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K·STATE Research and Extension

SWINE DAY 2021

Effects of Live Yeast and Yeast Extracts with and without Pharmacological Levels of Zinc on Nursery Pig Growth Performance and Fecal Consistency

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Summary

A total of 360 weanling barrows (Line 200 × 400, DNA Genetics; initial BW 12.4 ± 0.05 lb) were used in a 42-d study to evaluate yeast-based pre- and probiotics (Phileo by Lesaffre, Milwaukee, WI) in diets with or without pharmacological levels of Zn on growth performance and fecal dry matter (DM). Pens were assigned to 1 of 4 dietary treatments with 5 pigs per pen and 18 pens per treatment. Dietary treatments were arranged in a 2 × 2 factorial with main effects of live yeast-based pre- and probiotics (none vs. 0.10% ActiSaf Sc 47 HR+, 0.05% SafMannan, and 0.05% NucleoSaf from d 0 to 7, then concentrations were lowered by 50% from day 7 to 21) and pharmacological levels of Zn (110 vs. 3,000 ppm from d 0 to 7, and 2,000 ppm from d 7 to 21 provided by ZnO). All pigs were fed a common diet from d 21 to 42 post-weaning. There were no yeast × Zn interactions or effects due to yeast additives observed on any response criteria. From d 0 to 21 and d 0 to 42, pigs fed pharmacological levels of Zn had increased ($P < 0.001$) ADG and ADFI. Fecal samples were collected on d 4, 21, and 42 from the same three pigs per pen for DM analysis. On d 4, pigs fed pharmacological levels of Zn had greater fecal DM ($P = 0.043$); however, no differences were observed on d 21 or 42. In conclusion, pharmacological levels of Zn increased ADG, ADFI, and d 4 post-weaning fecal DM. There was no response observed from live yeast and yeast extracts for any growth or fecal DM criteria.

Introduction

Feeding pharmacological levels of Zn (2,000 to 3,000 ppm) in the early nursery has been an industry-wide practice used to improve growth performance and control instances of post-weaning diarrhea. However, feeding pharmacological levels of Zn has become an environmental concern and a concern for antimicrobial resistance (AMR) to antibiotics of importance to human and animal medicine.

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[3] Phileo by Lesaffre, Milwaukee, WI.

One potential replacement strategy for pharmacological levels of added Zn in the early nursery is the use of pre- and probiotics. Feeding probiotics can alter the gut's microflora by introducing live cultures of beneficial microorganisms into the digestive tract and can aid in suppressing their pathogenic counterparts. The improved microbial profile in the gut may allow the pig to have more protection against enteric diseases while subsequently improving growth performance.[4] Our hypothesis was that the additions of a live yeast (probiotic) and yeast extracts (prebiotics) would provide equal, if not additive growth responses to added Zn. Thus, the objective of this study was to determine the effects of pharmacological levels of Zn with or without the addition of the live yeast *Saccharomyces cerevisiae* strain NCYC Sc 47 and yeast-based prebiotics derived from *Saccharomyces cerevisiae* on nursery pig growth performance and fecal dry matter.

Materials and Methods

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan, KS. The facility has two identical barns that are completely enclosed, environmentally controlled, and mechanically ventilated. Treatments were equally represented in each barn. Each pen contained a 4-hole, dry self-feeder and a cup waterer to provide *ad libitum* access to feed and water. Pens (4 × 4 ft) had metal tri-bar floors and allowed approximately 2.7 ft^2/pig.

Animals and treatment structure

A total of 360 barrows (Line 200 × 400, DNA; initial BW 12.4 ± 0.05 lb) were used in a 42-d study with 5 pigs per pen and 18 pens per treatment (9 pens per barn). Upon arrival to the research site, pigs were randomly assigned to pens. Pens were then assigned to 1 of 4 dietary treatments in a randomized complete block design with pens blocked by BW. Pigs were healthy from placement throughout the trial with only three pigs being removed from the study.

