Journal of Animal and Veterinary Advances 4 (7): 688-693, 2005

Interactive Effects of Diet Complexity, Zinc Source and Feed-grade Antibiotics on Weanling Pig Growth Performance

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Abstract: Two trials were conducted to determine the effects of diet complexity, feed-grade antibiotic and zinc (Zn) source on weanling pig growth performance. In Exp. 1, 320 pigs (initially 4.42 ± 0.09 kg and 14 d of age) were allotted in a 2×2×2 factorial with main effects of diet complexity (simple or complex); added zinc oxide (ZnO; none or 3,000 ppm Zn from d 0 to 10 then 2,000 ppm from d 10 to 20); and feed-grade antibiotic (none or 55 mg neoterramycin/kg of diet). Experimental diets were fed from d 0 to 20 after weaning and then a common diet that contained no ZnO (other than provided in the trace mineral premix) or antibiotic was fed to all pigs from d 20 to 27. From d 0 to 10, a three-way interaction was observed ($p<0.02$) for ADG, which appeared to be a result of an additive response to both ZnO and the antibiotic in simple diets, whereas in complex diets, either ZnO or antibiotic was equally effective in improving ADG. Pigs fed complex diets had improved ($p<0.05$) ADFI throughout the trial and ADG was increased ($p<0.05$) in all phases except d 20 to 27. Pigs fed diets containing ZnO had greater ($p<0.05$) ADG from d 5 to 10, 0 to 20 and 0 to 27 and greater ($p<0.05$) ADFI from d 5 to 10, 0 to 10 and 0 to 20 compared to pigs fed no added Zn. The feed-grade antibiotic increased ($p<0.05$) ADG from d 10 to 20, 0 to 20 and 0 to 27. In Exp. 2, 288 pigs (initially 5.59 ± 0.12 kg and 18 d of age) were allotted in a 2×3 factorial with main effects of antibiotic (none or 55 mg carbadox/kg of diet) and Zn source (none, 250 ppm Zn from a Zn amino acid complex (ZnAA), or 3,000 ppm Zn from ZnO). From d 0 to 14, pigs fed diets containing ZnO had greater ($p<0.01$) ADG than pigs fed no added Zn and those fed ZnAA were intermediate. From d 14 to 27, added Zn did not affect ADG, but ADFI tended to increase ($p<0.07$) with added ZnO. Feed-grade antibiotic had no effect from d 0 to 14 but tended to increase ($p<0.08$) ADG and ADFI from d 14 to 27. These data suggest that diet complexity, added Zn and feed-grade antibiotic influence growth performance of weanling pigs. The diet complexity and Zn responses were observed primarily during the first 10 to 14 d of the studies and the antibiotic response was predominantly observed from d 10 or 14 to the end of the experiments. From d 0 to 14, pigs fed ZnO had greater ($p=0.05$) ADG than ZnAA, but both Zn sources increased ($p<0.01$ and 0.07, respectively) ADG compared with pigs fed no added Zn.

Key words: Antibiotic, Early-Weaned Pigs, Growth, Zinc

INTRODUCTION

Proper diet formulation is critical to stimulate feed intake, meet nutritional requirements and support optimal growth of early-weaned pigs. Complex diets containing high levels of milk products and specialty protein sources such as fish meal, blood meal and spray-dried animal plasma have been used to successfully stimulate feed intake and promote growth[1,2]. Other feed additives, such as high levels of ZnO[3,4] and feed-grade antibiotic[5,6], also have been shown to improve growth performance of weanling pigs. However, questions remain as to whether these additives will influence growth performance similarly in both simple and complex diets.

