INFLUENCE OF ADDED ZINC FROM ZINC SULFATE ON WEANLING PIG GROWTH PERFORMANCE AND PLASMA ZINC CONCENTRATION[1]

J. C. Woodworth, M. D. Tokach[2], J. L. Nelssen, R. D. Goodband, P. R. O'Quinn, and J. T. Sawyer

Summary

A total of 288 weanling pigs (13.4 lb and 18 d of age) was used in a 27 d growth assay to determine the effects of adding Zn from $ZnSO_4$ or ZnO on growth performance. Pigs were allotted to one of eight dietary treatments consisting of a control diet; diets containing one of six concentrations of Zn from $ZnSO_4$ (500, 1,000, 1,500, 2,000, 2,500, or 3,000 ppm); and a diet containing 3,000 ppm of Zn from ZnO. Increasing Zn from $ZnSO_4$ linearly improved ADG and F/G from d 9 to 19; however, adding $ZnSO_4$ to the diet decreased ADG from d 19 to 33. Thus, pigs fed diets containing $ZnSO_4$ or 3,000 ppm of Zn from ZnO had similar growth performance compared to pigs fed the control diet for the overall trial. In conclusion, no benefit was observed for the overall trial from adding increasing concentrations of Zn from $ZnSO_4$ or 3,000 ppm of Zn from ZnO.

(Key Words: Early-Weaned Pigs, Growth, Zinc)

Introduction

The benefits to growth performance from adding high (3,000 ppm) levels of Zn from ZnO are well known. However, similar results have not been reported from feeding the same levels of other Zn sources, such as $ZnSO_4$. Previous research also has shown that the availability of Zn from ZnO can be as much as 50% lower than the availability of Zn from $ZnSO_4$. Thus, one possible explanation for why high levels of Zn from $ZnSO_4$ do not support added growth performance similar to high levels of Zn from ZnO is because the pigs fed high levels of $ZnSO_4$ might have a borderline Zn toxicity that impairs growth performance.

Other research conducted at the University of Illinois has concluded that plasma Zn concentrations of 1.5 to 3.0 mg/L were correlated with increased growth performance of pigs. In a previous trial conducted at Kansas State University, pigs fed 3,000 ppm of Zn from ZnO had higher ADG and ADFI compared to those fed increasing concentrations (100 to 500 ppm) of Zn from $ZnSO_4$. However, pigs fed the diet containing $ZnSO_4$ did have improved growth performance compared to pigs fed only 165 ppm of Zn from ZnO in the trace mineral premix. Only pigs fed the diet containing 3,000 ppm of Zn from ZnO had plasma Zn concentrations above 1.5 mg/L. The current trial was designed to determine if feeding lower levels of a more available Zn source ($ZnSO_4$) would elicit similar growth performance as feeding high levels of ZnO by measuring growth and correlating it to plasma Zn concentrations.

Procedures

A total of 288 weanling pigs (initially 13.4 lb and 18 d of age; PIC) was blocked by initial weight and allotted randomly to each of eight dietary treatments in a 33 d growth

[1]Appreciation is expressed to Henry's Ltd. for supplying the pigs for this experiment and to Colin Bradley of the London Health Sciences Centre, London, Ontario, Canada for conducting the plasma Zn analysis.

[2]Northeast Area Extension Office, Manhattan, KS.

assay. Each treatment had eight replications (pens) per treatment and four or five pigs per pen.

All experimental diets (Table 1) were fed in meal form, in four phases (d 0 to 5, 5 to 9, 9 to 19, and 19 to 33) with decreasing specialty protein sources and nutrient concentrations in each subsequent phase. The eight experimental diets consisted of a control diet, six diets containing increasing (500, 1,000, 1,500, 2,000, 2,500, or 3,000 ppm) Zn from $ZnSO_4$; and a positive control diet containing 3,000 ppm of Zn from ZnO. All diets contained 165 ppm of Zn from ZnO provided by the trace mineral premix and were formulated with no feed grade medication. Pigs were fed the same experimental Zn concentrations throughout the 33 d study. Zinc sulfate and ZnO replaced cornstarch in the control diet to form the experimental treatments.

Pigs were housed in the Kansas State University segregated early-weaning facility. Each pen was 4 × 4 ft and contained one nipple waterer and one self-feeder to provide ad libitum access to feed and water. Initial temperature of the nursery was 90°F and was lowered approximately 3°F each week thereafter.

Pigs were weighed and feed disappearance was determined at weaning and on d 5, 9, 19, 26, and 33 after to calculate ADG, ADFI, and F/G. Two pigs per pen were selected randomly and bled on d 9, 19, and 33 to determine plasma Zn concentration. Samples were centrifuged, and the plasma from the two pigs in each pen was pooled for analysis.

Data were analyzed as a randomized complete block design with pen as the experimental unit. Linear, quadratic, and cubic polynomials were used to evaluate increasing concentrations of $ZnSO_4$. Orthogonal contrasts were used to investigate the mean differences between the basal control diet, the mean of diets containing $ZnSO_4$, and the positive control diet.