Dietary treatments were arranged in a 2 × 2 factorial with main effects of yeast-based pre- and probiotics (none vs. 0.10% ActiSaf Sc 47 HR+, 0.05% SafMannan, and 0.05% NucleoSaf from d 0 to 7, then concentrations were lowered by 50% from day 7 to 21; Table 1) and pharmacological levels of Zn (110 vs. 3,000 ppm from d 0 to 7, and 2,000 ppm from d 7 to 21 provided by ZnO). All pigs were fed a common diet from d 21 to 42 post-weaning without added yeast products or pharmacological levels of Zn. The live yeast *Saccharomyces cerevisiae* strain NCYC Sc 47 (ActiSaf Sc 47 HR+; Phileo by Lesaffre, Milwaukee, WI) served as the yeast-based probiotic. The yeast-based prebiotics included a yeast cell wall fraction with concentrated mannan-oligosaccharides and β-glucans from *Saccharomyces cerevisiae* (SafMannan; Phileo by Lesaffre, Milwaukee, WI) and a yeast extract containing ≥6% unbound nucleotides from *Saccharomyces cerevisiae* (NucleoSaf; Phileo by Lesaffre, Milwaukee, WI).

[4] Liao, S. F., and M. Nyachoti. 2017. Using probiotics to improve swine gut health and nutrient utilization. Animal Nutrition. 3:331-343. doi:10.1016/j.aninu.2017.06.007.

Diet preparation

Phase 1 diets were formulated to a 1.40% standardized ileal digestible (SID) Lys, and phase 2 and 3 diets were formulated to 1.35 % SID Lys (Table 1). All other nutrients were formulated to meet or exceed NRC (2012)[5] requirement estimates. Phase 1 and 2 diets were manufactured at the Kansas State University Poultry Unit (Manhattan, KS), and the common phase 3 diet was manufactured at a commercial feed mill (Hubbard Feeds; Beloit, KS). All three phases were fed in meal form. Pens of pigs were weighed and feed disappearance recorded weekly during the course of this study to determine ADG, ADFI, and F/G.

Chemical analysis

Phase 1 and 2 diet samples were collected at manufacturing and phase 3 diets were collected from multiple 50-lb bags using a feed probe to collect a representative sample for each respective diet and phase. Complete diet samples were stored at -4°F until they were homogenized, subsampled, and submitted for analysis. Duplicate composite samples per dietary treatment were analyzed (Ward Laboratories; Kearney, NE) for dry matter, crude protein, and Zn. Separate composite samples per dietary treatment were analyzed (Analabs; Fulton, IL) for active live yeast for phases 1 and 2 (Table 2).

Fecal collection

Fecal samples were collected on d 4, 21, and 42 of the experiment for fecal antimicrobial resistance profiles of *E. coli* and fecal dry matter analysis. Fecal samples were collected directly from the rectum of the same three randomly selected pigs from each pen and pooled by pen to form one composite sample. Fecal samples were stored at -4°F until fecal DM analysis. Fecal samples were pooled by pen, respective of day of collection, and dried at 131°F in a forced air oven for 48 h.

Economics

Total feed cost per pig, cost per lb of gain, revenue, and income over feed cost (IOFC) were calculated to evaluate the economics of including yeast additives and ZnO. Feed cost per pig placed was determined by multiplying total feed intake by diet cost. Feed cost per lb of gain was calculated by dividing the total feed cost per pig by the total weight gained. Revenue per pig placed was determined by total gain times the dressing percentage (0.75) and then multiplied by $0.70 carcass price in order to convert to a live price. Income over feed cost was calculated using revenue per pig placed minus feed cost per pig placed. For all economic evaluations, the following ingredients prices were used: corn = $7.06/bushel ($252/ton); soybean meal = $367/ton; L-Lys HCl = $0.80/lb; DL-methionine = $2.20/lb; MHA =$2.25/lb; L-threonine = $1.01/lb; L-tryptophan = $3.99/lb; L-valine = $2.32/lb; ZnO = $1.09/lb; ActiSaf Sc 47 HR+ = $2.80/lb; SafMannan = $1.40/lb; and NucleoSaf = $8.20/lb.

Statistical analysis

Growth performance, economics, and fecal dry matter data were analyzed using the nlme package of R (Version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria) as a randomized complete block design with body weight as the blocking factor and pen as the experimental unit. The main effects of yeast-derived probiotics and phar-

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

macological levels of Zn, as well as their interactions, were tested. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Growth performance

There were no interactions observed between the dietary addition of pharmacological levels of Zn and yeast-based pre- and probiotics (Table 3). Thus, the main effects of Zn and yeast additives are reported (Table 4). There was no evidence for difference ($P > 0.10$) when live yeast and yeast extracts were included in the diet for any of the response criteria for the entirety of the study.