The response observed from adding high levels of ZnO to weanling pig diets has not consistently been repeated with other Zn sources[3]. Ward *et al.*[7] showed that when diets contained feed-grade antibiotic and 250 ppm Zn from $ZnSO_4$, pigs fed 250 ppm Zn from zinc methionine had similar growth performance compared to pigs fed 2,000 ppm Zn from ZnO. However, Woodworth *et al.*[8] fed pigs diets that contained 165 ppm Zn from ZnO and no antibiotic and showed that 3,000 ppm Zn from ZnO resulted in greater growth performance than lower levels (100 to 500 ppm) of Zn from ZnAA. Consequently, the question arose whether the response observed from adding different Zn sources was dependent on the presence or absence of feed-grade antibiotic. Therefore, our objective was to determine the interactive effects on weanling pig growth performance of diet complexity, added Zn and (or) feed-grade antibiotic on growth performance of weanling pigs.

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Table 1: Composition of basal diets (as-fed basis), Exp. 1

	Day 0 to 5		Day 5 to 10		Day 10 to 20		Day 20 to 27
Ingredient, (%)	Simple	Complex	Simple	Complex	Simple	Complex	Common diet
Corn	44.70	38.41	50.07	45.53	54.58	51.76	53.32
Dried whey	-	25.00	-	20.00	-	10.00	-
Soybean meal, CP 46.5(%)	48.84	12.21	43.41	21.31	38.05	28.52	37.15
Spray-dried animal plasma	-	6.75	-	2.5	-	-	-
Select menhaden fish meal	-	6.00	-	2.50	-	-	-
Lactose	-	5.0	-	-	-	-	-
Soybean oil	2.00	2.00	2.00	2.00	3.00	3.00	6.00
Spray-dried blood meal	-	1.75	-	2.50	-	2.50	-
Monocalcium phosphate	1.70	0.70	1.80	1.27	1.90	1.84	1.73
Limestone	0.99	0.33	0.98	0.59	0.83	0.70	0.86
Cornstarch[a]	0.88	0.88	0.88	0.88	0.75	0.75	-
Vitamin premix[b]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.30	0.30	0.35
Trace mineral premix[c]	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-Methionine	0.09	0.17	0.06	0.12	0.04	0.08	0.04
L-Lysine HCl	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Calculated values, (%)							
Lysine	1.70		1.55		1.40		1.35
Methionine	0.48		0.44		0.38		0.38
Ca	0.90		0.90		0.90		0.90
P	0.80		0.80		0.80		0.80
Chemical analysis							
CP, (%)	22.51		21.99		21.54		20.73
Zn, ppm	183		171		209		195

[a]Zinc oxide (3,000 ppm Zn from d 0 to 10 or 2,000 ppm Zn from d 10 to 20) and (or) antibiotic (55 mg/kg of neoterramycin) replaced cornstarch to provide the experimental treatments, [b]Provided per kilogram of complete feed: 11,023 IU Vitamin A; 1,653 IU Vitamin D_3; 44 IU Vitamin E; 4.4 mg Vitamin K (menadione sodium bisulfite); 0.04 mg Vitamin B_{12}; 9.9 mg Riboflavin; 33.1 mg Pantothenic acid (as D-calcium pantothenate); and 55.1 mg Niacin, [c]Provided per kilogram of complete feed: 165.3 mg Zn (Oxide); 39.7 mg Mn (Oxide); 165.3 mg Fe (Sulfate); 16.5 mg Cu (Sulfate); 0.30 mg I (Calcium iodate); and 0.30 mg Se (Sodium selenite)

MATERIALS AND METHODS

Animals and facilities: Experiment 1 was conducted at the Kansas State University Segregated Early-Weaning Facility and Exp. 2 was conducted on a commercial farm in northeast Kansas. Experimental protocols were approved by the Kansas State University Institutional Animal Care and Use Committee. Pigs (Newsham Hybrids barrows, Exp. 1 and PIC C-22 pigs, Exp. 2) were blocked by initial weight and allotted randomly to pens, then each pen was randomly assigned to a dietary treatment. Pigs were housed in environmentally controlled nurseries in 1.2 × 1.2 m (Exp. 1) or 1.5 × 1.5 m (Exp. 2) pens and had *ad libitum* access to feed and water. Initial temperature of the nurseries was 33° C and was lowered approximately 1.5° C each week thereafter. Pigs and feeders were weighed on d 0, 5, 10, 20 and 27 (Exp. 1) or d 0, 7, 14, 21 and 27 (Exp. 2) to calculate ADG, ADFI and G:F.

