# INFLUENCE OF HIGH LEVELS OF ZINC FROM ZINC OXIDE, ZINC SULFATE, OR A ZINC AMINO ACID COMPLEX ON STARTER PIG PERFORMANCE [1]

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## Summary

Three hundred and sixty early-weaned barrows were fed either a control diet; diets containing added Zn (100, 200, 300, 400, or 500 ppm) from zinc sulfate or a zinc amino acid complex (AvailaZn); or a diet containing 3,000 ppm of additional Zn from zinc oxide. All diets contained 165 ppm of Zn from zinc oxide from the trace mineral premix. Pigs fed 3,000 ppm of Zn from zinc oxide had maximum growth performance compared to those fed other diets, whereas those fed added zinc sulfate and AvailaZn showed intermediate results relative to the negative control and the 3,000 ppm of Zn from zinc oxide diet. These results support previous Kansas State University research showing maximum performance being achieved with additions of 3,000 ppm of Zn from zinc oxide. Further research is needed to evaluate the intermediate response to zinc sulfate and AvailaZn and determine whether the benefits in ADG and F/G were due to a growth promotion response or whether the starter pig has a higher Zn requirement than met by the negative control (165 ppm Zn from zinc oxide).

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

## Introduction

Several experiments have demonstrated the benefits in daily gain and feed efficiency from adding high levels of Zn (3,000 ppm) from zinc oxide to starter diets. The same growth response with zinc sulfate has not been observed consistently. One study found no benefit in daily gain from adding 3,000 ppm of Zn from zinc methionine or zinc sulfate to the starter diet, but 3,000 ppm of Zn from zinc oxide improved pig performance. The difference in bioavailability may have caused the plasma Zn levels to become too high for pigs fed the zinc sulfate and methionine sources compared to zinc oxide. Recent research has suggested that a lower level of Zn (250 ppm) from a zinc amino acid complex (Zn Met or AvailaZn) will improve performance in a similar manner as high levels of zinc oxide (2,000 ppm). The trials finding this response had control diets containing 250 ppm of Zn from zinc sulfate from d 0 to 13 after weaning and 160 ppm of Zn from zinc sulfate from d 13 to 35. A question remains whether the benefits to the zinc amino acid complex were due to the 250 ppm of Zn from the complex or to the total Zn level of 410 to 500 ppm from zinc sulfate plus the complex.

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## Procedures

A total of 360 weanling barrows (initially 9.30 lb and 12 ± 2 d of age; Newsham Hybrids) was used in a 20-d growth assay. Pigs were blocked by initial weight and allotted randomly to each of 12 dietary treatments. Each treatment had five pigs per pen and six replications (pens) per treatment.

The 12 experimental diets consisted of a negative control diet containing 165 ppm of Zn from zinc oxide in the trace mineral premix; five diets containing added zinc sulfate (100, 200, 300, 400, and 500 ppm of Zn); five diets containing added zinc amino acid complex (100, 200, 300, 400, and 500 ppm of Zn); and a positive control diet containing 3,000 ppm of Zn from zinc oxide. The zinc amino acid complex used in this trial was AvailaZn, which is produced by the ZinPro Corporation.

All experimental diets were fed in meal form. Diets fed from d 0 to 5 after weaning were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P (Table 1). Diets fed from d 5 to 10 were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P. Diets fed from d 10 to 20 were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P. The zinc sulfate, AvailaZn, or zinc oxide replaced cornstarch in the control diet to provide the additional Zn. Pigs were fed the same experimental Zn concentrations throughout the 20 d study.

Pigs were weighed and feed disappearance was determined on d 0, 5, 10, and 20 to calculate ADG, ADFI, and F/G. Feed samples were collected and analyzed to determine Zn concentration. Two pigs per pen were selected randomly and bled on d 20 to determine serum Zn concentrations. Serum Zn values (Table 3) represent the treatment means of pooled samples from the two pigs per pen.

Data were analyzed as a randomized complete block design in a 2 × 5 factorial with two control diets. Linear and quadratic values were evaluated for zinc sulfate and AvailaZn including the negative control. Data were analyzed for main effects (Zn source and level) and two-way interactions. Contrast statements were used to investigate the mean differences between pigs fed the two control diets and the other diets.

## Results and Discussion

From d 0 to 5 and 5 to 10, no differences (P>.05, Tables 3 and 4) were observed among treatments. Pigs fed 100 ppm of Zn from AvailaZn had the highest numerical ADG and ADFI (.28 lb and .34 lb respectively, Table 2) but were not different (P>.10) from pigs in other treatments.

