2002

Effect of Diet Complexity on the Performance of Newly Weaned Pigs Fed Pharmacological Levels of Zinc Oxide

D.Y. Lee
South Dakota State University

G.W. Libal
South Dakota State University

C.R. Hamilton
South Dakota State University

D.N. Peters

Effect of diet complexity on the performance of newly weaned pigs fed pharmacological levels of zinc oxide

D. Y. Lee, G. W. Libal, C. R. Hamilton, and D. N. Peters
Department of Animal and Range Sciences

SDSU

SWINE 2001-6

Zinc (Zn) is an essential trace mineral for swine. The requirement for Zn has been suggested to be in the range of 50 to 100 mg/kg for pigs at various stages of growth. The bioavailability of zinc oxide (ZnO) as a source of Zn is lower than other Zn sources such as zinc sulfate ($ZnSO_4$), zinc carbonate ($ZnCO_3$), and Zn-methionine in weanling pigs. Recent studies have shown that adding pharmacological levels (2000-4000 mg/kg) of Zn as ZnO to corn-soybean meal based diets improved starter pig performance and was effective in controlling E. coli scours for weanling pigs. Very high levels of Zn can be toxic. Studies have demonstrated that Zn toxicosis is not found or is much less severe when ZnO is supplemented in corn-soybean meal diets for weanling pigs than when $ZnCO_3$ is the source of pharmacological levels of Zn. The response for weaned pigs to the addition of pharmacological levels of ZnO to simple diets containing corn, soybean meal, and dried-whey has not been compared to the addition of the same levels of Zn to complex diets containing these same ingredients plus animal protein supplements.

The objective of this study was to determine whether diet composition affected the growth promoting properties of ZnO in weaned pig diets.

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

Experimental Procedure

Two hundred fifty-eight crossbred pigs averaging 7.10 kg were weaned between 21 and 28 days of age and allotted to a split-split plot design on the basis of weight, gender, and ancestry. The split-split plot design included two nursery sites (whole-plot), two diet types (sub-plot), and three feed additive additions (sub-sub-plot). Each dietary treatment was fed to eight replicate pens containing five or six pigs per pen. Diet types were simple and complex based upon the ingredients they contained. Diets consisted of corn, soybean meal, 20% dried edible whey, and 1% soybean oil (simple) plus 10% lactose and 6% spray-dried porcine plasma (complex). Additions of no feed additive or 3000 mg/kg additional Zn from ZnO or 165-mg/kg apramycin sulfate (APR) to each diet type made the six dietary treatments.

The dietary treatments were:

- Simple diet
- Simple diet with 3000 mg/kg added Zn from ZnO
- Simple diet with 165 mg/kg APR
- Complex diet
- Complex diet with 3000 mg/kg added Zn from ZnO
- Complex diet with 165 mg/kg APR.

Experimental diets are shown in Table 1. The diets were formulated to meet or exceed all NRC (1988) nutrient requirements, including Zn, for pigs between 5 and 10 kg. All diets were formulated to provide 1.40% lysine and at least 100 mg/kg added Zn.

Pigs were weaned and housed in two groups (whole-plot). The first group weaned (120 pigs) was housed in 24 pens in nursery rooms at the Swine Research Center, and the second group weaned (138 pigs) was housed in 24 pens in the Animal and Range Sciences Complex on the South Dakota State University campus. Pens measured 1.2 m x 1.2 m and 1.2 m x 1.8 m at the two sites, respectively. Flooring consisted of either slotted plastic flooring or Tri-bar metal flooring. Replications were made within pen size and floor type. All pens were equipped with a single stainless steel self-feeder and one nipple waterer. All nurseries were mechanically ventilated and temperatures maintained within the thermoneutral zone, starting at 29 to 30°C and reduced 2°C each week. A 24-hour constant light schedule was maintained in all nursery sites.