In phase 1 (d 0 to 7) and phase 2 (d 7 to 21), pigs fed diets with pharmacological levels of Zn had increased ($P < 0.05$) ADG, ADFI, and d 7 and 21 BW; but there was no difference ($P > 0.10$) in F/G compared to those that were not fed pharmacological levels of Zn.

For the overall experimental period (d 0 to 21), pigs fed pharmacological levels of Zn had increased ($P < 0.001$) ADG and ADFI. However, there was no evidence for difference ($P > 0.10$) in F/G between those that were fed diets with or without added Zn or yeast additives on any response criteria. During the common period (d 21 to 42), there was no evidence for difference ($P > 0.10$) between any of the previous treatment combinations on growth performance.

For the overall study (d 0 to 42), pigs fed pharmacological levels of Zn had increased ($P < 0.05$) ADG, ADFI, improved F/G and heavier d 42 BW. There were no differences observed for pigs fed yeast-based pre- and probiotics.

Fecal dry matter

There were no interactions observed between the dietary addition of pharmacological levels of Zn and yeast-based pre- and probiotics or for the main effect of yeast additives for fecal dry matter. On d 4, pigs fed 3,000 ppm of Zn had greater fecal DM ($P = 0.039$) than those without added Zn. However, no differences were observed on d 21 or 42 between any of the dietary treatments for fecal DM.

Economics

No interactions between the addition of live yeast and pharmacological Zn were observed for any economic criteria. There was a tendency ($P = 0.062$) for increased feed cost per pig when yeast additives were included in the diet compared to a diet without yeast; however, there was no evidence for difference ($P = 0.923$) for feed cost per lb of gain. While there was no statistical difference ($P > 0.10$) between diets with or without yeast-based pre- and probiotics, pigs fed yeast had a numerical increase in revenue (+\$0.53) and IOFC (+\$0.19). Pigs fed pharmacological levels of Zn, provided by ZnO, had a tendency ($P = 0.076$) for increased feed cost per pig compared to those fed diets without added ZnO; yet, pigs fed pharmacological levels of Zn had lower ($P = 0.014$) feed cost per lb of gain. Furthermore, pigs fed added ZnO had increased ($P < 0.005$) revenue (+\$0.99) and IOFC (+\$0.67) compared to pigs diets without pharmacological Zn.

In conclusion, adding pharmacological levels of Zn has proven to be a useful additive to stimulate feed intake, increase growth, and improve fecal DM in the early nursery period. There was no statistical response observed from the dietary addition of live yeast and yeast extracts for any of the growth or fecal DM criteria.

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Table 1. Composition of phase 1 and phase 2 diets (as-fed basis)[1]

Item	Phase 1	Phase 2	Phase 3
Ingredients, %			
Corn	43.98	57.10	64.70
Soybean meal (46.5% CP)	18.10	26.35	31.30
Whey powder	25.00	10.00	---
Fish meal	4.50	---	---
Enzymatically-treated soybean meal[2]	3.75	2.00	---
Soybean oil	1.50	---	---
Calcium carbonate	0.30	0.90	0.85
Monocalcium P (21% P)	0.48	1.10	1.00
Salt	0.30	0.55	0.60
L-Lys-HCl	0.43	0.51	0.52
DL-Met	0.22	0.22	---
MHA[3]	---	---	0.25
L-Thr	0.18	0.21	0.22
L-Trp	0.07	0.06	0.06
L-Val	0.13	0.14	0.13
Vitamin premix[4]	0.25	0.25	---
Vitamin premix with phytase[5]	---	---	0.25
Trace mineral premix[6]	0.15	0.15	0.15
Phytase[7]	0.08	0.08	---
Zinc oxide[8]	±	±	---
Yeast additives[9]	±	±	---
Total	100	100	100

continued

Table 1. Composition of phase 1 and phase 2 diets (as-fed basis)[1]