Results and Discussion

From d 0 to 9, ADG tended to be lower ($P<.09$) and ADFI was lower ($P<.006$) for the mean of pigs fed diets containing $ZnSO_4$ compared to pigs fed the control diet or the diet containing 3,000 ppm of Zn from ZnO. Feed to gain ratio tended to be poorer ($P<.09$) for pigs fed the positive control diet compared to the mean of pigs fed diets containing $ZnSO_4$. Average daily gain, ADFI, and F/G were similar ($P>.10$) for pigs fed the control diet compared to pigs fed 3,000 ppm of Zn from ZnO. Increasing the concentration of $ZnSO_4$ did not affect ($P>.10$) ADG, ADFI, or F/G.

From d 9 to 19, ADG was similar ($P>.10$) for pigs fed the control diet, the diet containing 3,000 ppm of Zn from ZnO, and the mean of pigs fed diets containing $ZnSO_4$. Average daily gain increased (linear, $P<.05$) for pigs fed diets containing increasing concentrations of $ZnSO_4$. Average daily feed intake tended to be greater ($P<.09$) for pigs fed the positive control diet compared to the mean of pigs fed diets containing $ZnSO_4$, but was similar ($P>.10$) to that of pigs fed the control diet. Feed to gain ratio was similar ($P>.51$) for pigs fed the control diet compared to pigs fed diets containing 3,000 ppm of Zn from ZnO, but pigs fed either diet had poorer ($P<.06$) F/G compared to the mean of pigs fed diets containing $ZnSO_4$. Average daily feed intake and F/G tended to improve ($P<.10$) when pigs were fed diets containing increasing concentrations of $ZnSO_4$.

From d 19 to 33, pigs fed the control diet had greater ($P<.01$) ADG compared to the mean of pigs fed diets containing $ZnSO_4$ and tended to have greater ($P<.08$) ADG compared to pigs fed diets containing 3,000 ppm of Zn from ZnO. Average daily feed intake tended to be greater ($P<.10$) for pigs fed the control diet compared to the mean of pigs fed diets containing $ZnSO_4$. Pigs fed the control diet, diets containing 3,000 ppm of Zn from ZnO, or the mean of pigs fed diets containing $ZnSO_4$ had similar ($P<.10$) F/G. Increasing the concentration of $ZnSO_4$ did not affect

(P>.10) ADG or ADFI; however, F/G decreased then increased then decreased (cubic, P<.05) with increasing $ZnSO_4$, and pigs fed 1,000 ppm of Zn from $ZnSO_4$ had the best F/G.

Overall, from d 0 to 33, ADG was not influenced (P>.10) by Zn source or level. Average daily feed intake tended to be greater (P<.08) for pigs fed the control diet compared to the mean of pigs fed diets containing $ZnSO_4$. Pigs fed the diet containing 3,000 ppm of Zn from ZnO had similar (P >.10) ADFI compared to either the pigs fed the control diet or the mean of pigs fed diets containing $ZnSO_4$. Feed to gain ratio was similar (P > .10) for pigs fed the control diet, the mean of pigs fed diets containing $ZnSO_4$, and pigs fed the diet containing 3,000 ppm of Zn from ZnO. Similar to d 19 to 33, increasing the concentration of Zn from $ZnSO_4$ decreased then increased then decreased (cubic, P<.05) F/G, and pigs fed the diets containing 1,000 or 3,000 ppm of Zn from $ZnSO_4$ had the best F/G.

Plasma Zn concentrations on d 9 and 19 were lowest (P<.0001) for pigs fed the control diet and highest (P<.0001) for pigs fed the diet containing 3,000 ppm of Zn from ZnO, and the mean of pigs fed diets containing $ZnSO_4$ was intermediate. On d 33, the plasma Zn concentration was lowest (P<.0001) for pigs fed the control diet compared to either the mean of pigs fed diets containing $ZnSO_4$ or pigs fed the diet containing 3,000 ppm of Zn from ZnO. Increasing the concentration of Zn from $ZnSO_4$ increased (linear, P<.05) the plasma Zn concentrations on d 9, 19, and 33. Plasma Zn concentrations increased on d 19 and 13 only for pigs fed diets containing greater than 1,500 ppm of Zn from $ZnSO_4$ (cubic, P<.10) but plateaued on d 33 for pigs fed at least 2,500 ppm of Zn (cubic, P<.05).

These results suggest that overall growth performance of pigs did not benefit from diets containing increasing concentrations of Zn from $ZnSO_4$ or 3,000 ppm of Zn from ZnO. Pigs fed the basal control diet containing 165 ppm of Zn from ZnO provided by the trace mineral premix exhibited excellent growth performance for the duration of the trial. The lack of an added growth response from pigs fed diets containing 3,000 ppm of Zn from ZnO was possibly a reflection of the high health status of the pigs used in this experiment because one possible mode of action of the growth promoting response of high levels of Zn from ZnO is to prevent the occurrence of *E. coli* scours. These results also do not support those previously reported because no distinct correlation occurred between plasma Zn concentration and growth performance. From d 9 to 19, ADG numerically increased as plasma Zn concentration increased; however, no significant improvement in growth performance occurred when plasma Zn was higher than 1.5 mg/L.

