Effects of replacing pharmacological levels of dietary zinc oxide with lower dietary levels of various organic zinc sources for weanling pigs

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Effects of replacing pharmacological levels of dietary zinc oxide with lower dietary levels of various organic zinc sources for weanling pigs[1,2]

G. R. Hollis, S. D. Carter, T. R. Cline[3], T. D. Crenshaw, G. L. Cromwell, G. M. Hill, S. W. Kim, A. J. Lewis, D. C. Mahan, P. S. Miller, H. H. Stein, and T. L. Veum

NCR-42 Committee on Swine Nutrition[4,5]

ABSTRACT: Two 28-d randomized complete block design experiments were conducted to evaluate the effects of concentrations and sources of Zn on growth performance of nursery pigs. Seven stations participated in Exp. 1, which evaluated the efficacy of replacing 2,500 ppm of Zn from ZnO with 125, 250, or 500 ppm of Zn from Zn methionine. A control diet with 125 ppm of supplemental Zn was included at all stations. A total of 615 pigs were used in 26 replicates. Average weaning age was 20.6 d and the average initial BW was 6.3 kg. There were no differences in any growth response among the three supplemental Zn methionine levels fed in Exp. 1. Zinc supplementation from Zn methionine improved ADG compared with the control during all phases ($P < 0.05$), due primarily to an increase in ADFI. Pigs fed 2,500 ppm of Zn from ZnO gained faster ($P < 0.01$) than those fed the control diet during all phases, and faster ($P < 0.05$) than those fed supplemental Zn from Zn methionine for the 28-d experiment. Differences in gain were again due mainly to differences in feed intake. A second experiment compared five sources of supplemental organic Zn (500 ppm of Zn) with 500 and 2,000 ppm supplemental Zn from ZnO and a control (140 ppm total Zn). Six stations used a total of 624 pigs, with an average weaning age of 20.4 d and averaging 6.2 kg BW in 15 replicates. Pigs fed 2,000 ppm of Zn from ZnO gained faster ($P < 0.05$) than pigs fed the control or any of the 500 ppm of Zn treatments (ZnO or organic Zn). Pigs fed the 2,000 ppm of Zn from ZnO also consumed more feed than those receiving 500 ppm of Zn from ZnO or from any of the organic Zn sources ($P < 0.05$). Organic sources of Zn did not improve gain, feed intake, or feed efficiency beyond that achieved with the control diet. Supplemental Zn at a concentration of 500 ppm, whether in the form of the oxide or in an organic form, was not as efficacious for improved ADG as 2,000 to 2,500 ppm of Zn from ZnO.

Key Words: Organic Zinc, Weanling Pigs, Zinc

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Introduction

During the late 1980s, it was discovered that feeding pharmacological concentrations of ZnO to weanling pigs resulted in reduced diarrhea and increased growth rates (Poulsen, 1989). Subsequent research demonstrated that dietary levels of 2,000 to 4,000 ppm of Zn from ZnO enhanced pig growth responses even when scours were not a problem in weaned pigs (Poulsen, 1995; Smith et al., 1997; Hill et al., 2000). It also was suggested that ZnO was the only inorganic form of Zn that produced these results (Hahn and Baker, 1993; McCully et al., 1995; Schell and Kornegay, 1996). Recent data have indicated that organic Zn sources can be added to pig nursery diets at dietary concentrations below the pharmacological concentrations of ZnO com-

[1]Appreciation is extended to Akey, Inc., Lewisburg, OH 45338 for supplying the zinc premixes for this study.

[2]Each station followed the approved experimental procedures for their respective animal care committees.

[3]Correspondence: Dept. of Anim. Sci., Purdue Univ., West Lafayette, IN 47907-2054 (phone: 765-494-4846; fax: 765-494-9346; e-mail: tcline@purdue.edu).

