Kansas Agricultural Experiment Station Research Reports

Volume 10
Issue 6 *Swine Day*

Article 9

2024

Evaluation of Dietary Acidifiers in Low Acid-Binding Capacity-4 (ABC-4) Diets on Nursery Pig Performance and Fecal Dry Matter

Ethan B. Stas
Kansas State University, ebstas@ksu.edu

Mike D. Tokach
Kansas State University, mtokach@k-state.edu

Joel M. DeRouchey
Kansas State University, jderouch@k-state.edu

See next page for additional authors

Recommended Citation

Stas, Ethan B.; Tokach, Mike D.; DeRouchey, Joel M.; Woodworth, Jason C.; Goodband, Robert D.; and Gebhardt, Jordan T. (2024) "Evaluation of Dietary Acidifiers in Low Acid-Binding Capacity-4 (ABC-4) Diets on Nursery Pig Performance and Fecal Dry Matter," *Kansas Agricultural Experiment Station Research Reports*: Vol. 10: Iss. 6. https://doi.org/10.4148/2378-5977.8624

Evaluation of Dietary Acidifiers in Low Acid-Binding Capacity-4 (ABC-4) Diets on Nursery Pig Performance and Fecal Dry Matter

Authors

Ethan B. Stas, Mike D. Tokach, Joel M. DeRouchey, Jason C. Woodworth, Robert D. Goodband, and Jordan T. Gebhardt

K-STATE Research and Extension

SWINE DAY 2024

KANSAS STATE UNIVERSITY SWINE INDUSTRY DAY 2024

Evaluation of Dietary Acidifiers in Low Acid-Binding Capacity-4 (ABC-4) Diets on Nursery Pig Performance and Fecal Dry Matter

Ethan B. Stas, Mike D. Tokach, Joel M. DeRouchey, Jason C. Woodworth, Robert D. Goodband, and Jordan T. Gebhardt[1]

Summary

A total of 300 pigs (DNA 241 × 600, initially 13.2 lb) were used to evaluate dietary acidifiers in low acid-binding capacity-4 (ABC-4) diets on nursery pig performance and fecal dry matter (DM). At weaning, pigs were randomly allotted to one of six dietary treatments. There were five pigs per pen and 10 replications per treatment. Pigs were fed experimental diets in two phases with phase 1 fed from d 0 to 10 post-weaning followed by phase 2 from d 10 to 24. Four diets were formulated to an ABC-4 level of 200 and 250 meq/kg in phases 1 and 2, respectively, by utilizing four different dietary acidifiers. Dietary acidifiers included 0.36% fumaric acid (Primary Products Ingredients Americas LLC, Decatur, IL), 0.87% Activate DA (Novus, St. Charles, MO), 1.01% KEM-GEST (Kemin, Des Moines, IA), and 0.85% ACID-AID (Alltech, Nicholasville, KY). Diet 5 did not include any dietary acidifiers, which increased the ABC-4 level by 40 meq/kg in both phases. All diets contained 110 ppm of Zn provided by the trace mineral premix. Diet 6 was the same formulation as diet 5, but with the addition of 3,000 and 2,000 ppm of Zn from ZnO in phases 1 and 2, respectively. The addition of ZnO further increased the ABC-4 level of the diet by 87 and 54 meq/kg in phases 1 and 2, respectively. Following phase 2 experimental diets, all pigs were fed a common corn-soybean meal-based diet until the completion of the study on d 38 post-weaning. There were no differences ($P > 0.05$) observed between pigs fed the four dietary acidifiers for the duration of the study. In phase 2 (d 10 to 24), the experimental period (d 0 to 24), and overall (d 0 to 38), pigs fed the low ABC-4 diets containing acidifiers had improved ($P \leq 0.020$) F/G compared to pigs fed the higher ABC-4 diet (without acidifiers). In the experimental period (d 0 to 24), pigs fed diets containing ZnO tended to have improved ($P = 0.052$) F/G compared to pigs fed diets without added ZnO. In conclusion, utilizing dietary acidifiers to achieve a low ABC-4 level improved feed efficiency. The specific dietary acidifier utilized to target a low ABC-4 level did not affect the growth response in nursery pigs. However, most dietary acidifiers were included above their supplier-recommended inclusion rates to achieve the targeted low ABC-4 level and removing them only increased the ABC-4 by 40 meq/kg. Therefore, other aspects of diet formulation such as low ABC-4 specialty protein or lactose sources, low Ca

[1] Department of Diagnostic Medicine/Pathology, College of Veterinary Medicine, Kansas State University.

levels, a combination of acidifiers, or other methods must be considered when targeting low ABC-4 levels.