In this experiment, pigs fed diets containing any concentration of $ZnSO_4$ from d 0 to 9 had lower ADFI compared to pigs fed either the control diet or pigs fed the diet containing 3,000 ppm of Zn from ZnO. Similarly, previous research conducted at Kansas State University reported that pigs fed 100 to 400 ppm of Zn from $ZnSO_4$ or the combination of $ZnSO_4$ and ZnO had lower feed intakes compared to pigs fed diets containing either no added Zn or 3,000 ppm of Zn from ZnO. More research needs to be conducted to determine the reason for this poor response to $ZnSO_4$.

Table 1. Diet Compositions (As-Fed Basis)

Ingredient, %	Day 0 to 5	Day 5 to 9	Day 9 to 19	Day 19 to 33
Corn	38.34	45.31	51.60	58.37
Dried whey	25.00	20.00	10.00	-
Soybean meal (46.5% CP)	12.18	21.30	28.50	34.39
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	3.00
Spray-dried blood meal	1.75	2.50	2.50	-
Monocalcium phosphate	.70	1.27	1.60	1.48
Limestone	.51	.77	1.0	.97
Cornstarch[a]	.85	.85	.85	.85
Salt	.25	.30	.30	.35
Vitamin premix	.25	.25	.25	.25
Trace mineral premix[b]	.15	.15	.15	.15
L-Lysine HCL	.15	.15	.15	.15
DL-Methionine	.12	.15	.10	.04
Total	100.00	100.00	100.00	100.00
Calculated analysis, %				
Lysine	1.70	1.55	1.40	1.30
Methionine	.48	.44	.39	.36
Ca	.90	.90	.85	.75
P	.80	.80	.75	.70

[a]Zn sources replaced corn starch to provide 500, 1,000, 1,500, 2,000, 2,500, or 3,000 ppm of Zn from $ZnSO_4$, or 3,000 ppm of Zn from ZnO.
[b]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn from ZnO; 15 g Cu; 70 mg I; and 270 mg Se.

Table 2. Effects of Zinc from Increasing Levels of Zinc Sulfate on Weanling Pig Growth Performance[a,b]

		Zn from $ZnSO_4$						Zn from ZnO		Contrasts, P <[c]		
Item	Control	500	1,000	1,500	2,000	2,500	3,000	3,000	SEM	1	2	3
Day 0 to 9												
ADG, lb	.38	.29	.33	.35	.31	.34	.30	.38	.032	.09	.97	.08
ADFI, lb	.46	.34	.37	.40	.36	.38	.33	.48	.031	.006	.72	.002
F/G	1.22	1.19	1.19	1.16	1.23	1.15	1.11	1.27	.055	.37	.53	.09
Day 9 to 19												
ADG, lb[d]	.72	.72	.71	.78	.81	.82	.82	.76	.036	.13	.40	.67
ADFI, lb[e]	.94	.91	.87	1.00	.94	.98	.99	1.02	.039	.85	.14	.09
F/G[e]	1.32	1.30	1.24	1.29	1.17	1.21	1.19	1.35	.040	.06	.51	.008
Day 19 to 33												
ADG, lb	1.35	1.20	1.32	1.23	1.20	1.26	1.23	1.26	.036	.01	.08	.72
ADFI, lb	1.97	1.90	1.91	1.82	1.87	1.92	1.81	1.92	.054	.10	.49	.45
F/G[g]	1.46	1.59	1.45	1.49	1.55	1.52	1.47	1.53	.046	.34	.29	.67
Day 0 to 33												
ADG, lb	.89	.81	.86	.85	.84	.88	.85	.87	.024	.11	.47	.49
ADFI, lb	1.22	1.15	1.12	1.15	1.13	1.20	1.11	1.21	.040	.08	.92	.11
F/G[g]	1.37	1.42	1.30	1.35	1.34	1.37	1.29	1.40	.036	.56	.52	.16
Plasma, mg/L												
Day 9[d]	.71	.74	.76	1.05	1.13	1.45	1.59	1.77	.092	.0001	.0001	.0001
Day 19[df]	.92	.88	.81	1.22	1.49	1.96	2.19	1.82	.103	.0001	.0001	.0009
Day 33[dg]	1.12	1.21	1.16	1.23	1.86	2.29	2.22	1.91	.116	.0001	.0001	.06

[a]A total of 288 pigs (initially 13.4 lb and 18 d of age) with 4 or 5 pigs per pen and 8 pens per treatment.
[b]All diets contained 165 ppm of Zn from ZnO provided by the trace mineral premix.
[c]Contrasts were: 1) Control vs $ZnSO_4$, 2) Control vs 3,000 ppm of Zn from ZnO, and 3) $ZnSO_4$ vs 3,000 ppm of Zn from ZnO.
[d]Linear $ZnSO_4$, $P<.05$.
[e]Linear $ZnSO_4$, $P<.10$.
[f]Quadratic and Cubic $ZnSO_4$, $P < .10$.
[g]Cubic $ZnSO_4$, $P<.05$.