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The positive effect of pharmacological levels of zinc (Zn) from zinc oxide (ZnO), is well documented. Zinc at 3000 mg/kg has been shown to be as effective as carbadox (CARB) in the weaned pigs' diet. Recent research has demonstrated an unexpected effect on weaned pig performance from adding 3000 mg/kg of Zn from ZnO to simple diets. Normally, pigs fed complex diets with specialty ingredients outperform pigs fed simple diets, primarily because of increased feed intake. However, performance of pigs fed simple diets with added ZnO has been equal to performance of pigs fed complex diets with or without added ZnO (SWINE 2000-9 and SWINE 2000-10). Improvement in pig performance was not to the same degree with the addition of 3000 mg/kg Zn to a complex diet as to a simple diet. The results of some research suggests that 3000 mg/kg of Zn may be close to a toxic level in some instances. This experiment was designed to obtain data at a lower Zn level (2000 mg/kg). Of interest was whether 2000 mg/kg Zn from ZnO would give equal performance to 55 mg/kg CARB. Also of interest was if 2000 mg/kg Zn would elicit an improvement in performance from pigs fed the complex diet as well as pigs fed the simple diet. If the response to 2000 mg/kg was the same for both types of diets, this would suggest that added Zn was marginally toxic when included at 3000 mg/kg but not at 2000 mg/kg in a complex diet. If the response to Zn was found only in the simple diet, it would suggest the differences in responses to Zn previously observed for simple and complex diets was due to an interaction between Zn levels and feed ingredients affecting feed intake.

(Key Words: Weaned pigs, Diet complexity, Zinc oxide, Carbadox.)

Experimental Procedure

Pigs (168 averaging 7.02 kg) from a farrowing group were weaned (21 to 25 days of age) in two groups and blocked by weight. Six pigs were assigned per pen within four weight blocks on the basis of sex, ancestry, and weaning weight to six dietary treatments. The six randomly allotted treatments within a block were the result of a factorial arrangement of two diet types (simple or complex) and three types of feed additive additions (none, 2000 mg/kg Zn from ZnO, or 55 mg/kg CARB). Both the simple and the complex diets contained corn, soybean meal, 20% edible dried whey, and 1% soybean oil with the two complex diets containing additional ingredients. The phase I diet that was fed the first 14 days contained 10% lactose and 6% plasma and the phase II diet that was fed the last 7 days contained 2% spray-dried blood meal. Composition of the diets that were fed in meal form is shown in Table 1. The combination of type of diet and feed additive additions resulted in the following six treatments:

- Simple diet
- Simple diet with 2000 mg/kg added Zn from ZnO
- Simple diet with 55 mg/kg CARB
- Complex diets
- Complex diets with 2000 mg/kg added Zn from ZnO
- Complex diets with 55 mg/kg CARB.

Pigs were housed in the Animal Science Complex nursery which had vinyl slatted raised flooring. Room temperature was 30°C at the beginning and was decreased 2°C each week. One feeder and one nipple waterer were provided in each pen. Feed was added to feeders in small amounts and feed intake and feed wastage were recorded weekly. Pigs were individually weighed on a weekly basis.

The experiment was analyzed as a randomized complete block design with main effects in a 2 x 3 factorial arrangement. The pen of pigs was considered the experimental unit.

TABLE 1. COMPOSITION OF NURSERY DIETS, %

Ingredient	Simple	Complex	
		Phase I	Phase II
Ground corn	42.07	38.10	52.01
Soybean meal, 44%	33.34	21.19	21.19
Whey, spray-dried	20.00	20.00	20.00
Porcine plasma, spray-dried[a]	–	6.00	–
Lactose[b]	–	10.00	–
Blood meal, spray-dried	–	–	2.00
Soybean oil	1.00	1.00	1.00
Dicalcium phosphate	1.14	1.25	1.45
Limestone	.70	.71	.60
White salt	.25	.25	.25
Vitamin-TM mix[c]	1.50[dg]	1.50[eg]	1.50[fg]
Total	100.0	100.0	100.0

[a]Porcine plasma 780 produced by NutriBasics.
[b]Lactose manufactured by Davisco International, Inc.
[c]Premix provided the following per kg of diet: 100 mg Zn, 75 mg Fe, 25 mg Mn, 7.5 mg Cu, 175 :g I, 300 :g Se, 16.5 IU vitamin E, 3.3 mg riboflavin, 17.6 mg niacin, 13.2 :g vitamin B_{12}, 2.2 mg vitamin K_3, 13.2 mg pantothenic acid, 3960 IU vitamin A, and 396 IU vitamin D_3.
[d]Included 81.7 g L-lysine HCl and 90.8 g DL-methionine per 45.45 kg of complete diet.
[e]Included 77.2 g L-lysine HCl per 45.45 kg of complete diet.
[f]Included 68.1 g L-lysine HCl and 27.3 g DL-methionine per 45.45 kg of complete diet.
[g]Included either 126.2 g zinc oxide (72% Zn) manufactured by Zinc National, S.A., 113.6 g Carbadox (2.2% carbadox [Mecadox® TM premix-10]) produced by Pfizer, New York, NY, or no additive per 45.45 kg of complete diet.