Experiment 1. A total of 320 weanling barrows (initially 4.42 ± 0.09 kg and 14 d of age) were used in a 27-d growth assay. Eight experimental treatments were fed from d 0 to 20 after weaning and were arranged in a 2 × 2 × 2 factorial with main effects of diet complexity (simple or complex); added ZnO (none or 3,000 ppm Zn from d 0 to 10 then 2,000 ppm from d 10 to 20); and feed-grade antibiotic (none or 55 mg neoterramycin/kg diet). All diets contained 165 ppm Zn from ZnO provided by the trace mineral premix. All other mineral concentrations met or exceeded NRC[9] requirement estimates. Pens of pigs were allotted randomly to one of the eight dietary treatments with five pigs per pen and eight replications (pens) per treatment.

All experimental diets (Table 1) were fed in meal form in three phases (d 0 to 5, 5 to 10 and 10 to 20) with decreasing nutrient concentrations in each phase. Cornstarch in the basal diet was replaced on an equal weight basis with ZnO and (or) antibiotic to form the experimental treatments. A common diet was fed from d 20 to 27 that did not contain any additional Zn other than that which was supplied by the trace mineral premix or feed-grade antibiotic. Control diets were sampled and analyzed to determine CP by AOAC[10] methods and basal Zn concentration by nitric acid digestion followed by inductively coupled plasma emission spectroscopy (model J-Y 24, Jobin Yvon, Edison, NJ). The ZnO source used in this experiment was analyzed and contained 72% Zn.

Experiment 2. A total of 288 weanling pigs (initially 5.59 ± 0.12 kg and 18 d of age) were used in a 27-d growth assay. Pigs were allotted randomly to pens with

Table 2: Diet composition (as-fed basis), Exp. 2

Ingredient, (%)	Day 0 to 7	Day 7 to 14	Day 14 to 27
Corn	37.81	44.78	51.07
Dried whey	25.00	20.00	10.00
Soybean meal (46.5% CP)	12.18	21.30	28.50
Spray-dried animal plasma	6.75	2.50	-
Select menhaden fish meal	6.00	2.50	-
Lactose	5.00	-	-
Soy oil	2.00	2.00	3.00
Spray-dried blood meal	1.75	2.50	2.50
Monocalcium phosphate	0.69	1.26	1.59
Limestone	0.50	0.76	0.99
Cornstarch[a]	1.40	1.40	1.40
Salt	0.25	0.30	0.30
Vitamin premix[b]	0.25	0.25	0.25
L-Lysine HCl	0.15	0.15	0.15
Trace mineral premix[c]	0.15	0.15	0.15
DL-Methionine	0.12	0.15	0.10
Calculated analysis, (%)			
Lysine	1.70	1.55	1.40
Methionine	0.48	0.44	0.39
Ca	0.90	0.90	0.85
P	0.80	0.80	0.75
Chemical analysis			
CP, %	22.07	21.75	21.49
Zn, ppm	155.00	210.00	171.00

[a]Antibiotic, ZnAA and ZnO replaced cornstarch to provide the experimental treatments, [b]Provided per kilogram of complete feed: 11,023 IU Vitamin A; 1,653 IU Vitamin D_3; 44 IU Vitamin E; 4.4 mg Vitamin K (menadione sodium bisulfite); 0.04 mg Vitamin B_{12}; 9.9 mg Riboflavin; 33.1 mg Pantothenic acid (as D-calcium pantothenate); and 55.1 mg Niacin, [c]Provided per kilogram of complete feed: 165.3 mg Zn (Oxide); 39.7 mg Mn (Oxide); 165.3 mg Fe (Sulfate); 16.5 mg Cu (Sulfate); 0.30 mg I (Calcium iodate); and 0.30 mg Se (Sodium selenite)

eight pigs per pen and six replications (pens) per treatment. There were an equal number of barrows and gilts in each pen.

