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Effects of a Silicic Acid and Fructo-oligosaccharide Feed Additive in Nursery Pig Diets With or Without Pharmacological Levels of Zinc

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Summary

A total of 360 nursery pigs (DNA 600 × 241; initially 12.8 ± 0.03 lb) were used in a 42-d study to determine the effects on growth performance and fecal dry matter (DM) of a silicic acid (SA) and short-chain fructo-oligosaccharide (FOS) feed additive included in nursery pig diets with or without pharmacological levels of zinc (Zn) from zinc oxide. At approximately 19 d of age, pigs were weaned, blocked by initial BW, and allotted to one of four dietary treatments in a generalized randomized block design with 18 replicates per treatment. Diets were formulated in three phases and fed from d 0 to 10, 10 to 24, and 24 to 42. The four dietary treatments were arranged in a 2 × 2 factorial with main effects of SA/FOS feed additive (none or 0.5 lb/ton of complete feed; Improx, Addix Biotech, Weston, FL) and pharmacological levels of Zn from ZnO (none or 2,990 mg/kg added in phase 1 and 2,018 mg/kg in phase 2). All diets contained 110 mg/kg Zn from the base trace mineral premix. Pens of pigs were weighed on d 0, 10, 17, 24, 35, and 42 to determine growth performance, and on d 10 and d 24 of the study, fecal samples were collected from three pigs per pen to determine fecal DM. There were no interactions between SA/FOS and pharmacological levels of Zn throughout the study. Overall (d 0 to 42), pharmacological levels of Zn improved d 42 BW, ADG, ADFI, and F/G ($P \leq 0.007$). Fecal DM at both d 10 and 24 was higher ($P \leq 0.015$) in pigs fed pharmacological levels of Zn. There were no main effects observed for SA/FOS throughout the trial. In conclusion, there were no interactive effects between SA/FOS and pharmacological levels of Zn, as well as no main effects observed for SA/FOS throughout the study. Pigs fed pharmacological levels of Zn had improved ADG, ADFI, F/G, and fecal DM throughout the nursery period.

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Introduction

Zinc (Zn) is an essential micromineral in swine diets, contributing to protein, carbohydrate, and lipid digestion. The NRC[3] estimates the Zn requirement between 26.6 and 72.4 mg/d for nursery pigs. However, several have reported that pharmacological levels of Zn from zinc oxide, up to 3,000 mg/kg (2,600 mg/d), can reduce postweaning scouring and improve growth performance.[3] Pharmacological Zn improves growth performance by downregulating the mRNA expression of proinflammatory cytokines in the jejunal mucosa, helping prevent postweaning diarrhea (PWD) among other potential modes of action.[4] Due to environmental toxicity and antimicrobial resistance concerns, the European Union has prohibited producers from using pharmacological levels of Zn. Therefore, alternative ingredients are being investigated as potential replacements for pharmacological levels of Zn to reduce PWD while maintaining growth performance.

Silicic acid (SA) is a weak acid and is the active form of silicon, contributing to growth and skeletal development. Previous research found that sodium silicate, a mineral complex originating from SA, improved ADG and reduced feed conversion ratio at 0.1% inclusion. Sodium silicate improved fecal consistency scores and increased the relative abundance of Lactobacillus bacterium.[5]

Fructo-oligosaccharides (FOS) are prebiotics composed of non-digestible fibers that stimulate the growth of beneficial bacteria in the gastrointestinal tract (GIT) through fermentation. This can strengthen the intestinal epithelial barrier and improve the health of the animal.

Improx (Addix Biotech, Weston, FL) is a dried *Aspergillus niger* fermentation product composed of a combination of silicic acid and a short-chain fructo-oligosaccharide. Improx is marketed as a prebiotic additive for pork and poultry production and uses calcium carbonate as a carrier. However, no studies have been conducted in nursery pigs to evaluate the combination of silicic acid and a short-chain fructo-oligosaccharide. Therefore, this study was designed to evaluate the effects of a silicic acid (SA) and short-chain fructo-oligosaccharide (FOS) feed additive included in diets with or without pharmacological levels of zinc on growth performance and fecal dry matter of nursery pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used for this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center. Each pen contained a 3-hole, dry self-feeder and a nipple waterer to provide ad libitum access to feed and water. All diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center (Manhattan, KS) and fed in mash form.

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[3] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. doi:10.17226/13298.