Introduction

Nursery pigs are typically weaned with an underdeveloped gastrointestinal tract, which limits their ability to produce enough hydrochloric acid to maintain an optimal stomach pH.[2] Increased gastric pH above 4 is associated with impaired protein digestion and increased opportunity for pathogenic organisms to grow.[3] Formulation of diets for nursery pigs to a low acid-binding capacity at a pH of 4 (ABC-4) is a growing area of interest because of its ability to maintain an acidic stomach environment. Previous research has shown that low ABC-4 diets can have positive impacts on nursery pig performance and fecal dry matter.[4] There are many aspects to consider when formulating diets to target a low ABC-4 level. One common method to lower the ABC-4 of the diet is using dietary acidifiers.

Many commercial acidifiers are available for use in swine diets. However, previous studies evaluating acidifiers do not target a specific ABC-4 level or measure how commercial acidifiers alter the complete diet's ABC-4 value. Therefore, it is unknown if various commercially available acidifiers will have the same effect if formulated to the same ABC-4 level. This study will allow nutritionists and producers to better understand acidifiers' effect on the ABC-4 level of the diet and ultimately the effect it has on nursery pig performance when utilized as part of a low ABC-4 diet formulation strategy. Therefore, the objective of this study is to evaluate dietary acidifiers in low ABC-4 diets on nursery pig performance and fecal DM.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The experiment was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Each pen was equipped with a 4-hole, dry self-feeder and nipple waterer to provide ad libitum access to feed and water.

Animals and diets

A total of 300 pigs (DNA 241 × 600, initially 13.3 lb) were housed in two rooms and used in a 38-d nursery trial. Pigs were weaned at approximately 21 d of age into pens of five pigs each based on initial weight and gender. Pens were randomly assigned to one of six dietary treatments with 10 replications per treatment. Pigs were fed experimental diets in two phases with phase 1 from d 0 to 10 post-weaning, followed by phase 2 from d 10 to 24. Phases 1 and 2 diets were formulated to contain 1.35% SID Lys. Following phase 2, all pigs were fed a common corn-soybean meal-based diet until d 38 of the

[2] Pluske, J. R. 2016. Invited review: Aspects of gastrointestinal tract growth and maturation in the pre- and postweaning period of pigs. J. Anim. Sci. 94:399–411. doi:10.2527/jas2015-9767.
[3] Yen, J. T. 2001. Anatomy of the digestive system and nutritional physiology, In: Lewis, A. J., Southern, L. L., editors. Swine nutrition. Boca Raton (FL): CRC Press; p. 21–64.
[4] Stas, E. B., M. D. Tokach, J. C. Woodworth, J. M. DeRouchey, R. D. Goodband, and J. T. Gebhardt. 2023. Dietary acid-binding capacity-4 influences nursery pig performance and fecal dry matter. Kansas Agricultural Experiment Station Research Reports. Vol. 9: Iss. 7. doi:10.4148/2378-5977.8506.

trial. The common diet was formulated to 1.30% SID Lys and met or exceeded all other nutrient requirements established the NRC (2012).[5]