[4]Affiliation of authors at the time of the study: G. R. Hollis, Univ. of Illinois, Urbana; S. D. Carter, Oklahoma State Univ., Stillwater; T. R. Cline, Purdue Univ., West Lafayette, IN; T. D. Crenshaw, Univ. of Wisconsin, Madison; G. L. Cromwell, Univ. of Kentucky, Lexington; G. M. Hill, Michigan State University, East Lansing; S. W. Kim, Texas Tech Univ., Lubbock; A. J. Lewis, Univ. of Nebraska, Lincoln; D. C. Mahan, The Ohio State Univ., Columbus; P. S. Miller, Univ. of Nebraska, Lincoln; H. H. Stein, South Dakota State Univ., Brookings; and T. L. Veum, Univ. of Missouri, Columbia.

[5]Other members of the NCR-42 Committee at the time the trial was conducted: R. C. Ewan, Iowa State Univ., Ames; J. L. Nelssen, Kansas State Univ., Manhattan; G. C. Shurson, Univ. of Minnesota, St. Paul; and J. T. Yen (deceased), ARS-USDA, Clay Center, NE. The administrative advisor during the conduct of the study was R. A. Easter, Univ. of Illinois, Urbana.

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monly used in pig starter diets and still produce similar growth performance benefits (Ward et al., 1997; Fakler, et al., 1998; Case and Carlson, 2002). Lower concentrations of added dietary Zn would lessen the environmental risk from soil application of swine manure.

The objective of this research was to further evaluate the efficacy of lower levels (500 ppm) of Zn from several organic sources of Zn compared with pharmacological levels (2,000 to 2,500 ppm) of inorganic Zn from ZnO on performance of weanling pigs.

Materials and Methods

Two experiments were conducted by the North Central Regional (NCR-42) Swine Nutrition Committee. All stations followed procedures approved by their respective animal care and use committees.

Experiment 1

The first experiment evaluated the efficacy of replacing 2,500 ppm of Zn from ZnO (Prince Agri Products, Inc., Quincy, IL) with 125, 250, or 500 ppm concentrations of Zn from Zn methionine (Zinpro 100, Zinpro, Inc., Eden Prairie, MN). The feed-grade ZnO was a standard commercial product (Zinc Nacional S.A., Monterrey, Mexico) manufactured by the Waelz process (Mavromichalis et al., 2000), with a guaranteed concentration of 72% Zn. A control treatment, which contained only the Zn present in the trace mineral premix was included. Zinc sources in the trace mineral premix varied among stations.

Seven university research stations participated in the study (IL, KY, MI, MO, OH, OK, and WI). One station conducted their study at two different sites with different facilities. This was considered as an additional test station for a total of eight locations. The experiment was conducted as a randomized complete block design with 26 replicates. Each station conducted a minimum of two replicates at each site. Management and facility design varied by station, but the procedures followed were the same within each replicate. A total of 615 crossbred pigs of various genetic crosses were weaned at an average age of 20.6 d, with an initial average BW of 6.3 kg. Pigs were allotted to treatment pens based on BW, sex, and litter, with an equal number of pigs allotted to treatment pens within each replicate. Pigs were housed in completely enclosed nursery facilities that contained either wire mesh or plastic-covered wire mesh floors, with room temperatures adjusted as needed to meet the comfort zone of the pig. Information and overall performance responses for each station are shown in Table 1.

Diets (Table 2) were provided to pigs in meal form on an ad libitum basis. Diets for the period from 0 to 14 d after weaning (Phase 1) were formulated (as-fed basis) to contain 1.40% total lysine, whereas the Phase 2 diets (14 to 28 d after weaning) were formulated to contain 1.25% total lysine. Vitamin and mineral premixes differed at each station, but each resulted in diets that met or exceeded NRC (1998) nutrient standards. Samples of each diet from each station were analyzed for Zn by one laboratory, and the basal diets averaged 125 and 122 ppm of Zn for the two phases, respectively. The analysis of treatment diets containing added Zn were close to calculated values in all cases and are not reported.