The six experimental diets were arranged in a 2×3 factorial with main effects of feed-grade antibiotic (none or 55 mg carbadox/kg diet) and Zn source (none, 250 ppm Zn from ZnAA, or 3,000 ppm Zn from ZnO). Zinc source and (or) antibiotic replaced cornstarch in the basal diets to form the treatments, which were fed throughout the entire experiment. All diets contained 165 ppm Zn from ZnO provided by the trace mineral premix. All other mineral concentrations met or exceeded NRC[9] requirement estimates. All diets (Table 2) were fed in meal form and formulated similar to those used in commercial production. Control diets were sampled and analyzed for CP and Zn concentration using the same procedures described for Exp. 1. The ZnO and ZnAA sources were analyzed and contained 72 and 10% Zn, respectively.

STATISTICAL ANALYSIS

Data for both experiments were analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked on the basis of initial weight and analysis of variance was performed using the GLM procedure of SAS[11]. Experiment 1 was analyzed as a 2 × 2 × 2 factorial with main effects of diet complexity, added ZnO and added feed-grade antibiotic. Experiment 2 was analyzed as a 2 × 3 factorial with main effects of added feed-grade antibiotic and Zn source. The experimental model for both trials included the main effects and all possible interactions of the main effects. Orthogonal contrasts were used in Exp. 2 to compare means of pigs fed either no added Zn, ZnO, or ZnAA.

RESULTS

Experiment 1. From d 0 to 5, ADG and ADFI were improved ($p<0.05$; Table 3) by diet complexity. A diet complexity × Zn × antibiotic interaction was observed for G:F ($p<0.02$). The interaction was to the result of very poor and variable G:F of pigs fed the simple diets compared with those fed the complex diets. From d 5 to 10, both diet complexity and ZnO increased ($p<0.05$) ADG and ADFI.

From d 0 to 10, a diet complexity × Zn × antibiotic interaction was observed for ADG ($p<0.02$) (Table 3). Both Zn and antibiotic were needed to stimulate growth of pigs fed simple diets, whereas for pigs fed complex diets, either ZnO or antibiotic was equally effective in improving ADG. No other interactions were observed throughout the study. From d 0 to 10, pigs fed complex diets or ZnO had increased ($p<0.05$) ADFI and G/F.

From d 10 to 20, pigs fed complex diets had greater ($p<0.05$) ADG and ADFI than pigs fed simple diets. Pigs fed diets containing antibiotic had greater ($p<0.05$) ADG and G/F than pigs fed diets not containing antibiotic.

From d 0 to 20, pigs fed complex diets had greater ($p<0.05$) ADG, ADFI and G/F compared to pigs fed simple diets. Pigs fed diets containing antibiotic again had improved ($p<0.05$) ADG and G/F compared to pigs fed diets containing no antibiotic. Diets containing ZnO increased ($p<0.05$) ADG and ADFI of pigs compared to diets containing no ZnO.

From d 20 to 27, ADFI was increased ($p<0.05$) but G/F was poorer ($p<0.05$) for pigs previously fed complex diets or diets containing antibiotic.

For the entire period, d 0 to 27, pigs fed complex diets or diets containing antibiotic or ZnO had increased ($p<0.05$) ADG compared to pigs fed simple diets or diets not containing antibiotic or ZnO, respectively. Average daily feed intake was improved ($p<0.05$) for pigs fed complex diets compared to simple diets.