Dietary treatments consisted of four low ABC-4 diets utilizing different dietary acidifiers formulated to 200 and 250 meq/kg in phases 1 and 2, respectively. The dietary acidifiers utilized to achieve the low ABC-4 targets consisted of fumaric acid (Primary Products Ingredients Americas LLC, Decatur, IL), Activate DA (Novus, St. Charles, MO), KEM-GEST (Kemin, Des Moines, IA), and ACID-AID (Alltech, Nicholasville, KY) included at 0.36, 0.87, 1.01, and 0.84% of the diet in both phases, respectively. Fumaric acid, Activate DA, KEM-GEST, and ACID-AID had individual ingredient ABC-4 values of -10,873, -4,487, -3,800, and -4,680 meq/kg, respectively, which ultimately determined their inclusion to achieve the target ABC-4 of experimental diets. The level of Activate DA, KEM-GEST, and ACID-AID in the diets exceeded supplier-recommended inclusion rates to achieve the low ABC-4 levels of 200 and 250 meq/kg in phases 1 and 2, respectively. The fifth diet had the same formulation as the previously mentioned diets but did not contain any dietary acidifiers, which increased the ABC-4 of the diet by 40 meq/kg in both phases. Thus, the inclusion rate of all acidifiers was the amount required to achieve the same dietary ABC-4. All five dietary treatments contained 100 ppm of Zn provided by the trace mineral premix and did not contain any pharmacological levels of Zn. The final dietary treatment was formulated the same as the diet containing no acidifiers, but with the addition of 3,000 and 2,000 ppm of Zn from ZnO in phases 1 and 2, respectively. The addition of ZnO increased the diet ABC-4 value by 87 and 54 meq/kg in phases 1 and 2, respectively.

The basal diets for phases 1 and 2 were manufactured at Hubbard Feeds in Beloit, KS. The basal diets were divided into six batches and treatment ingredients were added and mixed at the Kansas State University O.H. Kruse Feed Technology Center in Manhattan, KS to form six experimental diets. Individual pig weight and feed disappearance were measured on d 10, 17, 24, 31, and 38 to determine ADG, ADFI, and F/G.

Fecal samples were collected on d 10, 17, and 24 to determine fecal DM percentage from the same three medium weight pigs from each pen. After collection, fecal samples were dried at 131°F (55°C) in a forced-air oven for 48 hours, and the ratio of dried to wet fecal weight determined the fecal percentage DM.

Statistical analysis

Data were analyzed as a completely randomized design using the RStudio environment (Version 1.3.1093, RStudio, Inc., Boston, MA) using R programming language [Version 4.0.2 (2020-06-22), R Core Team, R Foundation for Statistical Computing, Vienna, Austria] with pen as the experimental unit. Room was included in the model as a random effect. Effects of dietary acidifier, ABC-4 level, and ZnO were tested by using pre-planned contrast comparisons. The acidifier effect was tested by a contrast comparison of the four low ABC-4 diets with different acidifiers and excluded the diets not containing acidifiers. The ABC-4 level effect was tested by a comparison of the mean of the four low ABC-4 diets containing acidifiers against the high ABC-4 diet without acidifiers or added ZnO. The ZnO effect was tested by a pairwise comparison of the high ABC-4 diets with or without added ZnO. Fecal DM were analyzed using the

[5] NRC. 2012. Nutrient Requirements of Swine. 11th ed. Natl. Acad. Press, Washington, DC.

fixed effects of day, treatment, and the associated interaction accounting for repeated measures over time. Differences between treatments and day (where appropriate), as well as their interaction were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

All analyzed ABC-4 diet values were less than calculated values across both phases, which is consistent with previous research.[6] However, all diets not containing ZnO were only on average 27 and 19 meq/kg lower in analyzed ABC-4 values than calculated values for phases 1 and 2, respectively. The difference between analyzed and calculated ABC-4 values for the diet containing ZnO were 60 and 31 meq/kg for phases 1 and 2, respectively. The larger difference between calculated and analyzed ABC-4 values in diets containing ZnO is also consistent with previous research.[7]

There were no differences ($P > 0.10$) in growth performance between pigs fed the four dietary acidifiers for phase 1 (d 0 to 10), phase 2 (d 10 to 24), and the experimental period (d 0 to 24). In the common period (d 24 to 38), there was a tendency for an acidifier effect ($P = 0.094$), where pigs previously fed fumaric acid and Activate DA had numerically the most improved F/G. Overall (d 0 to 38), there were no differences ($P > 0.10$) in growth performance between pigs fed the four dietary acidifiers. In addition, there were no differences ($P > 0.10$) in fecal DM between pigs fed the 4 dietary acidifiers for all collection periods.