Experiment 2

Because of the better performance of the ZnO treatment group relative to the Zn methionine groups of Exp. 1, and because other organic Zn sources may respond differently in weaned pigs, a second experiment was conducted to evaluate the efficacy of various organic Zn sources compared with a feed-grade ZnO. The five commercially available organic Zn sources used were from each of the categories identified by AAFCO (2002). The Zn sources selected for this experiment are shown in Table 3.

The experiment evaluated the effects of replacing 2,000 ppm of Zn from ZnO with 500 ppm of Zn from each of the organic Zn sources (Table 3). In addition, a 500 ppm ZnO level and a control diet without added Zn (except that which was in the trace mineral premix) were included as treatment groups for a total of eight treatments. Diets (Table 2) were similar in composition to those of Exp. 1, except that when the organic Zn source was chelated or bound with an AA, dietary adjustments were made so that the AA concentrations were identical in each dietary treatment. Vitamins and other minerals were added as in Exp. 1 so that NRC (1998) standards were met or exceeded. The control diets fed from 0 to 14 and 14 to 28 d assayed 139 and 137 ppm of Zn, respectively. Treatment diets with added Zn were analyzed and were close to calculated values (data not reported).

The experiment was conducted as a randomized complete block design in 15 replicates with each station conducting a minimum of two replicates. A total of 624 crossbred pigs with an average weaning age of 20.4 d and averaging 6.2 kg BW was used in the trial. The experiment was conducted at six research stations (MI, MO, OH, SD, TX, and WI) using similar facilities and genotypes as in Exp. 1. Management and pig allotment procedures were similar to those in Exp. 1. Details of the facilities and overall pig performance responses for each of the research stations are reported in Table 1.

Zinc Analysis

Samples of all diets were sent to one laboratory for Zn analysis. The atomic absorption spectrophotometry method used followed AOAC (1995) procedures.

Statistical Analyses

The data from both experiments were analyzed using the ANOVA procedures outlined by Steel and Torrie

Table 1. Station, pig, and facility information and average pig performances

Item	Station[a] 1	2	3	4	5	6	7	8
	Exp. 1							
No. of replicates	4	2	2	3	3	4	3	4
No. of pigs	100	60	90	75	70	80	60	80
No. of pigs/pen	5	6	6	5	5	4	4	4
Pen space/pig, m^2	0.42	0.37	0.25	0.30	0.30	0.43	0.37	0.35
Weaning age, d	21.2	19.5	16.5	18.0	24.6	19.5	24.1	21.6
Initial BW, kg	6.4	6.3	4.7	6.5	7.0	6.2	6.9	6.1
ADG (0 to 28 d), g[b]	420	368	312	381	326	331	508	491
ADFI (0 to 28 d; as-fed basis), g	616	602	452	591	643	450	816	741
G:F ratio (0 to 28 d), g/kg[b]	682	609	688	644	507	736	624	644
	Exp. 2							
No. of replicates	3	2	3	2	2	3	—	—
No. of pigs	144	80	120	80	80	120	—	—
No. of pigs/pen	6	5	5	5	5	5	—	—
Pen space/pig, m^2	0.31	0.30	0.45	0.46	0.30	0.46	—	—
Weaning age, d	19.0	17.0	18.8	24.0	19.0	23.9	—	—
Initial BW, kg	7.1	4.7	6.3	6.6	6.1	6.2	—	—
ADG (0 to 28 d), g[b]	420	248	379	278	332	296	—	—
ADFI (0 to 28 d; as-fed basis), g[b]	663	419	687	449	502	442	—	—
G:F (0 to 28 d), g/kg[b]	633	592	552	620	663	670	—	—

[a]Stations numbered 1 to 6 in Exp. 1 are not necessarily the same station as Stations 1 to 6, respectively, in Exp. 2.
[b]Station effect, $P < 0.001$.