From d 10 to 20, ADG was highest (P<.02) for pigs fed the positive control diet containing 3,000 ppm of Zn from zinc oxide and lowest (P<.01) for pigs fed the negative control diet, whereas pigs fed zinc sulfate or AvailaZn had intermediate responses. Average daily gain increased then decreased for pigs fed AvailaZn (quadratic, P<.05), with pigs fed 200 ppm of added Zn having the greatest improvement. Increasing zinc sulfate had no effect (P>.05) on growth performance, but pigs fed the diet containing 100 ppm of added Zn had numerically the highest ADG. Source or level of Zn from d 10 to 20 did not affect average daily feed intake. Feed efficiency was improved (P<.01) for pigs fed the diet containing 3,000 ppm of Zn from zinc oxide compared to the other treatments. Feed efficiency worsened (linear, P<.02) for pigs fed diets containing increasing zinc sulfate, with the best F/G observed for pigs fed 100 ppm of added Zn. Pigs fed diets containing increasing AvailaZn had decreasing then increasing (quadratic, P<.02) F/G, with the best F/G observed in pigs fed 300 ppm of added Zn.

Cumulative results (d 0 to 20) resembled those for d 10 to 20. Average daily gain was greater (P<.05) for pigs fed the positive control diet compared to diets containing zinc sulfate or the negative control and tended to be higher (P<.07) compared to pigs fed diets containing AvailaZn. Average daily feed intake was not affected by Zn level or source. Feed efficiency was best (P<.04) for pigs fed the positive control diet compared to other sources. Pigs fed the diets containing added AvailaZn had decreasing then increasing (quadratic, P<.05) F/G, with pigs fed the diet containing 300 ppm of added Zn having the best F/G.

Analyzed dietary Zn concentrations (Table 2) generally increased with increasing Zn supplementation. However, some analyzed Zn concentrations showed considerable differences from calculated values. These differences could be due to the 20% variation permitted for Zn analysis.

Serum Zn levels were highest (P<.0001) for pigs fed the positive control (Table 3 and 4). No statistical difference (P>.05) occurred between the other treatments.

In conclusion, our results support previous research at Kansas State University showing maximum growth performance being achieved by including 3,000 ppm of Zn from zinc oxide to the starter diet. Pigs fed zinc sulfate and AvailaZn had intermediate performance, with improved ADG and F/G compared to the pigs fed the negative control but lower ADG than pigs fed the positive control with 3,000 ppm of Zn from zinc oxide. Further research is needed to evaluate the intermediate response to zinc sulfate and AvailaZn and determine whether the benefits in ADG and F/G were due to a growth promotion response or whether the starter pig has a higher Zn requirement than met by the negative control. Further research also is needed to determine whether a higher level of bioavailable Zn from an inorganic source is required to elicit the full response observed with organic Zn sources.

**Table 1. Diet Compositions (As-Fed Basis)**

| Ingredient, % | Day 0 to 5[a] | Day 5 to 10[b] | Day 10 to 20[c] |
|---|---|---|---|
| Corn | 38.69 | 45.61 | 51.95 |
| 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 | .69 | 1.26 | 1.59 |
| Limestone | .50 | .76 | .99 |
| Cornstarch[d] | .50 | .50 | .50 |
| Salt | .25 | .30 | .30 |
| Vitamin premix | .25 | .25 | .25 |
| L-Lysine HCL | .15 | .15 | .15 |
| Trace mineral premix[e] | .15 | .15 | .15 |
| DL-Methionine | .12 | .15 | .10 |
| Total | 100.00 | 100.00 | 100.00 |

[a]Diets were formulated to contain 1.70% lysine, .48% methionine, .90% Ca, and .80% P and were fed from d 0 to 5 after weaning.
[b]Diets were formulated to contain 1.55% lysine, .44% methionine, .90% Ca, and .80% P and were fed from d 5 to 10.
[c]Diets were formulated to contain 1.40% lysine, .39% methionine, .85% Ca, and .75% P and were fed from d 10 to 20.
[d]Zinc sulfate or AvailaZn replaced corn starch to provide an additional 100, 200, 300, 400, or 500 ppm of Zn. Zinc oxide replaced cornstarch to provide an additional 3,000 ppm of Zn.
[e]Provided per ton of complete feed: 36 g Mn; 150 g Fe; 150 g Zn from ZnO; 15 g Cu; 270 mg I; and 270 mg Se.