There were no differences ($P > 0.10$) in growth performance from pigs fed either ABC-4 level in phase 1 (d 0 to 10). In phase 2 (d 10 to 24) and the experimental period (d 0 to 24), pigs fed the low ABC-4 diets had improved ($P \leq 0.020$) F/G compared to pigs fed the 40 meq/kg higher ABC-4 diet. In the common period (d 24 to 38), there were no differences ($P > 0.10$) in growth performance between pigs previously fed either ABC-4 level. Overall (d 0 to 38), pigs fed the low ABC-4 diets had improved ($P = 0.013$) F/G compared to pigs fed the 40 meq/kg higher ABC-4 diet. There were no differences ($P > 0.10$) in fecal DM for pigs fed either ABC-4 level on all collection periods.

There were no differences ($P > 0.10$) in growth performance between pigs fed diets with or without added ZnO for phase 1 (d 0 to 10) and phase 2 (d 10 to 24). In the experimental period (d 0 to 24), pigs fed diets containing ZnO tended to have improved ($P = 0.052$) F/G compared to pigs fed diets without added ZnO. In the common period (d 24 to 38) and overall (d 0 to 38), there were no differences ($P > 0.10$) in growth performance between pigs fed diets with or without added ZnO. There were also no differences ($P > 0.10$) in fecal DM for pigs fed diets with or without added ZnO for all collection periods.

[6] Stas, E. B., M. D. Tokach, J. C. Woodworth, J. M. DeRouchey, R. D. Goodband, and J. T. Gebhardt. 2023. Dietary acid-binding cpacity-4 influences nursery pig performance and fecal dry matter. Kansas Agricultural Experiment Station Research Reports. 9:7. doi:10.4148/2378-5977.8506.

[7] Stas, E. B., M. D. Tokach, J. M. DeRouchey, R. D. Goodband, J. C. Woodworth, and J. T. Gebhardt. 2022. Evaluation of the acid-binding capacity of ingredients and complete diets commonly used for weanling pigs. Transl. Anim. Sci. 6:1-9. Doi:L10.1093/tas/txac104.

In conclusion, the different dietary acidifiers utilized to target a low ABC-4 diet had similar effects on performance. It is important to acknowledge that fumaric acid has a much lower ABC-4 value than the other three commercial acidifiers and therefore, has a lower inclusion than the other acidifiers to achieve the same reduction in diet ABC-4. The low ABC-4 diets improved feed efficiency compared to the high ABC-4 diets. However, removing the acidifiers only increased the ABC-4 by 40 meq/kg, which may not have been a large enough difference to observe differences in ADG and fecal DM as observed with previous studies where dietary ABC-4 differences were greater. This study illustrates the complexity of low ABC-4 diet formulation, and while dietary acidifiers are an important part of a low ABC-4 diet formulation strategy, there are other dietary aspects such as protein or lactose sources, Ca levels, P source, and other methods that must be considered to achieve an optimal ABC-4 level and improve nursery pig performance.

Table 1. Phase 1 diet composition (as-fed basis)[1]

Dietary acidifier:	**Acidifier 1**	**Acidifier 2**	**Acidifier 3**	**Acidifier 4**	**-**	**-**
ABC-4, meq/kg:	**200**	**200**	**200**	**200**	**240**	**327**
ZnO:	-	-	-		-	+
Ingredients, %						
Corn	54.65	54.14	54.00	54.18	55.01	54.61
Soybean meal	12.00	12.00	12.00	12.00	12.00	12.00
Crystalline lactose	15.00	15.00	15.00	15.00	15.00	15.00
Microbially enhanced soybean meal[2]	10.00	10.00	10.00	10.00	10.00	10.00
Spray-dried bovine plasma	2.50	2.50	2.50	2.50	2.50	2.50
Fumaric acid[3]	0.36	---	---	---	---	---
Activate DA[4]	---	0.87	---	---	---	---
KEM-GEST[5]	---	---	1.01	---	---	---
ACID-AID[6]	---	---	---	0.84	---	---
Corn oil	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	0.26	0.26	0.26	0.26	0.26	0.26
Monocalcium phosphate	0.98	0.98	0.98	0.98	0.98	0.98
Salt	0.83	0.83	0.83	0.83	0.83	0.83
L-Lys	0.46	0.46	0.46	0.46	0.46	0.46
DL-Met	0.22	0.22	0.22	0.22	0.22	0.22
L-Thr	0.19	0.19	0.19	0.19	0.19	0.19
L-Trp	0.07	0.07	0.07	0.07	0.07	0.07
L-Val	0.10	0.10	0.10	0.10	0.10	0.10
ZnO	---	---	---	---	---	0.40
Vitamin premix with phytase[7]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Total	100	100	100	100	100	100