Item	Phase 1	Phase 2	Phase 3
Calculated analysis			
SID amino acids, %			
Lys	1.40	1.35	1.35
Ile:Lys	56	55	55
Leu:Lys	109	111	114
Met:Lys	38	36	36
Met and Cys:Lys	57	57	57
Thr:Lys	63	63	63
Trp:Lys	20.6	20.2	20.3
Val:Lys	69	69	69
His:Lys	32	34	36
Total Lys, %	1.53	1.48	1.49
ME, kcal/lb	1,548	1,485	1,487
NE, kcal/lb	1,166	1,104	1,098
SID Lys:NE, g/Mcal	5.44	5.54	5.57
CP, %	20.9	20.5	21.2
Ca, %	0.69	0.77	0.72
P, %	0.68	0.66	0.61
STTD P, %	0.63	0.58	0.50
Zn, ppm	110 vs 3,000	110 vs 2,000	110

[1]Phase 1 diets were fed from d 0 to 7 (approximately 12.4 to 13.4 lb BW), and phase 2 diets were fed from d 7 to 21 (approximately 13.4 to 25.5 lb BW). A common diet, without ZnO or yeast probiotics, was fed during phase 3 from d 21 to 42 (approximately 25.5 to 53.0 lb BW).
[2]HP 300, Hamlet Protein, Findlay, OH.
[3]Methionine hydroxy analogue, Novus International, St. Charles, MO.
[4]Provided per lb of premix: 750,000 IU vitamin A; 300,000 IU vitamin D; 8,000 IU vitamin E; 600 mg vitamin K; 6 mg vitamin B_{12}; 9,000 mg niacin; 5,000 mg pantothenic acid; 1,500 mg riboflavin.
[5]Ronozyme HiPhos GT 2700 (DSM Nutritional Products, Parsippany, NJ) provided 566 FTU/lb and an estimated release of 0.12% STTD P. Provided per lb of premix: 750,000 IU vitamin A; 300,000 IU vitamin D; 8,000 IU vitamin E; 600 mg vitamin K; 6 mg vitamin B_{12}; 9,000 mg niacin; 5,000 mg pantothenic acid; 1,500 mg riboflavin.
[6]Provided per lb of premix: 73 g Zn from zinc sulfate; 73 g Fe from iron sulfate; 22 g Mn from manganese oxide; 11 g Cu from copper sulfate; 0.2 g I from calcium iodate; 0.2 g Se from sodium selenite.
[7]Ronozyme HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided 918 FTU/lb and an estimated release of 0.12% STTD P in phases 1 and 2.
[8]ZnO was fed to supply 3,000 ppm of Zn for the duration of phase 1 and 2,000 ppm of Zn for the duration of phase 2.
[9]Yeast pre- and probiotics included 0.10% ActiSaf Sc 47 HR+, 0.05% SafMannan, and 0.05% NucleoSaf in phase 1 diets, and then concentrations were lowered by 50% in phase 2 diets (Phileo by Lesaffre, Milwaukee, WI).

Table 2. Diet analysis (as-fed basis), %[1]

	No yeast probiotics		Yeast probiotics[2]	
	Low Zn	**High Zn**	**Low Zn**	**High Zn**
Phase 1 diets				
DM, %	91.8	91.9	91.9	91.9
CP, %	20.5	19.9	20.2	20.1
Ca, %	1.23	1.23	1.20	1.20
P, %	0.77	0.75	0.77	0.76
Zn, ppm	263	3,230	245	3,204
Live yeast, CFU/g	200	500	7,100,000	9,700,000
Phase 2 diets				
DM, %	90.2	90.1	89.7	89.8
CP, %	18.9	19.0	19.1	19.6
Ca, %	1.38	1.41	1.38	1.33
P, %	0.73	0.72	0.74	0.72
Zn, ppm	234	2,435	257	2,233
Live yeast, CFU/g	300	700	10,500,000	5,900,000
Phase 3 common diet				
DM, %	88.4	---	---	---
CP, %	20.7	---	---	---
Ca, %	0.95	---	---	---
P, %	0.61	---	---	---
Zn, ppm	199	---	---	---

[1]Complete diet samples were obtained from each treatment during manufacturing and homogenized to form a composite sample. Samples were submitted to Ward Laboratories (Kearney, NE) to analyze DM, CP, Ca, P, and Zn. Phase 1 and 2 diets were also sent to Analabs (Fulton, IL) to analyze active live yeast.
[2]Yeast pre- and probiotics included ActiSaf Sc 47 HR+ at 0.1%, SafMannan at 0.05% and NucleoSaf at 0.05% in phase 1 diets, and then concentrations were lowered by 50% in phase 2 diets (Phileo by Lesaffre, Milwaukee, WI).