Table 3: Effects of diet complexity, zinc oxide and feed-grade antibiotic on weanling pig performance, Exp. 1[a]

	Simple				Complex				
	-ZnO[b]		+ZnO		-ZnO		+ZnO		
Item	-Med[c]	+Med	-Med	+Med	-Med	+Med	-Med	+Med	SE
Day 0 to 5									
ADG (g[d])	14	-39	22	39	96	107	105	100	17
ADFI (g[d])	64	55	68	81	112	104	110	102	7
G/F[ef]	-0.09	-1.4	0.25	0.34	0.79	0.99	0.94	0.93	0.34
Day 5 to 10									
ADG (g[de])	106	115	137	173	142	199	244	233	19
ADFI (g[de])	178	186	228	243	257	266	320	317	13
G/F	0.56	0.53	0.60	0.70	0.55	0.75	0.77	0.70	0.11
Day 0 to 10									
ADG (g[def])	60	37	79	106	119	153	175	161	14
ADFI (g[de])	121	120	148	162	185	185	215	210	9
G/F[de]	0.42	0.19	0.53	0.62	0.63	0.82	0.82	0.76	0.12
Day 10 to 20									
ADG (g[dg])	310	360	336	387	361	415	368	405	16
ADFI (g[d])	462	458	468	437	446	516	494	515	26
G/F[g]	0.71	0.81	0.73	0.91	0.83	0.83	0.77	0.82	0.05
Day 0 to 20									
ADG (g[deg])	184	199	208	246	240	284	271	283	12
ADFI (g[de])	289	289	308	300	315	351	355	362	14
G/F[dg]	0.66	0.70	0.68	0.83	0.76	0.82	0.78	0.80	0.04
Day 20 to 27									
ADG (g)	458	483	459	483	449	461	484	426	18
ADFI (g[dg])	703	765	753	496	759	893	831	841	31
G/F[dg]	0.67	0.64	0.61	0.61	0.60	0.53	0.59	0.51	0.03
Day 0 to 27									
ADG (g[deg])	254	272	273	308	294	330	326	320	11
ADFI (g[d])	395	412	423	428	431	491	478	486	16
G/F	0.66	0.67	0.65	0.72	0.69	0.68	0.69	0.67	0.03

[a]Means represent a total of 320 pigs (initially 4.42 ± 0.09 kg and 14 d of age) with five pigs per pen and eight pens per treatment. All diets contained 165 ppm Zn from ZnO provided by the trace mineral premix, [b]-ZnO was no added Zn and +ZnO was 3,000 ppm Zn from d 0 to 10 and 2,000 ppm Zn from d 10 to 20, [c]-Med was no feed-grade antibiotic and +Med was 55 mg neoterramycin/kg diet, [d]Complexity effect, $p<0.05$, [e]ZnO effect, $p<0.05$, [f]Complexity×antibiotic×Zn interaction, $p<0.02$, [g]Antibiotic effect, $p<0.05$

Experiment 2 and from d 0 to 7, neither Zn source nor antibiotic had any effect ($p>0.10$) (Table 4) on ADG, ADFI, or G/F. From d 7 to 14, pigs fed diets containing ZnO had greater ADG ($p<0.01$) and ADFI ($p<0.03$) than pigs fed diets containing no supplemental Zn or ZnAA. Gain to feed ratio of pigs fed diets containing ZnO was greater ($p<0.01$) than that of pigs fed diets containing no supplemental Zn and tended to be greater ($p<0.08$) than that of pigs fed diets containing ZnAA. Pigs fed diets containing ZnAA tended to have greater ($p=0.10$) ADG compared to pigs fed diets containing no supplemental Zn.

From d 0 to 14, ADG was greater ($p<0.05$) for pigs fed diets containing ZnO than for pigs fed diets containing ZnAA or no supplemental Zn and ADG tended to be greater ($p<0.07$) for pigs fed diets containing ZnAA than for pigs fed diets containing no supplemental Zn. Average daily feed intake of pigs fed diets containing ZnO was greater ($p<0.01$) than that of pigs fed diets containing no supplemental Zn and tended to be greater ($p<0.08$) than that of pigs fed diets containing ZnAA. Gain to feed ratio was greater ($p<0.04$) for pigs fed diets with ZnO or ZnAA than for pigs fed diets containing no supplemental Zn.