**Table 2. Analyzed Zinc Concentrations (ppm) of Formulated Diets[a]**

| | | Zinc from Zinc Sulfate (ppm) | | | | | Zinc from AvailaZn (ppm) | | | | | Zinc from ZnO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control[b] | 100 | 200 | 300 | 400 | 500 | 100 | 200 | 300 | 400 | 500 | 3,000 ppm |
| Day 0 to 5 | | | | | | | | | | | | |
| Zn | 172 | 312 | 339 | 582 | 559 | 809 | 326 | 362 | 466 | 703 | 739 | 3,627 |
| Day 5 to 10 | | | | | | | | | | | | |
| Zn | 204 | 324 | 407 | 436 | 505 | 773 | 335 | 416 | 559 | 607 | 774 | 3,475 |
| Day 10 to 20 | | | | | | | | | | | | |
| Zn | 255 | 298 | 337 | 461 | 586 | 660 | 318 | 425 | 412 | 629 | 819 | 3,150 |

[a]Values (as-fed basis) represent analysis of one sample per diet for each time period. [b]All diets contained an additional 165 ppm of Zn from zinc oxide as part of the trace mineral premix.

**Table 3. Influence of High Levels of Zinc from Zinc Oxide, Zinc Sulfate, or AvailaZn on Starter Pig Performance[a]**

| | | Zinc from Zinc Sulfate (ppm) | | | | | Zinc from AvailaZn (ppm) | | | | | Zinc from Zinc Oxide |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Control[b] | 100 | 200 | 300 | 400 | 500 | 100 | 200 | 300 | 400 | 500 | 3,000 ppm |
| Day 0 to 5 | | | | | | | | | | | | |
| ADG, lb | 0.21 | 0.21 | 0.22 | 0.24 | 0.18 | 0.21 | 0.28 | 0.22 | 0.19 | 0.20 | 0.24 | 0.20 |
| ADFI, lb | 0.23 | 0.24 | 0.26 | 0.25 | 0.22 | 0.26 | 0.34 | 0.25 | 0.24 | 0.23 | 0.26 | 0.27 |
| F/G | 1.14 | 1.14 | 1.20 | 1.04 | 1.19 | 1.30 | 1.20 | 1.18 | 1.32 | 1.15 | 1.10 | 1.39 |
| Day 5 to 10 | | | | | | | | | | | | |
| ADG, lb | 0.36 | 0.36 | 0.36 | 0.30 | 0.37 | 0.38 | 0.37 | 0.36 | 0.41 | 0.36 | 0.39 | 0.39 |
| ADFI, lb | 0.56 | 0.55 | 0.60 | 0.56 | 0.56 | 0.63 | 0.63 | 0.59 | 0.58 | 0.54 | 0.59 | 0.57 |
| F/G | 1.52 | 1.52 | 1.67 | 1.89 | 1.52 | 1.69 | 1.72 | 1.67 | 1.41 | 1.56 | 1.52 | 1.45 |
| Day 0 to 10 | | | | | | | | | | | | |
| ADG, lb | 0.28 | 0.28 | 0.29 | 0.27 | 0.28 | 0.29 | 0.32 | 0.29 | 0.30 | 0.28 | 0.32 | 0.30 |
| ADFI, lb | 0.40 | 0.39 | 0.43 | 0.40 | 0.39 | 0.45 | 0.48 | 0.42 | 0.41 | 0.39 | 0.43 | 0.42 |
| F/G | 1.39 | 1.39 | 1.47 | 1.47 | 1.41 | 1.54 | 1.49 | 1.47 | 1.37 | 1.39 | 1.35 | 1.43 |
| Day 10 to 20 | | | | | | | | | | | | |
| ADG, lb | 0.70 | 0.83 | 0.78 | 0.78 | 0.80 | 0.78 | 0.77 | 0.81 | 0.79 | 0.78 | 0.75 | 0.88 |
| ADFI, lb | 1.09 | 1.08 | 1.10 | 1.08 | 1.05 | 1.11 | 1.13 | 1.13 | 1.05 | 1.04 | 1.10 | 1.16 |
| F/G | 1.56 | 1.30 | 1.41 | 1.39 | 1.32 | 1.41 | 1.45 | 1.39 | 1.32 | 1.33 | 1.47 | 1.32 |
| Day 0 to 20 | | | | | | | | | | | | |
| ADG, lb | 0.49 | 0.56 | 0.53 | 0.52 | 0.54 | 0.53 | 0.55 | 0.55 | 0.55 | 0.53 | 0.53 | 0.59 |
| ADFI, lb | 0.74 | 0.74 | 0.76 | 0.74 | 0.72 | 0.78 | 0.81 | 0.77 | 0.73 | 0.71 | 0.76 | 0.79 |
| F/G | 1.49 | 1.33 | 1.43 | 1.43 | 1.33 | 1.45 | 1.47 | 1.41 | 1.33 | 1.35 | 1.43 | 1.35 |
| Day 20 Serum[c] | | | | | | | | | | | | |
| Zn, mg/L | 1.13 | 1.11 | 1.10 | 1.09 | 1.03 | 1.11 | 1.10 | 0.99 | 1.07 | 1.09 | 1.14 | 2.46 |