[4] Zhu, C., L. Hang, Z. Chen, L. Wang, X. Wu, Z. Chen, W. Zhang, R. Liang, and Z. Jiang. 2016. Dietary zinc oxide modulated antioxidant capacity, small intestine development, and jejunal gene expression in weaned piglets. Biol. Trace Elem. Res. 175:331–338. doi:10.1007/s12011-016-0767-3.

[5] Zhao, W. H., S. L. Yun, and I. H. Kim. 2026. Dietary silicate: a biogenic strategy to enhance growth, gut health, and nutrient utilization in finishing pigs through low-carbon diets. Porc. Health. Manag. 12: 8. doi:10.1186/s40813-026-00494-5.

Animals and diets

A total of 360 weanling pigs (DNA 600 × 241; initially 12.8 ± 0.03 lb) were used in a 42-d study to determine the effects on growth performance and fecal dry matter (DM) of a silicic acid (SA) and short-chain fructo-oligosaccharide (FOS) feed additive included in nursery pig diets with or without pharmacological levels of zinc oxide. At approximately 19 d of age, pigs were weaned, blocked by initial BW, and allotted to one of four dietary treatments in a generalized randomized block design, with five pigs per pen and 18 replicates per treatment. Pigs were blocked to create six replicates each of light, medium, and heavy-weight pens per treatment. Diets were corn-soybean meal-based and arranged in a 2 × 2 factorial design, with main effects of SA/FOS (0 or 0.5 lb/ton of complete feed) and Zn from ZnO (0 or 2,990 mg/kg added in phase 1 and 2,018 mg/kg added in phase 2). All diets contained 110 mg/kg of Zn from the trace mineral premix. Diets were formulated in three phases and fed from d 0 to 10, 10 to 24, and 24 to 42, respectively (Table 1). Pig weights and feed disappearance were measured on d 0, 10, 17, 24, 35, and 42 to determine ADG, ADFI, and feed efficiency. On d 10 and 24, fecal samples were collected from the same three randomly selected pigs in each pen to determine fecal DM. Fecal samples were dried at 131°F (55°C) in a forced-air oven for 48 h, and the ratio of dried-to-wet fecal weight determined the percentage fecal dry matter.

Statistical analysis

Data were analyzed as a generalized randomized block design as a two-way ANOVA using the lmer function from the lme4 package in R Studio (Version 4.5.0, R Core Team, Vienna, Austria) with pen serving as the experimental unit and treatment and weight block as fixed effects. Fecal DM samples were analyzed as a one-way ANOVA using the GLIMMIX procedure in SAS OnDemand for Academics (SAS Institute, Inc., Cary, NC), using the fixed effects of day, block, treatment, and the associated interaction, accounting for repeated measures over time. Fecal samples were analyzed separately for each pig, and pen was used as a random effect to account for subsampling when used for the statistical analysis. Results were considered significant with $P \leq 0.05$ and were considered marginally significant with $0.05 < P \leq 0.10$.

Results and Discussion

There were no interactions between SA/FOS and pharmacological levels of Zn throughout the study (Table 2). Furthermore, there were no main effects observed for SA/FOS feed additive throughout the trial. During phase 1 (d 0 to 10), pigs fed pharmacological levels of Zn had improved d 10 BW, ADG, and F/G compared with pigs fed diets without pharmacological levels of Zn ($P < 0.001$; Table 3). In phase 2 (d 10 to 24), pigs fed pharmacological levels of Zn had improved d 24 BW, ADG, ADFI, and F/G compared with pigs fed diets without pharmacological levels of Zn ($P < 0.001$). In phase 3 (d 24 to 42), no differences between treatments were observed. Overall (d 0 to 42), pharmacological levels of Zn improved d 42 BW, ADG, ADFI, and F/G ($P \leq 0.007$). Fecal DM at both d 10 and 24 was higher ($P \leq 0.015$) in pigs fed pharmacological levels of Zn.

In conclusion, there were no interactive effects observed between SA/FOS and pharmacological Zn levels, and no main effects were observed for SA/FOS throughout the study. Pigs fed pharmacological levels of Zn had improved ADG, ADFI, and F/G in the overall period and increased fecal DM on d 10 and 24.