(1980), with the GLM procedures of SAS (SAS Inst., Inc., Cary, NC). In both experiments, the pen was considered the experimental unit for all measurements. The statistical model included station, replicate within station, treatment, station × treatment, and residual. Station and treatment effects were tested with the station × treatment term, and the interaction was tested with the residual. Preplanned treatment contrasts in

Table 2. Composition of control diets, %, as fed basis

Feed ingredient	Exp. 1 0 to 14 d[a]	Exp. 1 14 to 28 d[b]	Exp. 2 0 to 14 d[c]	Exp. 2 14 to 28 d[d]
Corn, ground	40.67	53.78	40.15	54.30
Soybean meal, dehulled 48% CP	19.50	20.25	19.50	19.50
Dried whey	20.00	20.00	20.00	20.00
Plasma, spray dried porcine[e]	6.00	—	6.00	—
Blood cells, spray dried[e]	—	2.00	—	2.00
L-Lysine·HCl	0.15	0.15	0.15	0.15
DL-Methionine	0.11	0.11	0.10	0.10
Lactose	10.00	—	10.00	—
Corn oil	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.40	1.40	1.55	1.45
Limestone, ground	0.52	0.52	0.75	0.55
Salt	0.15	0.15	0.20	0.35
Trace mineral premix[f]	+	+	+	+
Vitamin premix[f]	+	+	+	+
Antimicrobial agent[g]	+	+	+	+
Zinc sources[h]	±	±	±	±

[a]The control diet was calculated to contain 1.40% total lysine and analyzed an average of 125 ppm of Zn.
[b]The control diet was calculated to contain 1.25% total lysine and analyzed an average of 122 ppm of Zn.
[c]The control diet was calculated to contain 1.40% total lysine and analyzed an average of 139 ppm of Zn.
[d]The control diet was calculated to contain 1.25% total lysine and analyzed an average of 137 ppm of Zn.
[e]Plasma (APC 920) and blood cells (301G) were obtained from American Protein Corporation Ames, IA.
[f]Trace minerals and vitamins were added at different concentrations at the various stations, but they met or exceeded NRC (1998) standards. Premixes were added at the expense of corn.
[g]Products differed among stations.
[h]The Zn sources were added at different concentrations based on their Zn content and the desired amount added to the treatment diets.

Table 3. Zinc sources and distributors (Exp. 1 and 2)[a]

Source	AAFCO No.[b]	Zinc, %	Distributor
Zinc oxide[c]	57.117	72	Prince Agri. Products, Inc., Quincy, IL
Zinc polysaccharide complex[d]	57.29	22	Quali-Tech, Chaska, MN
Zinc proteinate	57.23	15	Chelated Minerals Corp., Salt Lake City, UT
Zinc amino acid complex[e]	57.150	10	Zinpro Corp., Eden Prairie, MN
Zinc amino acid chelate	57.142	10	Albion Labs, Atlantic, IA
Zinc methionine[f]	57.151	10	Zinpro Corp., Eden Prairie, MN

[a]Each product was obtained from the retail market by one investigator and distributed to the other investigators as needed for their experiment.
[b]AAFCO = Association of American Feed Control Officials, Oxford, IN.
[c]The feed-grade ZnO was a standard commercial product (Zinc Nacionale S.A., Monterrey, Mexico) manufactured by the Waelz process and purchased from Prince Agri Products, Inc., Quincy, IL.
[d]SQM Zinc.
[e]Availa-Zn 100.
[f]Zinpro 100.

Exp. 1 were the control diet vs. the mean of all other diets; the ZnO treatment vs. the mean of the Zn methionine treatments; linear and quadratic regressions within the three Zn methionine treatments; and the 500 ppm of Zn methionine diet vs.the positive control (2,500 ppm from ZnO) diet. In Exp. 2, preplanned contrasts were control vs. the mean of the other treatment groups; the 2,000 ppm ZnO diet vs. the mean of the 500 ppm Zn levels from ZnO and the five organic Zn sources; and the 500 ppm Zn oxide diet vs. each of the five organic Zn sources. A probability level of $P < 0.05$ was considered statistically significant.