From d 14 to 27, ADFI of pigs fed diets containing ZnO was greater ($p<0.05$) than that of pigs fed diets containing either ZnAA or no supplemental Zn. Gain to feed ratio of pigs fed diets containing ZnO was poorer ($p<0.04$) than that of pigs fed diets containing no supplemental Zn and tended to be poorer ($p<0.08$) than that of pigs fed diets containing ZnAA. Pigs fed diets containing antibiotic tended to have greater ($p<0.08$) ADG and ADFI than pigs fed diets containing no antibiotic.From d 0 to 27, ADG of pigs fed diets containing ZnO was greater ($p<0.04$) than that of pigs fed diets containing no supplemental Zn but was similar ($p>0.10$) to that of pigs fed diets containing ZnAA. Average daily feed intake was greater ($p<0.03$) for pigs fed diets containing ZnO than for pigs fed diets containing either ZnAA or no supplemental Zn.

Table 4: Effects of zinc source and feed-grade antibiotic on performance of weanling pigs, Exp. 2[a]

	No antibiotic			Antibiotic[c]			
Item / Zn source[b]	None	ZnAA	ZnO	None	ZnAA	Zn	OSE
Day 0 to 7							
ADG (g)	114	128	123	109	139	126	33
ADFI (g)	166	175	170	151	161	178	13
G/F	0.67	0.69	0.72	0.72	0.86	0.69	0.04
Day 7 to 14							
ADG (g)	247	267	331	222	267	340	20
ADFI (g)	356	368	440	365	399	433	22
G/F	0.71	0.72	0.75	0.60	0.67	0.79	0.04
Day 0 to 14							
ADG (g)	181	197	227	166	203	233	14
ADFI (g)	261	272	305	258	280	305	15
G/F	0.70	0.72	0.74	0.64	0.72	0.76	0.03
Day 14 to 27							
ADG (g)	461	450	493	513	510	509	18
ADFI (g)	637	623	700	678	683	752	19
G/F	0.72	0.72	0.70	0.76	0.74	0.69	0.02
Day 0 to 27							
ADG (g)	316	319	355	333	351	366	12
ADFI (g)	442	441	495	460	474	520	15
G/F	0.71	0.72	0.72	0.72	0.74	0.71	0.02

Table 4: Continued Statistical analysis of mean values (p<)

				Contrasts[d]		
Item	Zn source	Antibiotic	Source × antibiotic	1	2	3
Day 0 to 7						
ADG (g)	0.51	0.87	0.91	0.24	0.62	0.48
ADFI (g)	0.66	0.63	0.74	0.56	0.73	0.36
G/F	0.70	0.15	0.22	0.42	0.67	0.71
Day 7 to 14						
ADG (g)	0.01	0.76	0.66	0.10	0.01	0.01
ADFI (g)	0.01	0.58	0.71	0.32	0.03	0.01
G/F	0.01	0.10	0.15	0.21	0.08	0.01
Day 0 to 14						
ADG (g)	0.01	0.92	0.72	0.07	0.05	0.01
ADFI (g)	0.04	0.89	0.94	0.32	0.08	0.01
G/F	0.01	0.42	0.18	0.04	0.28	0.01
Day 14 to 27						
ADG (g)	0.71	0.06	0.68	0.80	0.44	0.60
ADFI (g)	0.07	0.08	0.96	0.91	0.04	0.05
G/F	0.09	0.62	0.31	0.77	0.08	0.04
Day 0 to 27						
ADG (g)	0.11	0.17	0.82	0.54	0.14	0.04
ADFI (g)	0.03	0.17	0.95	0.77	0.03	0.02
G/F	0.62	0.70	0.67	0.58	0.32	0.65