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Table 1. Ingredient composition of experimental diets (as-fed basis)[1]

	Phase 1		Phase 2		Phase 3
Added Zn, mg/kg[2]	0	2,990	0	2,018	0
Ingredients, %					
Corn	43.49	43.09	57.29	57.00	66.33
Soybean meal, 47.7% CP	20.89	20.89	24.25	24.25	29.73
Whey powder	15.00	15.00	10.00	10.00	---
Whey permeate	9.00	9.00	---	---	---
Microbial enhanced SBM[3]	6.25	6.25	3.75	3.75	---
Soybean oil	2.00	2.00	1.00	1.00	---
Calcium carbonate	0.38	0.38	0.58	0.58	0.80
Monocalcium phosphate, 21% P	1.10	1.10	0.95	0.95	0.95
Sodium chloride	0.35	0.35	0.56	0.56	0.60
L-Lys-HCl	0.45	0.45	0.49	0.49	0.50
DL-Met	0.28	0.28	0.26	0.26	0.20
L-Thr	0.20	0.20	0.22	0.22	0.23
L-Trp	0.04	0.04	0.06	0.06	0.05
L-Val	0.11	0.11	0.13	0.13	0.13
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.02	0.02	0.02	0.02	0.02
Phytase[4]	0.06	0.06	0.06	0.06	0.06
Zinc oxide[2]	0.00	0.40	0.00	0.29	0.00
SA/FOS[5]	+/-	+/-	+/-	+/-	+/-
Total	100	100	100	100	100
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lys	1.35	1.35	1.35	1.35	1.30
Ile:Lys	59	59	57	57	55
Leu:Lys	113	113	115	115	115
Met:Lys	41	41	39	39	36
Met and Cys:Lys	58	58	58	58	58
Thr:Lys	65	65	65	65	65
Trp:Lys	21	21	21	21	20
Val:Lys	70	70	70	70	70
His:Lys	34	34	35	35	37
Total Lys, %	1.49	1.49	1.49	1.49	1.44
NE, kcal/lb	1,177	1,172	1,137	1,134	1,103
SID Lys:CP	6.49	6.49	6.43	6.43	6.33
Ca, %	0.66	0.66	0.66	0.66	0.70
STTD P, %	0.58	0.58	0.51	0.51	0.46
Ca:P	1.01	1.01	1.09	1.09	1.19

Analyzed composition					
CP[6]	20.9	20.6	20.6	20.2	20.6
Zn[7]	134.5	2,198.3	180.8	1,551.7	167.2

[1] Phase 1 diets were fed from d 0 to 10, phase 2 diets were fed from d 10 to 24, and phase 3 diets were fed from d 24 to 42 of the study.

[2] Zinc oxide was added to corresponding treatment diets to provide 2,990 mg/kg Zn in phase 1 and 2,018 mg/kg Zn in phase 2. All diets contained 110 mg/kg Zn from $ZnSO_4$ in the trace mineral premix.

[3] Access Starter Protein (Prairie Aquatech, Brookings, SD).

[4] HiPhorius 2400 (Novonesis, Kongens Lyngby, Denmark), provided an estimated release of 0.12% STTD P with 1,500 FYT/kg.

[5] Improx (Addix Biotech, Weston, FL) was added at 0.5 lb/ton in phases 1, 2, and 3, respectively, for the corresponding treatment diets.

[6] Nitrogen was estimated by N combustion, using the Dumas methodology, and then multiplied by a factor of 6.25 to obtain the CP values.

[7] Samples were analyzed for zinc analysis using ICP-OES at the University of Missouri Agricultural Experiment Station Chemical Laboratory.

2. Interactive effects of a silicic acid (SA)/fructo-oligosaccharide (FOS) feed additivewith or without pharmacological levels of zinc from ZnO on growth performance and fecal dry matter of weanling pigs[1]

	SA/FOS[2]					
	No		Yes			*P* =
Pharmacological Zn[3]:	-	+	-	+	SEM	Zn × SA/FOS
BW, lb						
d 0	12.8	12.8	12.8	12.8	0.03	0.837
d 10	14.6	15.4	14.5	15.4	0.19	0.697
d 24	26.9	29.5	26.6	30.1	0.51	0.438
d 42	55.6	57.8	54.8	58.3	0.80	0.423
d 0 to 10 (phase 1)						
ADG, lb	0.20	0.28	0.18	0.27	0.018	0.763
ADFI, lb	0.34	0.37	0.34	0.36	0.016	0.960
F/G	1.94	1.32	2.88	1.36	0.317	0.362
d 10 to 24 (phase 2)						
ADG, lb	0.85	1.00	0.84	1.05	0.031	0.327
ADFI, lb	1.32	1.46	1.37	1.52	0.036	0.863
F/G	1.57	1.47	1.64	1.46	0.033	0.185
d 24 to 42 (phase 3)						
ADG, lb	1.60	1.57	1.57	1.57	0.026	0.597
ADFI, lb	2.49	2.46	2.44	2.48	0.037	0.318
F/G	1.56	1.57	1.56	1.58	0.013	0.439
d 0 to 42 (overall)						
ADG, lb	0.82	0.88	0.81	0.91	0.019	0.219
ADFI, lb	1.30	1.36	1.31	1.39	0.025	0.569
F/G	1.59	1.54	1.64	1.53	0.020	0.140
Fecal DM, %[4]						
d 10	17.3	21.3	15.9	20.4	1.02	0.807
d 24	20.8	22.2	20.7	23.1	0.81	0.468