Results

As expected, there were rather large differences among stations ($P < 0.001$) with respect to ADG, ADFI, and G:F in both experiments, as shown in Table 1. In some instances, the station × treatment interaction was significant, but this was always due to differences in the magnitude of the responses to Zn.

Experiment 1

The effects of replacing 2,500 ppm added Zn from ZnO with varying concentrations of added Zn from Zn methionine are summarized in Table 4. During the initial 7-d period, there were no treatment differences in ADG, ADFI, or G:F (data not shown).

As expected, pigs fed 2,500 ppm of Zn from ZnO gained faster than controls during each phase of the experiment ($P < 0.01$). Pigs fed added Zn from Zn methionine gained faster ($P < 0.05$) and tended to gain more efficiently ($P < 0.06$) during the initial 14 d of the experiment compared with those fed the control diet. During this initial 14-d period, however, pigs receiving Zn from ZnO tended to gain faster ($P < 0.06$) and more efficiently ($P < 0.05$) than those receiving Zn from Zn methionine, regardless of concentration of Zn methionine fed. Feed intake during this phase was numerically greater with Zn addition, but most differences were not significant. The only significant difference ($P < 0.01$) was between the ZnO and control diets. Performance responses were similar for the three concentrations of Zn methionine.

From 14 to 28 d of the experiment, pigs fed Zn from Zn methionine gained faster and consumed more feed when compared with those fed the control diet ($P < 0.05$). During this period, pigs fed the 2,500 ppm of added Zn from ZnO consumed more feed ($P < 0.05$) and gained faster ($P < 0.05$) than those fed the three lower levels of Zn methionine. Gain:feed ratio was not affected by dietary Zn addition.

During the entire 28-d experimental period, pigs fed Zn from Zn methionine gained faster ($P < 0.05$) and consumed more feed ($P < 0.05$) than pigs fed the control diet, but G:F was unaffected by either source of Zn addition (oxide or methionine). Zinc oxide addition at 2,500 ppm resulted in faster gain ($P < 0.05$) and greater feed intake ($P < 0.05$) than Zn methionine addition fed at any level. No difference was observed in efficiency of feed utilization between Zn sources during the overall 28-d period. There was no difference in responses among pigs fed the three concentrations of Zn methionine. Pigs fed 500 ppm of Zn from Zn methionine gained slower than pigs fed 2,500 ppm of Zn from ZnO ($P < 0.05$), but there was no difference in feed intake or G:F.

Experiment 2

The effects of replacing 500 or 2,000 ppm added Zn from ZnO with 500 ppm added Zn from various organic Zn sources are summarized in Table 5. As in Exp. 1, there were no treatment differences during the initial 7-d period (data not shown).

During Phase 1 (d 0 to 14), Phase 2 (d 14 to 28), and for the overall 28-d period, pigs consuming 2,000 ppm of added Zn from ZnO had higher ADG ($P < 0.05$) compared with pigs fed the control diet ($P < 0.01$) or pigs receiving 500 ppm added Zn from ZnO or any of the organic sources ($P < 0.05$). During the initial 14-d period, pigs receiving 500 ppm of additional Zn from each of the organic sources had similar performance compared to those fed 500 ppm of additional Zn from ZnO. Feed intake during the initial 14-d period and for the

Table 4. Effect of Zn source and level on weanling pig performance responses (Exp. 1)[a]

Item	Source:	Control[b]	Zn methionine			ZnO	SEM
	Added Zn, ppm:	0	125	250	500	2,500	
	Treatment No.:	1	2	3	4	5	
ADG, g							
0 to 14 d[cd]		268	290	287	292	308	8
14 to 28 d[cdef]		472	489	492	499	524	9
0 to 28 d[cdef]		371	391	389	396	415	7
ADFI (as-fed basis), g							
0 to 14 d[c]		383	397	394	401	405	9
14 to 28 d[cdef]		793	844	822	840	886	20
0 to 28 d[cde]		586	618	607	617	642	11
G:F, g/kg							
0 to 14 d[cdef]		700	730	728	728	760	10
14 to 28 d		595	579	599	594	584	7
0 to 28 d		633	633	641	642	642	6