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS (%, AS FED)

	Simple diets			Complex diets		
Added ZnO, mg/kg	0	3000	0	0	3000	0
APR, mg/kg	0	0	165	0	0	165
Ingredients						
Ground corn	43.05	42.63	41.82	39.12	38.70	37.89
Soybean meal, 44%	33.34	33.34	33.58	21.19	21.19	21.43
Edible dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Plasma, spray-dried[a]	0	0	0	6.0	6.00	6.00
Lactose[b]	0	0	0	10.00	10.00	10.00
Soybean oil	1.00	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.14	1.14	1.15	1.25	1.25	1.26
Limestone	.70	.70	.69	.71	.71	.70
Salt	.25	.25	.25	.25	.25	.25
Antimicrobial agent[c]	0	0	1.00	0	0	1.00
L-lysine HCl[d]	.18	.18	.17	.17	.17	.16
DL-methionine[d]	.20	.20	.20	.17	.17	.17
Premix[de]	.14	.14	.14	.14	.14	.14
Zinc oxide[df]	0	.42	0	0	.42	0
Total	100	100	100	100	100	100

[a]Porcine plasma 780, produced by NutriBasics.
[b]Lactose manufactured by Davisco International, Inc.
[c]Apralan® 7.5, apramycin sulfate.
[d]Premixed with ground corn before adding with macro ingredients. Ground corn added to give total inclusion rate of 1%.
[e]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.
[f]Zinc oxide (72% Zn) manufactured by Zinc National, S.A.

Pigs were fed experimental diets for 28 days. Pig weights, feed consumption, and feed wastage were measured weekly. Feed samples were collected during the experimental period from both sites. Diet samples were analyzed for crude protein, Ca, P, Zn, and lysine. The calculated nutrient levels and chemically determined nutrient levels of the diets are summarized in Table 2.

Blood samples were taken by anterior vena cava puncture from one representative, intermediate weight pig per pen on day 10 and again from the same pig on day 20. Plasma zinc was determined by atomic absorption procedures and plasma urea nitrogen concentrations were determined by colorimetric procedures.

All data were analyzed as a split-split plot design with pens as the experimental units. Nursery site (whole-plot) was tested using the replication by nursery site interaction as an error term, the effect of diet type (sub-plot) was tested using replication by diet type within nursery site as the error term, and the effect of additive (sub-sub-plot) was tested using the residual error term. Pair-wise t-tests were used to detect differences among three or more main effect or treatment means using the LSD (least significant difference) option of SAS (1988).

Results

Nursery site affected feed intake from 0 to 7 days, feed wastage from 0 to 14 days, and 10-day plasma Zn concentrations. However, because diet type and feed additive had similar effects on criteria evaluated across nursery sites, nursery site performance will not be reported. Only diet type, feed additive main effect means, and the means for the interaction between diet type and feed additive will be reported and discussed. Other interactions, such as nursery site by diet type and replicate by nursery site, occurred infrequently.

Pig performance means for diet type and feed additive are shown in Table 3. Pigs fed complex diets gained more ($P<.01$) than those fed simple diets for the first 7days, first 14 days, and overall 28-day period but not for day 15 to 28. They also had higher ($P<.01$) ADFI than those fed simple diets for each period and the overall study. Feed wastage was greater ($P<.01$) for pigs fed simple diets than pigs fed complex diets for day 0 to 14, day 15 to 28, and overall. Pigs fed complex diets had greater ($P<.01$) gain/feed than those fed simple diets during the initial 14 days and lower ($P<.01$) gain/feed during the last 14 days with no overall effect of diet type on gain/feed ($P>.10$).

Pharmacological levels of Zn from ZnO resulted in greater ADFI and ADG ($P<.01$) than adding APR or feeding the basal (no additive) diet during the first 14 days and the entire experimental period. Feed intake and gain were increased ($P<.01$) with added ZnO or APR compared to feeding no additives during day 15 to 28. Feeding the basal diet with no additive resulted in greater ($P<.01$) feed wastage than feeding ZnO or APR during the first 14 days. Additional ZnO resulted in greater ($P<.01$) gain/feed than feeding APR for the first 7 days and APR or no feed additive for the first 14 days. For the overall period, however, pigs fed added ZnO had greater ($P<.01$) gain/feed than pigs fed the basal diet with no feed additive, while those fed added APR were intermediate.

Table 4 summarizes plasma Zn concentrations and PUN concentrations on day 10 and 20. Plasma Zn concentrations were higher and PUN concentrations lower on day 10 and day 20 for pigs fed complex diets than those fed simple diets. Higher ($P<.01$) plasma Zn concentrations were obtained by feeding pigs additional ZnO than feeding APR or no additive on both sampling days. Pigs fed diets with added ZnO had lower PUN concentrations than pigs fed diets with APR on day 10 ($P<.07$) but not pigs fed the diet with no additives ($P>.10$). Feed additive effects ($P>.10$) were not found for PUN at day 20.