[1] A total of 360 pigs (DNA 600 × 241; initially 12.8 ± 0.03 lb) weaned at approximately 19 d of age were used in a 42-d nursery trial with 18 replicates per treatment and five pigs per pen.

[2] Improx (Addix Biotech, Weston, FL) was included at 0.5 lb/ton in phases 1, 2, and 3, for the respective treatments.

[3] Zn from ZnO was added at 2,990 mg/kg in phase 1 and 2,018 mg/kg in phase 2. All diets contained 110 mg/kg Zn from the trace mineral premix.

[4] Fecal samples were collected from three pigs per pen (54 pigs per treatment) on d 10 and 24 of the study to determine fecal DM. Zn × SA/FOS × day interaction, $P = 0.785$. SA/FOS × day interaction, $P = 0.181$. Zn × day interaction, $P = 0.039$.

Table 3. Main effects of a silicic acid (SA)/fructo-oligosaccharide (FOS) feed additive or pharmacological levels of zinc from ZnO on growth performance and fecal dry matter of weanling pigs[1]

	SA/FOS[2]				Pharmacological Zn[3]			
Item:	-	+	SEM	*P* =	-	+	SEM	*P* =
BW, lb								
d 0	12.8	12.8	0.02	0.847	12.8	12.8	0.02	0.592
d 10	15.0	15.0	0.14	0.780	14.6	15.4	0.14	< 0.001
d 24	28.2	28.3	0.36	0.762	26.7	30.0	0.36	< 0.001
d 42	56.7	56.6	0.57	0.875	55.2	58.0	0.57	0.001
d 0 to 10 (phase 1)								
ADG, lb	0.24	0.23	0.013	0.462	0.19	0.27	0.013	< 0.001
ADFI, lb	0.35	0.35	0.012	0.929	0.34	0.37	0.012	0.130
F/G	1.63	2.12	0.231	0.252	2.41	1.34	0.231	< 0.001
d 10 to 24 (phase 2)								
ADG, lb	0.93	0.95	0.022	0.537	0.85	1.02	0.022	< 0.001
ADFI, lb	1.39	1.44	0.026	0.147	1.34	1.49	0.026	< 0.001
F/G	1.52	1.55	0.024	0.508	1.61	1.46	0.024	< 0.001
d 24 to 42 (phase 3)								
ADG, lb	1.58	1.57	0.018	0.543	1.58	1.57	0.018	0.629
ADFI, lb	2.48	2.46	0.026	0.739	2.47	2.47	0.026	0.954
F/G	1.56	1.57	0.009	0.557	1.56	1.57	0.009	0.294
d 0 to 42 (overall)								
ADG, lb	0.85	0.86	0.014	0.754	0.82	0.90	0.014	< 0.001
ADFI, lb	1.33	1.35	0.018	0.351	1.31	1.38	0.018	0.007
F/G	1.56	1.58	0.014	0.404	1.61	1.54	0.014	< 0.001
Fecal DM, %[4]								
d 10	19.3	18.1	0.72	0.255	16.6	20.8	0.72	< 0.001
d 24	21.5	21.9	0.55	0.632	20.7	22.6	0.55	0.015

[1] A total of 360 pigs (DNA 600 × 241; initially 12.8 ± 0.03 lb) weaned at approximately 19 d of age were used in a 42-d nursery trial with 18 replicates per treatment and five pigs per pen.

[2] Improx (Addix Biotech, Weston, FL) was included at 0.5 lb/ton in phases 1, 2, and 3, for the respective treatments.

[3] Zn from ZnO was added at 2,990 mg/kg in phase 1 and 2,018 mg/kg in phase 2. All diets contained 110 mg/kg Zn from the trace mineral premix.

[4] Fecal samples were collected from three pigs per pen (54 pigs per treatment) on d 10 and 24 of the study to determine fecal DM. SA/FOS × day interaction, *P* = 0.181. Zn × day interaction, *P* = 0.039.