[a]A total of 360 weanling pigs (initially 9.30 lb and 12 d of age), five pigs per pen and six pens per treatment. [b]All diets contained an additional 165 ppm of Zn from zinc oxide as part of the trace mineral premix. [c]Values represent treatment means of pooled samples from two pigs per pen.

**Table 4. Statistical Analysis of Mean Values (P <)**

| | Zn Sulfate | | AvailaZn | | Interaction | | | | Contrasts, (P <)[a] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Linear | Quad. | Linear | Quad. | Source | Level | Source × Level | CV | 1 | 2 | 3 | 4 | 5 |
| Day 0 to 5 | | | | | | | | | | | | | |
| ADG | .87 | .27 | .77 | .59 | .47 | .41 | .25 | 29.1 | .86 | .50 | .37 | .81 | .64 |
| ADFI | .72 | .26 | .31 | .67 | .12 | .06 | .08 | 19.8 | .17 | .17 | .69 | .64 | .19 |
| F/G | .74 | .66 | .83 | .33 | .56 | .97 | .18 | 24.6 | .21 | .69 | .22 | .95 | .12 |
| Day 5 to 10 | | | | | | | | | | | | | |
| ADG | .63 | .49 | .79 | .91 | .42 | .96 | .45 | 27.5 | .58 | .75 | .69 | .86 | .37 |
| ADFI | .96 | .64 | .76 | .80 | .77 | .63 | .56 | 16.8 | .79 | .55 | .80 | .68 | .94 |
| F/G | .44 | .22 | .66 | .82 | .46 | .97 | .10 | 21.5 | .70 | .72 | .39 | .44 | .21 |
| Day 0 to 10 | | | | | | | | | | | | | |
| ADG | .65 | .84 | .92 | .89 | .29 | .66 | .84 | 20.4 | .70 | .53 | .89 | .98 | .61 |
| ADFI | .90 | .41 | .57 | .73 | .40 | .27 | .23 | 15.4 | .46 | .32 | .97 | .62 | .65 |
| F/G | .61 | .48 | .54 | .49 | .53 | .94 | .38 | 14.6 | .70 | .68 | .94 | .45 | .80 |
| Day 10 to 20 | | | | | | | | | | | | | |
| ADG | .15 | .15 | .40 | .05 | .59 | .86 | .66 | 10.3 | .0003 | .03 | .008 | .01 | .02 |
| ADFI | .57 | .70 | .48 | .85 | .95 | .45 | .87 | 10.7 | .29 | .91 | .14 | .87 | .13 |
| F/G | .02 | .22 | .11 | .02 | .46 | .22 | .26 | 8.9 | .003 | .01 | .20 | .003 | .38 |
| Day 0 to 20 | | | | | | | | | | | | | |
| ADG | .39 | .24 | .51 | .19 | .87 | .89 | .92 | 10.9 | .006 | .07 | .07 | .09 | .05 |
| ADFI | .67 | .56 | .48 | .99 | .71 | .32 | .67 | 11.1 | .31 | .76 | .31 | .94 | .21 |
| F/G | .12 | .56 | .09 | .05 | .81 | .24 | .08 | 7.5 | .02 | .04 | .30 | .03 | .36 |
| Day 20 Serum | | | | | | | | | | | | | |
| Zn | .26 | .74 | .90 | .07 | .77 | .58 | .65 | 16.7 | .0001 | .56 | .0001 | .64 | .0001 |

[a]Contrasts were 1) neg control vs 3,000 ppm of Zn (ZnO), 2) neg control vs AvailaZn, 3) 3,000 ppm of Zn (ZnO) vs AvailaZn, 4) neg control vs Zn sulfate, and 5) 3,000 ppm of Zn (ZnO) vs Zn sulfate.