Results

Nursery pig performance for the 3-week trial is summarized by main effects, diet type and feed additive addition, in Table 2.

During weeks 1 and 2, pigs that received the complex diet (phase I) consumed more feed (P<.10 week 1 and P<.005 week 2) and gained faster (P<.05) than pigs receiving the simple diet. However, during week 3, no difference (P>.10) in feed intake or gain was observed between pigs receiving the simple diet and the complex diet (phase II). Overall, more feed was consumed (P<.05) by the pigs fed the complex diets, but no difference in gain (P>.10) was observed. Gain/feed was higher (P<.05) during the first week but lower during the second (P<.001) and third weeks (P.01) for pigs receiving the complex diets. This resulted in an overall 3-week advantage (P<.10) in gain/feed for pigs receiving the simple diet.

Feed additive had no effect (P>.10) on daily gain, feed intake, or gain/feed the first week of the trial. However, during the second week, the addition of either 2000 mg/kg of Zn from ZnO or 55 mg/kg of CARB increased feed intake (P<.005), gain (P<.001), and gain/feed (P<.005) compared to feeding a diet with no feed additive. During week 3, pigs receiving the diets with CARB consumed more feed (P<.05) and tended to gain faster (P=.13) than pigs receiving no additive but not faster than pigs receiving additional Zn. For the first 2 weeks and for the overall trial, pigs that received either 2000 mg/kg Zn or 55 mg/kg CARB consumed more feed (P<.05), gained more (P<.05), and had higher gain/feed P<.10) than pigs without feed additives in their diets.

Table 3 summarizes the nursery pig performance showing the interaction means between type of diet and feed additive included in the diet. No interactions (P>.10) were found by analysis of variance between diet type and feed additive additions to those diets. To evaluate the hypothesis associated with the treatments, the treatments were evaluated with a multiple range test.

During the first week, pigs receiving the complex, phase I diet with added Zn had greater

TABLE 2. NURSERY PIG PERFORMANCE AS AFFECTED BY DIET COMPLEXITY AND FEED ADDITIVES (MAIN EFFECT MEANS)

	Diet type[a]				Feed additives[b]				
	Simple	Complex	SE	Prob.[c]	None	ZnO	CARB	SE	Prob.
Initial wt, kg	7.03	7.02	.01	ns	7.02	7.04	7.01	.02	ns
Final wt, kg	13.36	12.83	.26	ns	12.15	13.53	13.60	.32	.05
Week 1									
Daily gain, g	82	153	15	.05	89	135	129	19	ns
Daily feed, g	136	173	11	.10	136	167	161	14	ns
Gain/feed	533	876	82	.05	578	740	796	101	ns
Week 2									
Daily gain, g	303	334	8	.05	256	355	345	10	.001
Daly feed, g	336	408	9	.005	316	421	379	11	.005
Gain/feed	906	819	8	.001	824	848	914	10	.005
Week 3									
Daily gain, g	446	417	19	ns	389	438	468	23	.13
Daily feed, g	571	603	16	ns	533	597	631	20	.05
Gain/feed	781	690	16	.01	729	736	741	20	ns
Weeks 1 and 2									
Daily gain, g	193	243	10	.05	173	245	237	12	.05
Daily feed, g	236	290	10	.01	226	294	270	11	.05
Gain/feed	811	835	15	ns	760	831	880	20	.05
Weeks 1, 2, and 3									
Daily gain, g	277	301	12	ns	245	309	314	15	.05
Daily feed, g	348	395	11	.05	328	395	390	14	.05
Gain/feed	794	762	12	.10	744	783	806	14	.10

[a]Simple and complex diets contained corn, soybean meal, 20% edible dried whey, and 1% soybean oil. In addition, the phase I complex diet contained 10% lactose and 6% plasma and the phase II complex diet contained 2% spray-dried blood meal.

[b]None (no feed additive), ZnO (3000 mg/kg Zn added as zinc oxide), and CARB (55 mg/kg carbadox added).