continued

Table 1. Phase 1 diet composition (as-fed basis)[1]

Dietary acidifier:	Acidifier 1	Acidifier 2	Acidifier 3	Acidifier 4	-	-
ABC-4, meq/kg:	**200**	**200**	**200**	**200**	**240**	**327**
ZnO:	-	-	-		-	+
Calculated analysis						
SID amino acids, %						
Lys	1.35	1.35	1.35	1.35	1.35	1.35
Ile:Lys	55	55	55	55	55	55
Leu:Lys	119	118	118	118	119	119
Met:Lys	35	35	35	35	35	35
Met and Cys:Lys	56	56	56	56	56	56
Thr:Lys	63	63	63	63	63	63
Trp:Lys	20.3	20.3	20.3	20.3	20.3	20.3
Val:Lys	70	70	70	70	70	70
His:Lys	36	36	36	36	36	36
Total Lys, %	1.51	1.51	1.51	1.51	1.51	1.51
NE, kcal/lb	1,188	1,182	1,181	1,183	1,193	1,188
SID Lys:NE, g/Mcal	5.15	5.18	5.18	5.18	5.14	5.16
CP, %	20.3	20.3	20.3	20.3	20.4	20.3
Ca, %	0.46	0.46	0.46	0.46	0.46	0.46
P, %	0.51	0.51	0.51	0.51	0.51	0.51
STTD P, %	0.46	0.46	0.46	0.46	0.46	0.46
Analyzed ABC-4, meq/kg	173	173	173	173	213	267

[1] Phase 1 diets were fed from d 0 to 10 post-weaning.
[2] ME-PRO; Prairie Aquatech; Brookings, SD.
[3] Primary Products Ingredients Americas LLC, Decatur, IL
[4] Novus; St. Charles, MO.
[5] Kemin; Des Moines, IA.
[6] Alltech; Nicholasville, KY.
[7] Quantum Blue 5G (ABVista, Plantation, FL) provided an estimated release of 0.13% STTD P with 567 FTU/lb.

Table 2. Phase 2 diet composition (as-fed basis)[1]

Dietary acidifier:	Acidifier 1	Acidifier 2	Acidifier 3	Acidifier 4	-	-
ABC-4, meq/kg:	**250**	**250**	**250**	**250**	**290**	**344**
ZnO:	-	-	-		-	+
Ingredients, %						
Corn	60.60	60.09	59.94	60.12	60.96	60.71
Soybean meal	18.75	18.75	18.75	18.75	18.75	18.75
Crystalline lactose	7.50	7.50	7.50	7.50	7.50	7.50
Microbially enhanced soybean meal[2]	8.00	8.00	8.00	8.00	8.00	8.00
Fumaric acid[3]	0.36	---	---	---	---	---
Activate DA[4]	---	0.87	---	---	---	---
KEM-GEST[5]	---	---	1.01	---	---	---
ACID-AID[6]	---	---	---	0.84	---	---
Corn oil	1.00	1.00	1.00	1.00	1.00	1.00
Limestone	0.41	0.41	0.41	0.41	0.41	0.41
Monocalcium phosphate	1.03	1.03	1.03	1.03	1.03	1.03
Salt	0.80	0.80	0.80	0.80	0.80	0.80
L-Lys	0.52	0.52	0.52	0.52	0.52	0.52
DL-Met	0.23	0.23	0.23	0.23	0.23	0.23
L-Thr	0.22	0.22	0.22	0.22	0.22	0.22
L-Trp	0.08	0.08	0.08	0.08	0.08	0.08
L-Val	0.12	0.12	0.12	0.12	0.12	0.12
ZnO	---	---	---	---	---	0.25
Vitamin premix with phytase[7]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Total	100	100	100	100	100	100

continued

Table 2. Phase 2 diet composition (as-fed basis)[1]