[a]A total of 615 pigs (123 pigs/treatment) with an average initial BW of 6.3 kg was used in 26 replicates (eight stations).
[b]The control diet contained an average of 125 and 122 ppm of Zn during the 0 to 14 and 14 to 28 d periods, respectively.
[c]Control vs. ZnO, $P < 0.01$.
[d]Control vs. mean of Zn methionine treatments ($P < 0.05$) for ADG and ADFI; $P < 0.06$ for G:F.
[e]ZnO vs. mean of Zn methionine treatments, $P < 0.05$.
[f]ZnO vs. 500 ppm of Zn from Zn methionine, $P < 0.05$.

overall 28-d experimental period was greater for pigs receiving 2,000 ppm of added Zn from ZnO than for those receiving 500 ppm of added Zn from ZnO or any of the organic sources ($P < 0.05$). Pigs fed 500 ppm of Zn from ZnO ate more during Phase 1 ($P < 0.05$) than pigs fed Diet 6, a 500-ppm organic Zn diet.

Over the 28-d experimental period, pigs fed 2,000 ppm of added Zn from ZnO gained faster ($P < 0.05$) and consumed more feed ($P < 0.05$) than those fed 500 ppm of added Zn from ZnO or any of the organic sources. Feed efficiency was not affected by dietary Zn addition during any phase of this 28-day study.

In this study, only pigs fed 2,000 ppm of Zn from ZnO had improved gain and feed intake over the controls. Organic sources of Zn did not improve ADG, ADFI, or G:F beyond that achieved with the control diet.

Discussion

Results of these two studies indicate that feeding pharmacological concentrations (2,000 or 2,500 ppm) of inorganic Zn from ZnO improves the growth rate of weanling pigs compared with pigs receiving the control diet or 500 ppm of added Zn from ZnO or any organic

Table 5. Effect of dietary Zn source and level on weanling pig performance responses (Exp. 2)[a]

Item	Diet:	Control[b]	ZnO		Zinc polysaccharide	Zinc proteinate	Zinc complex	Zinc chelate	Zinc methionine	SEM
	Zn, ppm:	0	500	2,000	500	500	500	500	500	
	Treatment No.:	1	2	3	4	5	6	7	8	
ADG, g										
0 to 14 d[cd]		215	227	238	215	224	209	213	233	7
14 to 28 d[cd]		424	420	468	417	427	428	440	434	15
0 to 28 d[cd]		318	322	352	315	324	317	324	332	9
ADFI (as-fed basis), g										
0 to 14 d[de]		329	338	348	326	343	310	323	329	11
14 to 28 d[d]		728	712	763	698	732	721	725	741	19
0 to 28 d[d]		526	523	553	510	535	514	521	537	12
G:F g/kg										
0 to 14 d		656	670	692	661	654	683	657	697	14
14 to 28 d		599	594	615	602	584	595	608	599	13
0 to 28 d		618	623	641	624	611	621	627	630	10

[a]A total of 624 pigs (78 pigs per treatment group) with an average initial BW of 6.2 kg was used in 15 replicates (six stations).
[b]The control diet contained an average of 139 and 137 ppm of Zn during the 0 to 14 and 14 to 28 d periods, respectively.
[c]Control vs. 2,000 ppm of Zn from ZnO, $P < 0.01$.
[d]2,000 ppm of Zn from ZnO vs. mean of all treatments with 500 ppm of Zn, $P < 0.05$.
[e]500 ppm of Zn from ZnO vs. organic Zn (Treatment 6), $P < 0.05$.

source, which supports the findings of Hahn and Baker (1993), Carlson et al. (1999), and Hill et al. (2000). However, these findings are in contrast to those of Ward et al. (1996), who reported that supplementing starter pig diets with 250 ppm of Zn from Zn methionine gave equal performance to 2,000 ppm of Zn from ZnO when both diets were supplemented with 160 ppm of Zn from $ZnSO_4$. Also, Fakler et al. (1998) suggested that performance by pigs fed organic AA complexes may be improved over those pigs fed standard inorganic sources, but their study employed nutrient levels (80 to 100 ppm added), not pharmacological levels, of Zn. Woodworth et al. (1999) noted that gain was not improved by a Zn AA complex compared with pharmacological concentrations of ZnO.