[c]Probabilities associated with main effect means. P<.10 accepted as significant.

gains (P<.05), consumed more feed (P<.10), and had greater gain/feed (P<.05) than pigs fed the simple diet with added Zn. This was also true for gain (P<.01) and feed intake (P<.01) for week 2. However, gain/feed was higher (P<.05) for pigs receiving the simple diet with added Zn than for pigs receiving the complex, phase I diet with added Zn. During week 3 feed intake was higher (P<.10) and gain/feed higher (P<.10) for pigs receiving the simple diet with added Zn than the complex, phase II diet with added Zn with no difference in gain (P>.10). As a result, gain and feed intake were higher (P<.05) for pigs fed the complex diet with added Zn than for the pigs fed the simple diet with added Zn for the first 2-week period. For the overall period, feed intake was higher (P<.05) for pigs fed the simple diet with added Zn than for pigs fed the complex diets with added Zn with no difference in gain or gain/feed (P>.10). These results indicate that when 2000 mg/kg of Zn from ZnO are included in the diets pigs receiving simple diets will perform the same in the nursery as pigs receiving more complex diets. However, the pattern of growth will be different with early nursery performance favoring pigs receiving complex diets because of increased feed intake and later performance favoring pigs receiving simple diets.

Gain and feed intake (P<.01) during the second week and feed intake and gain/feed (P<.10) for the first 2 weeks were higher for pigs receiving simple diets when added Zn was included. For the third week and for the overall period, the response to ZnO within the simple diet was lost (P>.10). During the second week, and for the first 2 weeks combined, gain/feed was higher for pigs receiving the simple diet with CARB than for pigs receiving the simple diet

TABLE 3. NURSERY PIG PERFORMANCE AS AFFECTED BY DIET COMPLEXITY AND FEED ADDITIVES (INTERACTION MEANS)

Diet complexity	Simple			Complex			
Feed additives	None	ZnO	CARB	None	ZnO	CARB	SE
Initial wt, kg	7.01	7.02	7.02	7.03	7.05	7.01	.02
Final wt, kg[nq]	11.9	13.0	13.7	12.4	14.1	13.6	.45
Week 1							
Daily gain, g[b]	48	84	116	130	186	142	26
Daily feed, g[a]	117	135	155	155	198	166	20
Gain/feed[b]	353	528	718	801	952	873	14
Week 2							
Daily gain, g[cejor]	246	329	335	267	381	355	14
Daily feed, g[ceoq]	282	378	349	350	465	408	16
Gain/feed[bgjol]	883	876	958	765	821	870	15
Week 3							
Daily gain, g[p]	404	435	498	373	441	439	33
Daily feed, g[amq]	515	556	641	552	638	621	28
Gain/feed[aik]	784	782	777	674	690	705	28
Weeks 1 and 2							
Daily gain, g[bdnq]	147	206	225	198	283	248	18
Daily feed, g[bdnp]	200	257	252	252	332	287	17
Gain/feed[fr]	737	804	892	784	857	867	28
Weeks 1, 2, and 3							
Daily gain, g[nq]	233	283	316	257	336	312	21
Daily feed, g[bnq]	305	356	383	352	437	398	20
Gain/feed[kp]	762	792	829	727	775	783	20

[a]P<.10 Simple diet with ZnO vs complex diet with ZnO.
[b]P<.05 simple diet with ZnO vs complex diet with ZnO.
[c]P<.01 simple diet with ZnO vs complex diet with ZnO.
[d]P<.10 simple diet with ZnO vs simple diet.
[e]P<.01 simple diet with ZnO vs simple diet.
[f]P<.10 simple diet with ZnO vs simple diet with CARB.
[g]P<.01 simple diet with ZnO vs simple diet with CARB.
[h]P<.10 simple diet with ZnO vs complex diet.
[i]P<.05 simple diet with ZnO vs complex diet.
[j]P<.01 simple diet with ZnO vs complex diet.
[k]P<.10 simple diet with ZnO vs complex diet with CARB.
[l]P<.10 simple diet with ZnO vs complex diet with CARB.
[m]P<.10 complex diet with ZnO vs complex diet.
[n]P<.05 complex diet with ZnO vs complex diet.
[o]P<.01 complex diet with ZnO vs complex diet.
[p]P<.10 simple diet with CARB vs simple diet.
[q]P< 05 simple diet with CARB vs simple diet.
[r]P<.01 simple diet with CARB vs simple diet.

with added Zn as was feed intake (P<.10) for week 3. Numerical advantages in gain, feed intake, and gain/feed were observed for the addition of ZnO to simple diets for the overall nursery period. The advantage of adding 2000 mg/kg Zn as ZnO to simple diets was not as dramatic as had been observed in previous trials when 3000 mg/kg Zn was added to simple diets. Additions of CARB gave improvements in gain (P<.01) and feed intake (P<.05) during the second and third week and for the overall period (P<.05) for pigs fed the simple diet.