Dietary acidifier:	Acidifier 1	Acidifier 2	Acidifier 3	Acidifier 4	-	-
ABC-4, meq/kg:	**250**	**250**	**250**	**250**	**290**	**344**
ZnO:	-	-	-		-	+
Calculated analysis						
SID amino acids, %						
Lys	1.35	1.35	1.35	1.35	1.35	1.35
Ile:Lys	56	56	56	56	56	56
Leu:Lys	117	117	117	117	117	117
Met:Lys	37	37	37	37	37	37
Met and Cys:Lys	56	56	56	56	56	56
Thr:Lys	63	63	63	63	63	63
Trp:Lys	21.0	21.0	21.0	21.0	21.0	21.0
Val:Lys	70	70	70	70	70	70
His:Lys	36	36	36	36	36	36
Total Lys, %	1.50	1.50	1.50	1.50	1.50	1.50
NE, kcal/lb	1,145	1,139	1,137	1,139	1,149	1,146
SID Lys:NE, g/Mcal	5.35	5.38	5.39	5.38	5.34	5.35
CP, %	20.7	20.7	20.7	20.7	20.7	20.7
Ca, %	0.54	0.54	0.54	0.54	0.54	0.54
P, %	0.54	0.54	0.54	0.54	0.54	0.54
STTD P, %	0.46	0.46	0.46	0.46	0.46	0.46
Analyzed ABC-4, meq/kg	233	227	227	227	280	313

[1] Phase 2 diets were fed from d 10 to 24 post-weaning.
[2] ME-PRO; Prairie Aquatech; Brookings, SD.
[3] Primary Products Ingredients Americas LLC, Decatur, IL
[4] Novus; St. Charles, MO.
[5] Kemin; Des Moines, IA.
[6] Alltech; Nicholasville, KY.
[7] Quantum Blue 5G (ABVista, Plantation, FL) provided an estimated release of 0.13% STTD P with 567 FTU/lb.

Table 3. Effects of formulating diets to equal ABC-4 by using different acidifiers on nursery pig performance and fecal dry matter (DM)[1]

Dietary acidifier:	Acidifier 1[2]	Acidifier 2[3]	Acidifier 3[4]	Acidifier 4[5]	-	-				
Phase 1 ABC-4, meq/kg:	200	200	200	200	240	327				
Phase 2 ABC-4, meq/kg:	250	250	250	250	290	344		*P* =		
ZnO:	-	-	-	-	-	+	SEM	Acidifier[6]	ABC-4[7]	ZnO[8]
BW										
d 0	13.3	13.3	13.3	13.4	13.3	13.3	0.04	0.970	0.795	0.953
d 10	16.1	15.9	16.0	16.2	16.2	16.7	0.32	0.796	0.726	0.254
d 24	24.9	24.7	24.7	24.4	24.5	25.9	0.61	0.934	0.751	0.072
d 38	45.7	44.9	44.6	44.6	44.9	45.4	1.28	0.946	0.907	0.682
Phase 1 (d 0 to 10)										
ADG, lb	0.28	0.26	0.27	0.29	0.29	0.33	0.031	0.807	0.699	0.244
ADFI, lb	0.32	0.30	0.31	0.32	0.33	0.35	0.029	0.773	0.395	0.518
G:F	0.89	0.81	0.86	0.89	0.85	0.92	0.059	0.621	0.883	0.417
F/G[9]	1.13	1.23	1.17	1.12	1.18	1.09	---	0.621	0.883	0.417
Phase 2 (d 10 to 24)										
ADG, lb	0.62	0.62	0.62	0.59	0.59	0.65	0.040	0.626	0.495	0.146
ADFI, lb	1.07	1.03	1.03	0.99	1.07	1.12	0.041	0.739	0.433	0.305
G:F	0.58	0.60	0.60	0.59	0.55	0.58	0.032	0.669	0.009	0.135
F/G[9]	1.72	1.66	1.66	1.70	1.81	1.72	---	0.669	0.009	0.135
Experimental period (d 0 to 24)										
ADG, lb	0.48	0.47	0.47	0.46	0.46	0.52	0.026	0.939	0.781	0.131
ADFI, lb	0.76	0.72	0.73	0.71	0.76	0.80	0.030	0.928	0.357	0.324
G:F	0.64	0.64	0.65	0.65	0.61	0.65	0.025	0.973	0.020	0.052
F/G[9]	1.57	1.56	1.54	1.55	1.65	1.55	---	0.973	0.020	0.052
Common period (d 24 to 38)										
ADG, lb	1.48	1.45	1.43	1.44	1.46	1.38	0.095	0.848	0.810	0.107
ADFI, lb	2.07	2.03	2.07	2.05	2.09	2.02	0.115	0.852	0.513	0.312
G:F	0.72	0.72	0.69	0.71	0.70	0.68	0.011	0.094	0.376	0.199
F/G[9]	1.40	1.40	1.45	1.42	1.43	1.46	---	0.094	0.376	0.199

