6	33.6	33.6	0.45	0.986	0.175	0.0002	0.011	0.251		
d 47	63.7	65.7	65.3	65.4	65.8	66.2	66.2	0.94	0.952	0.409	0.240	0.387	0.239		
d 5 to 26															
ADG, lb	0.78	0.83	0.85	0.88	0.88	0.92	0.92	0.018	0.894	0.121	<.0001	0.002	0.208		
ADFI, lb	1.11	1.13	1.16	1.21	1.20	1.26	1.26	0.026	0.826	0.399	<.0001	0.017	0.914		
F/G	1.43	1.36	1.37	1.38	1.37	1.37	1.37	0.024	0.612	0.317	0.515	0.321	0.084		
d 26 to 47															
ADG, lb	1.57	1.61	1.58	1.56	1.58	1.62	1.62	0.033	0.262	0.648	0.978	0.449	0.405		
ADFI, lb	2.53	2.56	2.58	2.57	2.59	2.67	2.67	0.054	0.500	0.845	0.273	0.155	0.757		
F/G	1.61	1.59	1.64	1.65	1.64	1.65	1.65	0.020	0.404	0.682	0.039	0.154	0.322		
d 5 to 47															
ADG, lb	1.18	1.22	1.22	1.22	1.23	1.27	1.27	0.020	0.416	0.322	0.045	0.062	0.244		
ADFI, lb	1.82	1.85	1.87	1.89	1.89	1.96	1.96	0.035	0.555	0.665	0.022	0.058	0.830		
F/G	1.55	1.51	1.54	1.55	1.54	1.55	1.55	0.015	0.736	0.360	0.29	0.639	0.083		
Caloric efficiency ³															
d 5 to 26															
ME	2,125	2,026	2,033	2,057	2,028	2,023	2,023	35.5	0.611	0.315	0.359	0.207	0.083		
NE	1,568	1,495	1,500	1,517	1,496	1,492	1,492	26.2	0.613	0.315	0.350	0.200	0.083		
d 5 to 47															
ME	2,298	2,244	2,288	2,300	2,283	2,293	2,293	22.9	0.732	0.360	0.364	0.754	0.083		
NE	1,693	1,653	1,685	1,695	1,682	1,689	1,689	16.9	0.730	0.361	0.368	0.762	0.083		

¹ A total of 240 nursery pigs (PIC 1050, initially 21 d of age and 13.4 lb BW) were used in a 47-d study with 5 pigs per pen and 8 pens per treatment.

² Experimental treatment diets were fed from d 5 to d 26, and a common diet was fed to all pigs from d 26 to 47.

³ Caloric efficiency is expressed as kcal per pound of live weight gain.