Within complex diets, adding 2000 mg/kg Zn generally improved pig performance. During the second week, gain (P<.01), feed intake (P<.01), and gain/feed (P<.05) were increased due to added Zn. In the third week, feed intake was

increased (P<.10). For the overall period, feed intake and gain as well as final weight were higher (P<.05) for pigs receiving the complex diet with added Zn compared to pigs receiving the complex diet. These results demonstrated the efficacy of Zn additions at the 2000 mg/kg concentration to complex diets, a response not observed in previous trials when 3000 mg/kg Zn was added. The only advantage for the addition of CARB to complex diets over the addition of ZnO was found in an improvement (P<.10) of gain/feed during the third week.

Summary

One hundred sixty-eight pigs (21 to 25 days of age) averaging 7.02 kg were weaned, blocked by weight, and assigned to six dietary treatments within four weight blocks on the basis of sex, ancestry, and weaning weight. The six treatments were the result of a factorial arrangement of two diet types (simple or complex) and three types of feed additive additions (none, 2000 mg/kg Zn from ZnO, or 55 mg/kg CARB). The 21-day experiment was analyzed as a randomized block design with main effects in a 2 x 3 factorial arrangement.

Pigs that received the complex diets consumed more feed and gained more than pigs receiving the simple diet during weeks 1 and 2 but not during week 3. Overall, pigs receiving the complex diets consumed more feed than pigs receiving the simple diets, but no difference in gain was observed. There was an overall advantage in gain/feed for pigs receiving the simple diet.

Feed additive had no effect on daily gain, feed intake, or gain/feed the first week of the trial. During the second week, the addition of either 2000 mg/kg of Zn or 55 mg/kg of CARB increased feed intake, gain, and gain/feed compared to feeding a diet with no feed additive. Overall, pigs receiving the diets with CARB consumed more feed and tended to gain more than pigs receiving no feed additive but not more than pigs receiving additional Zn. Pigs that received either 2000 mg/kg Zn or 55 mg/kg CARB consumed more feed, gained more, and had higher gain/feed than pigs without additive additions to their diets.

When 2000 mg/kg of Zn from ZnO were included in the simple diets, pigs performed at the same level in the nursery as pigs receiving more complex diets. Early nursery performance favored pigs receiving complex diets and later performance favored pigs receiving simple diets because of increased feed intake. For pigs receiving simple diets, numerical advantages in gain, feed intake, and gain/feed were observed for the addition of ZnO for the overall period. This response was less dramatic than had been previously observed with 3000 mg/kg added Zn. Additions of CARB indicated improvements in gain and feed intake for the overall period for pigs fed the simple diet. Within complex diets, ZnO generally improved pig performance demonstrating the efficacy of Zn additions at the 2000 mg/kg concentration to complex diets, a response not observed in previous trials when 3000 mg/kg Zn was added.

Implications

The addition of 2000 mg/kg of Zn from ZnO or the addition of 55 mg/kg of CARB improves nursery pig performance. Performance of pigs receiving complex diets is generally better than that of pigs receiving simple diets.

The addition of 2000 mg/kg of Zn from ZnO to the simple diet provides pig performance that equals that of pigs fed the complex diets with either ZnO or CARB additions and exceeds that of pigs fed the complex diet with no feed additive. However, the pattern of growth will be different with early nursery performance favoring pigs receiving complex diets because of increased feed intake and later performance favoring pigs receiving simple diets. The response to 2000 mg/kg of added Zn in simple diets is not as great as had been observed with 3000 mg/kg Zn in previous experiments. The addition of 2000 mg/kg of Zn from ZnO to the complex diet provided for increased pig performance compared to the complex diet with no feed additive. This response was not observed in previous trials with 3000 mg/kg Zn from ZnO.

These results in combination with the results of previous experiments suggest that different concentrations of Zn from ZnO may be appropriate depending on the ingredient complexity of the diet. The addition of 3000 mg/kg of Zn may be necessary to obtain maximum performance for pigs fed simple diets but may have an inhibitory effect on the appetite of pigs consuming complex diets. The addition of 2000 mg/kg of Zn provides for increased performance of pigs receiving complex diets but may not be sufficient for maximum performance of pigs receiving simple diet.