Table 3. Interactive effects of yeast probiotics and pharmacological levels of Zn on nursery pig performance[1]

	No yeast probiotics		Yeast probiotics			*P* =		
Item	Low Zn	High Zn	Low Zn	High Zn	SEM	Yeast × Zn	Yeast	Zn
BW, lb								
d 0	12.4	12.4	12.4	12.4	0.05	0.963	0.779	0.901
d 7	12.8	13.4	13.0	13.4	0.17	0.359	0.508	0.001
d 21	24.0	25.5	24.4	25.5	0.35	0.531	0.533	<0.001
d 42	51.1	52.9	51.3	53.0	0.59	0.912	0.744	0.002
Phase 1 (d 0 to 7)								
ADG, lb	0.05	0.14	0.09	0.14	0.021	0.360	0.489	0.001
ADFI, lb	0.15	0.20	0.17	0.19	0.015	0.324	0.847	0.042
F/G	3.09	1.76	2.29	1.04	1.081	0.976	0.474	0.229
Phase 2 (d 7 to 21)								
ADG, lb	0.78	0.86	0.81	0.87	0.018	0.546	0.401	<0.001
ADFI, lb	0.96	1.08	1.00	1.09	0.027	0.538	0.507	<0.001
F/G	1.23	1.26	1.23	1.25	0.017	0.777	0.815	0.163
Experimental period (d 0 to 21)								
ADG, lb	0.54	0.62	0.57	0.62	0.017	0.400	0.288	<0.001
ADFI, lb	0.69	0.79	0.72	0.79	0.022	0.456	0.461	<0.001
F/G	1.29	1.27	1.27	1.26	0.015	0.806	0.230	0.256
Phase 3 common period (d 21 to 42)								
ADG, lb	1.29	1.30	1.28	1.31	0.017	0.685	0.947	0.264
ADFI, lb	1.93	1.92	1.90	1.93	0.024	0.451	0.573	0.811
F/G	1.50	1.47	1.48	1.47	0.012	0.619	0.466	0.146
Overall (d 0 to 42)								
ADG, lb	0.91	0.96	0.93	0.97	0.014	0.721	0.433	0.001
ADFI, lb	1.31	1.35	1.31	1.36	0.021	0.982	0.830	0.031
F/G	1.44	1.41	1.42	1.40	0.010	0.518	0.268	0.039
Fecal dry matter, %[2]								
d 4	18.0	19.8	17.5	20.1	1.13	0.708	0.955	0.043
d 21	22.8	21.3	22.5	23.4	1.10	0.281	0.397	0.786
d 42	24.5	24.6	23.5	23.8	1.20	0.909	0.437	0.891
Economics, $								
Feed cost/pig[3]	11.41	11.74	11.76	12.08	0.181	0.997	0.062	0.076
Feed cost/lb gain[4]	0.306	0.295	0.303	0.298	0.0036	0.345	0.923	0.014
Revenue[5]	18.76	19.91	19.45	20.29	20.288	0.631	0.100	0.003
IOFC[6]	7.35	8.17	7.70	8.21	8.210	0.451	0.344	0.002

[1]A total of 360 barrows (initially 12.4 ± 0.05 lb) were used in a 42-d growth study with 5 pigs per pen and 18 pens per treatment. Yeast pre- and probiotics included ActiSaf Sc 47 HR+ at 0.1%, SafMannan at 0.05% and NucleoSaf at 0.05% in phase 1 diets, and then concentrations were lowered by 50% in phase 2 diets (Phileo by Lesaffre, Milwaukee, WI). Zinc oxide was added to supply 3,000 ppm of Zn for the duration of phase 1, and 2,000 ppm of Zn for the duration of phase 2.

[2]Fecal samples from the same 3 pigs/pen were collected on d 4, 21, and 42.

[3] Feed cost per pig = total feed cost ÷ pigs placed in the pen.

[4] Feed cost per lb gain = feed cost per pig ÷ body weight gain per pig.