A diet x feed additive interaction was detected ($P<.05$) for ADFI from day 15 to 28 and over the entire 28-day period. Added Zn increased ($P<.05$) ADFI for pigs fed simple diets during all periods except day 0 to 7 but had little effect on ADFI for pigs fed complex diets. Pigs fed simple diets with 3000 mg/kg added Zn had ADFI that was similar ($P=.50$) to pigs fed complex diets with or without feed additives for day 15 to 28 and the overall 28-day period. Compared with pigs fed the diet with no feed additives, adding APR to simple diets did not affect ($P>.10$) ADFI, while APR increased ($P<.05$) ADFI for pigs fed complex diets only for the 15 to 28-day period.

A diet x feed additive interaction was detected ($P<.05$) for ADFI from day 15 to 28 and over the entire 28-day period. Added Zn increased ($P<.05$) ADFI for pigs fed simple diets during all periods except day 0 to 7 but had little effect on ADFI for pigs fed complex diets.

TABLE 2. NUTRIENT CONTENT OF EXPERIMENTAL DIETS (AS FED)

	Simple diets			Complex diets		
Added ZnO, mg/kg[a]	0	3000	0	0	3000	0
APR, mg/kg[b]	0	0	165	0	0	165
Calculated nutrient content						
Crude protein, %	21.00	20.96	20.00	20.00	19.96	20.00
Lysine, %	1.40	1.40	1.40	1.40	1.40	1.40
Calcium, %	.80	.80	.80	.80	.80	.80
Phosphorus, %	.70	.70	.70	.70	.70	.70
Chemically determined nutrient content						
Crude protein, %	20.96	20.67	20.03	19.52	19.02	19.40
Lysine, %	1.24	1.25	1.26	1.37	1.32	1.31
Calcium, %	.80	.73	.79	.73	.81	.79
Phosphorus, %	.70	.68	.65	.71	.72	.72
Zinc, mg/kg	115	3248	233	121	3680	232

[a]Added level of zinc provided as zinc oxide.

[b]Added level of Apramycin sulfate.

TABLE 3. NURSERY PERFORMANCE AS AFFECTED BY DIET TYPE AND FEED ADDITIVES (MAIN EFFECT MEANS)[a]

	Diet type[b]			Feed additive[c]			
	Simple	Complex	±SE	None	ZnO	APR	±SE
Avg daily gain, g							
Day 0 to 7[def]	99	180	9	141	156	122	12
Day 0 to 14[df]	184	269	7	195[h]	275[g]	209[h]	9
Day 15 to 28	515	541	8	496[h]	551[g]	538[g]	10
Overall[df]	350	405	6	346[h]	413[g]	373[h]	8
Avg daily feed, g							
Day 0 to 7[ef]	144	227	8	199	188	170	10
Day 0 to 14[f]	254	346	8	282[h]	340[g]	278[h]	10
Day 15 to 28[df]	732	806	12	717[h]	813[g]	776[g]	15
Overall[df]	493	575	9	498[h]	577[g]	527[h]	11
Feed wastage, g							
Day 0 to 7	14	12	1	15	14	10	2
Day 0 to 14[def]	29	18	2	31[h]	22[g]	19[g]	2
Day 15 to 28[f]	73	31	11	66	51	39	14
Overall[ef]	51	25	6	48	36	29	7
Gain/feed							
Day 0 to 7[d]	.65	.77	.04	.67[gh]	.82[g]	.63[h]	.05
Day 0 to 14[df]	.71	.77	.02	.67[h]	.81[g]	.73[h]	.02
Day 15 to 28[f]	.71	.67	.01	.70	.68	.70	.01
Overall	.71	.70	.01	.69[h]	.72[g]	.71[gh]	.01

[a]Forty-eight pens in two locations fed two diet types and three feed additives.
[b]Consisted of corn, soybean meal, and 20% dried edible whey and 1% soybean oil (Simple) plus 10% lactose and 6% spray-dried porcine plasma (Complex).
[c]No feed additive (none), 3000 mg/kg of added zinc provided as zinc oxide (ZnO), and 165 mg/kg of Apramycin sulfate (APR).
[d]Diet x feed additive interaction (P<.05).
[e]Nursery site location effects (P<.05).
[f]Diet effect (P<.01).
[gh]Feed additive means without a common superscript differ (P<.01).