In Exp. 1, ADG and ADFI were improved by both sources of Zn (ZnO and Zn methionine) compared with the controls during the 14- to 28-d period and for the entire experiment; however, pigs fed ZnO were superior for these criteria compared with those fed Zn methionine. Although the exact mechanisms of performance enhancement from Zn are unknown, it has been suggested that the effect is in the intestine, probably involving the microflora, and that the solubility of Zn compounds affect efficacy (Poulsen, 1995; Cromwell, 2001). It can be theorized that the lower solubility of ZnO compared with Zn methionine is the reason for the better performance of ZnO fed pigs in this trial, but fecal excretion data reported by Case and Carlson (2002) argue against this hypothesis. They reported that fecal excretion of Zn did not differ among pigs fed ZnO or two organic Zn sources at 500 ppm of dietary Zn.

For the overall 28-d period, there was no improvement in G:F. Poulsen (1995) and Smith et al. (1997), although reporting an increase in growth rate for weanling pigs fed pharmacological amounts (2,500 or 3,000 ppm of Zn from ZnO) of Zn, found no improvements in feed intake. Hill et al. (2000) found both improved ADG and ADFI during various phases of their 28-d study when 3,000 ppm of Zn as the oxide was fed. Case and Carlson (2002) found no improvement in ADFI over a 28-d period for pigs receiving 500 ppm of Zn from two different organic sources.

In Exp. 2, gain and feed intake were improved when pigs were fed 2,000 ppm of Zn as the oxide compared with those fed any of the organic Zn sources; however, for the overall 28-d period, Zn source did not affect feed efficiency. Pouslen (1995) and Smith et al. (1997) found no improvement in feed efficiency from Zn in a 28-d trial. Hill et al. (2001) reported a quadratic response in feed efficiency to increasing concentrations of Zn (0 to 3,000 ppm of Zn added as ZnO) during a 28-d trial. It is obvious that the gain response to pharmacological levels of Zn is more uniform, and is almost always positive, whereas the response in feed efficiency is quite variable.

Although pig performance improves from feeding pharmacological concentrations of Zn as ZnO, there are environmental concerns associated with high concentrations of Zn in manure (Carter et al., 2002; Meyer et al., 2002; Rincker et al., 2002). Martinez et al. (2002) reported that pigs fed 2,000 ppm of Zn as ZnO excreted 203 mg of Zn/d for the first 14 d after weaning. Rincker et al. (2002) reported that total Zn excretion was similar when 2,000 ppm of Zn was fed as oxide or methionine, but urinary Zn was a greater component when Zn methionine was fed compared with ZnO. The data reported by Case and Carlson (2002) indicate that in excess of 99% of the Zn is excreted in the feces, regardless of source (ZnO or organic Zn) or dietary level (150, 500, or 3,000 ppm). Similarly, Meyer et al. (2002) showed that short-term feeding of Zn to the nursery pig resulted in Zn excretion equal to that of a grower-finisher pig fed 100 ppm of Zn. The previous NCR-42 Zn study (Hill et al., 2000) showed that feeding 1,500 ppm of Zn was as efficacious as 3,000 ppm and would obviously decrease Zn excretion by approximately half.

Supplemental Zn at 500 ppm from ZnO or several organic sources was not as effective in stimulating growth, feed intake, or efficiency as when a pharmacological (2,000 ppm) level of Zn was fed as ZnO. It is imperative to understand the mechanism(s) involved in the growth promotion efficacy provided by pharmacological concentrations of Zn in the form of ZnO to minimize the amount of Zn excreted into the environment.

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