[a]Values represent the means of 288 pigs (initially 5.59 ± 0.12 kg and 18 d of age) with eight pigs per pen and six pens per treatment. All diets contained 165 ppm Zn from ZnO provided by the trace mineral premix, [b]Zinc source: None = no added Zn; ZnAA = 250 ppm Zn from ZnAA; and ZnO = 3,000 ppm Zn from ZnO, [c]Antibiotic was 55 mg of carbadox/kg of diet, [d]Contrasts were: 1) None vs. ZnAA, 2) ZnAA vs. ZnO and 3) None vs. ZnO

DISCUSSION

In Exp. 1, pigs fed complex diets had improved growth performance compared to pigs fed simple diets, especially in the earlier phases. Similarly, Dritz *et al.*[2] observed that pigs fed complex diets had improved ADG from weaning until they reached 7.0 kg BW; however, from 7 to 18.7 kg BW, diet complexity had no effect on ADG or ADFI. Except for an interaction for ADG from d 0 to 10, there were no other 2- or 3-way interactions observed suggesting that the benefits observed from diet complexity, ZnO and antibiotic are additive.

The use of feed-grade antibiotics as growth promoters by the swine industry has been thoroughly reviewed[5,12,13] found that added antibiotic was effective in improving growth performance in both conventional and segregated early-weaning facilities, especially in the later phases of the experiments. Results from our experiments also showed that the beneficial antibiotic effect occurred mostly in the later phases of the experiments.

Adding high levels of Zn from ZnO improved growth performance in our experiments as in other research[3,14]. Carlson *et al.*[4] fed early weaned (12 d of age) and conventionally weaned (25 d of age) pigs a control diet for 4 weeks or a diet containing 3,000 ppm Zn from ZnO for wk 1, 2, 1 and 2, 2 and 3, or 1 through 4 postweaning. Pigs fed diets containing 3,000 ppm Zn from ZnO for at least the first 2 wk postweaning had improved growth performance, regardless of weaning age. The response to added Zn in our trials also occurred mostly in the first phases of the experiments, but carried over to the entire period. An experiment conducted by Lee *et al.*[15] tested the interactive effects of diet complexity, ZnO and antibiotic and reported no antibiotic effect, but added Zn and greater diet complexity improved growth performance. However, Hill *et al.*[16] showed that lower levels of ZnO (1,500 or 2,000 ppm Zn) and antibiotic additively improved growth performance, similar to our findings. More research should be conducted to fully elucidate the interactive effects of dietary Zn and feed-grade antibiotic on weanling pig growth performance.

Pigs fed Zn from ZnAA in Exp. 2 did not have improved growth performance similar to that of pigs fed ZnO from d 7 to 14 or 0 to 14 but instead had intermediate responses compared to pigs fed diets containing ZnO and no supplemental Zn. However, overall there were no differences in ADG or G/F between pigs fed diets containing Zn from ZnO or ZnAA. Ward *et al.*[17] also showed no differences in growth performance of pigs fed diets containing 250 ppm Zn from ZnMet or 2,000 ppm Zn from ZnO; however, all diets contained 250 ppm Zn from $ZnSO_4$ and only d 13 to 33 data was reported. Other research has shown that organic Zn sources will not influence growth as much as high levels of ZnO[3,8]. One possible explanation for the different influences of the Zn sources is that Zn from ZnAA was not supplemented at high enough levels to elicit the full growth-promoting response. Smith *et al.*[14] showed that when using ZnO as the Zn source, growth performance improved with increasing Zn concentrations up to 4,000 ppm. Consequently, higher levels of ZnAA possibly could elicit a response more like that of the ZnO.

IMPLICATIONS

These data suggest that diet complexity and both added zinc and feed-grade antibiotic influenced growth performance of weanling pigs. The diet complexity and zinc responses were observed primarily for the first portion of the trials, whereas the antibiotic response was observed at the end of the experiments. High levels of zinc from zinc oxide improved daily gain more than lower levels of zinc from a zinc amino acid complex from days 7 to 14 and 0 to 14, but both sources improved daily gain compared with no added zinc.

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