continued

Table 3. Effects of formulating diets to equal ABC-4 by using different acidifiers on nursery pig performance and fecal dry matter (DM)[1]

Dietary acidifier:	Acidifier 1[2]	Acidifier 2[3]	Acidifier 3[4]	Acidifier 4[5]	-	-				
Phase 1 ABC-4, meq/kg:	200	200	200	200	240	327				
Phase 2 ABC-4, meq/kg:	250	250	250	250	290	344		*P* =		
ZnO:	-	-	-	-	-	+	SEM	Acidifier[6]	ABC-4[7]	ZnO[8]
Overall (d 0 to 38)										
ADG, lb	0.84	0.83	0.82	0.82	0.83	0.84	0.034	0.980	0.990	0.880
ADFI, lb	1.23	1.20	1.22	1.21	1.25	1.25	0.054	0.903	0.357	0.944
G:F	0.69	0.69	0.68	0.68	0.66	0.67	0.007	0.310	0.013	0.652
F/G[9]	1.46	1.45	1.48	1.46	1.51	1.50	---	0.310	0.013	0.652
Fecal DM, %[10]										
d 10	25.4	24.3	25.4	24.4	25.8	27.6	1.13	0.707	0.391	0.218
d 17	24.3	21.6	22.7	22.6	23.0	24.6		0.711	0.848	0.269
d 24	23.2	23.4	21.6	22.2	22.3	23.6		0.403	0.357	0.357

[1] A total of 300 pigs (initial BW of 13.3 ± 0.04 lb) were used in a 38-d nursery trial. A total of four dietary treatments were utilized with four low ABC-4 diets utilizing dietary acidifiers and two high ABC-4 diets with or without pharmacological levels on Zn from ZnO. Dietary acidifiers were added to achieve an equal ABC-4 level across the four low ABC-4 diets.

[2] Fumaric acid; Tate & Lyle, Decatur, IL. Included at 0.36% of the diet with an ABC-4 of -10,873 meq/kg.

[3] Activate DA; Novus, St. Charles, MO. Included at 0.87% of the diet with an ABC-4 of -4,487 meq/kg.

[4] KEM-GEST; Kemin, Des Moines, IA. Included at 1.01% of the diet with an ABC-4 of -3,800 meq/kg.

[5] ACID-AID; Alltech, Nicholasville, KY. Included at 0.84% of the diet with an ABC-4 of -4,680 meq/kg.

[6] Compares the four low ABC-4 diets. Excludes the high ABC-4 diets.

[7] Compares the mean of the low ABC-4 diets and the high ABC-4 without ZnO. Excludes the ABC-4 diet with ZnO.

[8] Compares the two high ABC-4 diets. Excludes all low ABC-4 diets.

[9] Calculated using the inverse of G:F. Therefore, no SEM is reported and *P* values are the same as G:F.

[10] Treatment × day, $P = 0.885$; Treatment, $P = 0.056$; Day, $P < 0.001$. The *P*-values represented in the data table show the effect of treatment within day.