Pigs fed simple diets with 3000 mg/kg added Zn had ADFI that was similar (P=.50) to pigs fed complex diets with or without feed additives for day 15 to 28 and the overall 28-day period. Compared with pigs fed the diet with no feed additives, adding APR to simple diets did not affect (P>.10) ADFI, while APR increased (P<.05) ADFI for pigs fed complex diets only for the 15 to 28-day period.

During day 0 to 14, adding Zn or APR reduced (P<.05) feed wastage when pigs were fed simple diets but not when complex diets were fed. A similar pattern occurred for other periods.

Significant diet by feed ingredient interactions for gain/feed resulted for day 0 to 7 and day 0 to 14 but not for other periods. Pigs fed the simple diet with 3000 mg/kg added Zn had gain/feed that was more than 50% greater (P<.05) than pigs fed the other simple diets and not different (P>.10) from gain/feed for pigs fed the complex diet with added APR from day 0 to 7 and day 0 to 14. However, poorer (P<.05) gain/feed for simple diets with added Zn was observed from day 15 to 28. Apramycin had no effect (P>.10) on gain/feed within complex diets except from day 0 to 14, when improvement was noted (P<.05) over the complex diet with no feed additive.

TABLE 4. ZINC AND PUN CONCENTRATIONS IN PLASMA OF WEANED PIGS AS AFFECTED BY DIET TYPE AND FEED ADDITIVES (MAIN EFFECT MEANS)

Item	Diet type		Feed additive			
	Simple	Complex	None	ZnO	APR	±SD[a]
Plasma zinc, mg/kg						
Day 10[def]	81	107	64[h]	148[g]	70[h]	20
Day 20[f]	90	128	68[h]	175[g]	85[h]	31
Plasma urea nitrogen, mg/dl						
Day 10[f]	11.56	6.20	8.73[ij]	7.53[i]	10.36[j]	3.29
Day 20[f]	9.39	7.30	7.95	8.59	8.50	2.49

[a]Standard deviation: 48 pens in two locations fed two diet types and three feed additive treatments. One pig fed the complex diet without feed additive died on day 13.
[b]Consisted of corn, soybean meal, and 20% dried edible whey and 1% soybean oil (Simple) plus 10% lactose and 6% spray-dried porcine plasma (Complex).
[c]No feed additive (none), 3000 mg/kg of added zinc provided as zinc oxide (ZnO), and 165 mg/kg of Apramycin sulfate (APR).
[d]Diet x feed additive interaction (P<.05).
[e]Nursery site location effect (P<.05).
[f]Diet effect (P<.01).
[gh]Feed additive means without a common superscript differ (P< .01).
[ij]Feed additive means without a common superscript differ (P<.07).

TABLE 5. NURSERY PERFORMANCE AS AFFECTED BY DIET TYPE AND FEED ADDITIVES (INTERACTION MEANS)[a]

	Simple diets[b]			Complex diets[c]			
Added Zn, mg/kg	0	3000	0	0	3000	0	
APR, mg/kg	0	0	165	0	0	165	±SE
Avg daily gain, kg							
Day 0 to 7	91[f]	140e	66[f]	190[d]	172[de]	178[de]	16
Day 0 to 14	142[f]	266[de]	145[f]	249[e]	284[d]	273[de]	13
Day 15 to 28	479[f]	555[d]	513[ef]	514[ef]	547[de]	562[d]	14
Overall period	310[f]	410[de]	329[f]	381[e]	416[d]	418[d]	11
Avg daily feed, g							
Day 0 to 7	146[e]	162[e]	123[e]	251[d]	214[d]	216[d]	14
Day 0 to 14	226[f]	312[e]	223[f]	337[de]	369[d]	332[de]	14
Day 15 to 28	664[f]	820[de]	711[f]	770[e]	807[de]	842[d]	21
Overall period	445[e]	566[d]	467[e]	558[d]	588[d]	587[d]	16
Avg feed wastage, g							
Day 0 to 7	18	15	9	11	13	11	3
Day 0 to 14	44[d]	26[e]	18[e]	18[e]	19[e]	20[e]	3
Day 15 to 28	105[d]	64[de]	50[e]	27[e]	37[e]	28[e]	20
Overall period	74[d]	45[e]	34[e]	23[e]	28[e]	24[e]	10
Gain/feed							
Day 0 to 7	.58[e]	.88[d]	.49[f]	.77[d]	.77[d]	.77[d]	.07
Day 0 to 14	.62[g]	.85[d]	.64[g]	.72[f]	.77[ef]	.82[de]	.03
Day 15 to 28	.72[d]	.68[e]	.72[d]	.67[e]	.68[e]	.67[e]	.01
Overall period	.70[de]	.72[d]	.70[de]	.68[e]	.71[de]	.71[de]	.01