[5] Revenue = (gain per pig × $66.69/cwt) × assumed 75% yield.

[6] Income over feed cost = revenue − feed cost per pig.

Table 4. Main effects of yeast probiotics and pharmacological levels of Zn on nursery pig performance[1]

	Yeast probiotics				Zinc			
Item	**No yeast**	**Yeast**	**SEM**	***P* =**	**Low Zn**	**High Zn**	**SEM**	***P* =**
BW, lb								
d 0	12.4	12.4	0.05	0.779	12.4	12.4	0.05	0.901
d 7	13.1	13.2	0.13	0.508	12.9	13.4	0.13	0.001
d 21	24.7	24.9	0.27	0.533	24.2	25.5	0.27	<0.001
d 42	52.0	52.2	0.45	0.744	51.2	52.9	0.45	0.002
Phase 1 (d 0 to 7)								
ADG, lb	0.10	0.11	0.016	0.489	0.07	0.14	0.016	0.001
ADFI, lb	0.18	0.18	0.011	0.847	0.16	0.19	0.011	0.042
F/G	2.43	1.66	0.753	0.474	2.69	1.40	0.753	0.229
Phase 2 (d 7 to 21)								
ADG, lb	0.82	0.84	0.013	0.401	0.80	0.86	0.013	<0.001
ADFI, lb	1.02	1.04	0.020	0.507	0.98	1.08	0.020	<0.001
F/G	1.25	1.24	0.013	0.815	1.23	1.26	0.013	0.163
Experimental period (d 0 to 21)								
ADG, lb	0.58	0.60	0.012	0.288	0.55	0.62	0.012	<0.001
ADFI, lb	0.74	0.75	0.016	0.461	0.71	0.79	0.016	<0.001
F/G	1.28	1.27	0.012	0.230	1.28	1.27	0.012	0.256
Phase 3 common period (d 21 to 42)								
ADG, lb	1.30	1.30	0.013	0.947	1.29	1.31	0.013	0.264
ADFI, lb	1.93	1.91	0.018	0.573	1.92	1.92	0.018	0.811
F/G	1.49	1.48	0.009	0.466	1.49	1.47	0.009	0.146
Overall (d 0 to 42)								
ADG, lb	0.94	0.95	0.010	0.433	0.92	0.96	0.010	0.001
ADFI, lb	1.33	1.33	0.016	0.830	1.31	1.35	0.016	0.031
F/G	1.42	1.41	0.007	0.268	1.43	1.41	0.007	0.039
Fecal dry matter, %[2]								
d 4	18.9	18.8	0.82	0.955	17.7	20.0	0.82	0.043
d 21	22.0	22.9	0.81	0.397	22.6	22.3	0.81	0.786
d 42	24.5	23.6	0.85	0.437	24.0	24.2	0.85	0.891
Economics, $								
Feed cost/pig[3]	11.58	11.92	0.129	0.062	11.58	11.91	0.129	0.076
Feed cost/lb gain[4]	0.301	0.300	0.0028	0.923	0.304	0.296	0.0028	0.014
Revenue[5]	19.34	19.87	0.274	0.100	19.11	20.10	0.274	0.003
IOFC[6]	7.76	7.95	0.188	0.344	7.52	8.19	0.188	0.002

[1]A total of 360 barrows (initially 12.4 ± 0.05 lb) were used in a 42-d growth study with 5 pigs per pen and 18 pens per treatment. Yeast pre- and probiotics included ActiSaf Sc 47 HR+ at 0.10%, SafMannan at 0.05% and NucleoSaf at 0.05% in phase 1 diets, and then concentrations were lowered by 50% in phase 2 diets (Phileo by Lesaffre, Milwaukee, WI). Zinc oxide was added to supply 3,000 ppm of Zn for the duration of phase 1, and 2,000 ppm of Zn for the duration of phase 2.

[2]Fecal samples from the same 3 pigs/pen were collected on d 4, 21, and 42.

[3] Feed cost per pig = total feed cost ÷ pigs placed in the pen.

[4] Feed cost per lb gain = feed cost per pig ÷ body weight gain per pig.

[5] Revenue = (gain per pig × $66.69/cwt) × assumed 75% yield.

[6] Income over feed cost = revenue – feed cost per pig.