[a]Forty-eight pens in two locations fed two diet types and three feed additive treatments.
[b]Consisted of corn, soybean meal, and 20% dried edible why and 1% soybean oil (Simple) plus 10% lactose and 6% spray-dried porcine plasma (Complex).
[c]No feed additive (none), 3000 mg/kg of added zinc provided as zinc oxide (ZnO), and 165 mg/kg of Apramycin sulfate (APR).
[defg]Means within the same row without a common superscript differ (P<.05).

There was a diet type by feed additive interaction ($P<.05$) for plasma Zn concentration at day 10 but not at day 20 (Table 6). Pigs fed the complex diet with added ZnO had the greatest ($P<.05$) plasma Zn concentration followed by pigs fed the simple diet with added ZnO on day 10 and day 20. Pigs fed the complex diet with added APR had greater plasma Zn levels ($P<.05$) on day 20 than pigs fed the simple diet or the simple diet with APR.

There were no diet type by additive interactions ($P>.10$) for any PUN data. Pigs fed simple diets with 165 mg/kg added APR had higher day 10 PUN ($P<.05$) but not day 20 PUN ($P>.10$) than pigs fed simple diets with added Zn, while pigs fed the simple diet with no additive were intermediate. There were no differences in PUN concentrations ($P>.10$) among pigs receiving any of the complex diets on day 10 or day 20.

TABLE 6. ZINC AND PUN CONCENTRATIONS IN PLASMA OF WEANED PIGS AS AFFECTED BY DIET TYPE AND FEED ADDITIVES (INTERACTION MEANS)

	Simple diets[a]			Complex diets[b]			
Added Zn, mg/kg	0	3000	0	0	3000	0	
Added APR, mg/kg	0	0	165	0	0	165	±SD[c]
Plasma zinc concentration, mg/kg							
Day 10	58[f]	120[e]	67[f]	71[f]	176[d]	74[f]	21
Day 20[f]	60[g]	143[e]	67[g]	75[fg]	206[d]	103[f]	31
Plasma urea nitrogen, mg/dl							
Day 10	11.93[de]	9.54[e]	13.20[d]	5.54[f]	5.54[f]	7.51[ef]	3.49
Day 20[f]	8.79	9.78	9.61	7.11	7.39	7.39	2.58

[a]Consisted of corn, soybean meal, and 20% dried edible whey and 1% soybean oil (Simple) plus 10% lactose and 6% spray-dried porcine plasma (Complex).
[b]No feed additive (none), 3000 mg/kg of added zinc provided as zinc oxide (ZnO), and 165 mg/kg of Apramycin sulfate (APR).
[c]Standard deviation: there were 48 pens in two locations fed two diet types and three feed additive treatments. One pig fed the complex diet without additive died on day 13.
[defg]Different superscripts within the same row were different at $P<.05$.

Summary

Two hundred fifty-eight weaned crossbred pigs (7.10 kg initial weight, 21 to 28 days of age, 28-day trial) were utilized in a split-split plot design that included eight replications of two nursery sites, two diet types, and three feed additives. Diet types consisted of corn, soybean meal, 20% dried edible whey, and 1% soybean oil (simple) plus 10% lactose and 6% spray-dried porcine plasma (complex). Additions to those diets of no additive, 3000 mg/kg additional Zn from ZnO, or 165 mg/kg APR made the six dietary treatments.

Pigs fed complex diets consumed more feed, had less feed wastage, and gained faster than those fed simple diets for nearly every period and the overall study. Pigs fed complex diets had greater gain/feed than those fed simple diets during the initial 14 days and lower gain/feed during the last 14 days with no overall effect of diet type on gain/feed.

Pharmacological levels of Zn from ZnO resulted in greater ADFI and ADG than adding APR or feeding the diet with no feed additive during the first 14 days and the entire experimental period. Feed intake and gain were increased with added ZnO or APR compared to feeding the basal diet during day 15 to 28. Additional ZnO resulted in greater gain/feed than feeding APR for the first 7 days and feeding APR or no feed additive for the first 14 days. For the overall period, however, pigs fed added ZnO had greater gain/feed than pigs fed the diet with no feed additive, while those fed added APR were intermediate. Feeding the diet with no additive resulted in greater feed wastage than feeding ZnO or APR during the first 14 days.

Interactions between diet type and feed additives included in the diet were observed. Pigs fed the simple diet with 3000 mg/kg added Zn from ZnO consumed more feed and gained faster than those fed simple diets without added Zn. Pigs fed simple diets with 3000 mg/kg added Zn had gain/feed that was more than 50% greater than those fed the other simple diets and not different from gain/feed for pigs fed the complex diet with added APR from day 0 to 7 and day 0 to 14. However, poorer gain/feed for simple diets with added Zn was observed from day 15 to 28. Within the pigs fed the complex diet, added Zn had little effect on ADFI but resulted in greater ADG overall than feeding no feed additive. Pigs fed simple diets had a greater response to added Zn resulting in ADFI and ADG that were similar to feeding a complex diet with or without added Zn or added APR.

Pigs fed the complex diet with added APR had ADFI and ADG that were similar during the initial 14 days of the study but greater for day 15 to 28 and overall periods to those fed the complex diet with no feed additives. APR had no effect on gain/feed within complex diets except from day 0 to 14, when improvement was noted over the complex diet with no feed additive. Adding APR to simple diets did not improve ADFI or ADG for any period.

Pigs fed the complex diet with added ZnO had the greatest plasma Zn concentration followed by pigs fed the simple diet with added ZnO on day 10 and day 20. Pigs fed the complex diet with added APR had greater day 20 plasma Zn concentrations than pigs fed the simple diet or the simple diet with APR. No differences in PUN concentrations among any complex diets on day 10 or day 20 were observed. However, pigs fed simple diets with 165 mg/kg added APR had higher day 10 PUN than pigs fed simple diets with added Zn, while pigs fed the simple diet with no additive were intermediate.

Implications

Performance data confirmed that pigs fed complex diets have greater feed intake and growth than those fed simple diets. Adding 3000 mg/kg Zn as ZnO resulted in greater gains and feed intakes than adding 165 mg/kg APR to either simple or complex diets for the overall 28-day period. These results reconfirm the efficacy of pharmacological additions of Zn as ZnO in both traditional corn-soybean meal-dried whey diets and more complex diets.

Pigs fed the simple diet with 3000 mg/kg added Zn had similar gain and feed intake to those fed any complex diet during the first 14 days and overall 28-day period of this study. This study suggests that pharmacological additions of Zn as ZnO to simple diets increases voluntary feed intake and improves N utilization (based on PUN data) to cause an increased growth rate that is similar to the growth rate expected with a complex diet.

The plasma zinc concentrations of pigs fed both simple and complex diets with 3000 mg/kg added Zn were only two times higher than those of pigs fed both simple and complex diets without additional Zn. This suggests that a large portion of the Zn provided as ZnO is not absorbed but remains in the intestinal tract and eventually is excreted in the feces. It also suggests a gastrointestinal tract mode of action rather than a systemic mode of action for ZnO's improvement of pig performance.

Plasma urea nitrogen concentrations (day 10) were lower when pigs were fed complex diets with no differences found in PUN among complex diets. Feeding 3000 mg/kg Zn as ZnO decreased plasma urea nitrogen concentration on day 10 compared to feeding no additive or 165 mg/kg APR when pigs were fed simple diets. Feeding pharmacological levels of Zn may allow the newly weaned pig to more efficiently utilize dietary protein for maintenance and growth.