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Evaluation of Dietary Electrolyte Balance on Nursery Pig Performance

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Evaluation of Dietary Electrolyte Balance on Nursery Pig Performance

Abstract

A total of 2,880 pigs (PIC 327 × L42; initial BW 11.4 lb) were used in a 35-d growth performance trial evaluating the effects of dietary electrolyte balance (dEB) on growth performance of nursery pigs. There were 30 pigs per pen (60 pigs per double-sided feeder) and 12 replications (feeder) per treatment. Pens of pigs were allotted by BW and sex on arrival, and randomly assigned to 1 of 4 dietary treatments. Treatment diets were corn-soybean meal-based with dried whey and other specialty protein sources used in Phase 1 with decreased amounts in Phase 2. Dietary electrolyte balance was determined using the following equation: dEB = ((Na*434.98) + (K*255.74) – (Cl*282.06)) mEq/ kg. Phase 1 diets had dEB's of 84, 137, 190, and 243 mEq/kg. Phase 2 diets had dEB's of 29, 86, 143, and 199 mEq/kg. Limestone was used as the main Ca source in the high dEB diet and was replaced by increasing levels of $CaCl_2$ to form the other experimental diets. The lowest dEB diets were achieved by adding 1.17% and 1.25% $CaCl_2$ in Phase 1 and Phase 2, respectively. The highest dEB diets required additions of 0.55 and 0.80% limestone for Phases 1 and 2, respectively. The two intermediate diets were then balanced to have an equal stepwise increase in dEB. Dietary Ca concentrations were maintained in the three highest dEB diets, but increased in the low dEB diet with the increasing level of $CaCl_2$. After d 21 of experimental diets, a common Phase 3 diet (Table 3) was fed to all pigs and was a typical nursery diet fed in commercial production with a dEB of 257 mEq/kg. From d 0 to 8 (Phase 1), decreasing dEB decreased (quadratic, $P < 0.05$) ADG, ADFI, and final BW, and worsened (quadratic, $P = 0.042$) F/G. Likewise, from d 8 to 21 (Phase 2), ADG (quadratic, $P = 0.022$) and ADFI (linear, $P = 0.011$) decreased as dEB was decreased, resulting in a worsening of feed efficiency (quadratic, $P < 0.001$). From d 0 to 21, ADG and ADFI decreased (linear, $P < 0.05$) as dEB decreased resulting in poorer (quadratic, $P < 0.001$) F/G. When a common diet was fed from d 21 to 35 (Phase 3), pigs that were previously fed low dEB diets had improved (linear, $P < 0.001$) ADG and F/G; however, no differences were observed for feed intake. Overall (d 0 to 35), decreasing dEB in nursery diets from d 0 to 21 caused a reduction in ADG and final BW (linear, $P < 0.001$), which was the result of a tendency for lower ADFI (linear $P = 0.077$) and poorer feed efficiency (quadratic, $P = 0.028$). In conclusion, feeding reducing levels of dietary dEB in nursery diets resulted in poorer growth performance of weanling pigs.

Keywords

dietary electrolyte balance, growth performance, nursery pig

Cover Page Footnote

Appreciation is expressed to Jason Tebay and Dr. Matt Allerson, Holden Farms, for their technical support and expertise in conducting the experiment.

Authors

A. Jones, J. C. Woodworth, S. S. Dritz, M. D. Tokach, J. M. DeRouchey, and R. D. Goodband

Evaluation of Dietary Electrolyte Balance on Nursery Pig Performance[1]

A.M. Jones, J.C. Woodworth, S.S. Dritz,[2] M.D. Tokach, J.M. DeRouchey, and R.D. Goodband

Summary

A total of 2,880 pigs (PIC 327 × L42; initial BW 11.4 lb) were used in a 35-d growth performance trial evaluating the effects of dietary electrolyte balance (dEB) on growth performance of nursery pigs. There were 30 pigs per pen (60 pigs per double-sided feeder) and 12 replications (feeder) per treatment. Pens of pigs were allotted by BW and sex on arrival, and randomly assigned to 1 of 4 dietary treatments. Treatment diets were corn-soybean meal-based with dried whey and other specialty protein sources used in Phase 1 with decreased amounts in Phase 2. Dietary electrolyte balance was determined using the following equation: dEB = ((Na*434.98) + (K*255.74) – (Cl*282.06)) mEq/kg. Phase 1 diets had dEB's of 84, 137, 190, and 243 mEq/kg. Phase 2 diets had dEB's of 29, 86, 143, and 199 mEq/kg. Limestone was used as the main Ca source in the high dEB diet and was replaced by increasing levels of $CaCl_2$ to form the other experimental diets. The lowest dEB diets were achieved by adding 1.17% and 1.25% $CaCl_2$ in Phase 1 and Phase 2, respectively. The highest dEB diets required additions of 0.55 and 0.80% limestone for Phases 1 and 2, respectively. The two intermediate diets were then balanced to have an equal stepwise increase in dEB. Dietary Ca concentrations were maintained in the three highest dEB diets, but increased in the low dEB diet with the increasing level of $CaCl_2$. After d 21 of experimental diets, a common Phase 3 diet (Table 3) was fed to all pigs and was a typical nursery diet fed in commercial production with a dEB of 257 mEq/kg. From d 0 to 8 (Phase 1), decreasing dEB decreased (quadratic, $P < 0.05$) ADG, ADFI, and final BW, and worsened (quadratic, $P = 0.042$) F/G. Likewise, from d 8 to 21 (Phase 2), ADG (quadratic, $P = 0.022$) and ADFI (linear, $P = 0.011$) decreased as dEB was decreased, resulting in a worsening of feed efficiency (quadratic, $P < 0.001$). From d 0 to 21, ADG and ADFI decreased (linear, $P < 0.05$) as dEB decreased resulting in poorer (quadratic, $P < 0.001$) F/G. When a common diet was fed from d 21 to 35 (Phase 3), pigs that were previously fed low dEB diets had improved (linear, $P < 0.001$) ADG and F/G; however, no differences were observed for feed intake. Overall (d 0 to 35), decreasing dEB in nursery diets from d 0 to 21 caused a reduction in ADG and final BW (linear, $P < 0.001$), which was the result of a tendency for lower ADFI (linear $P = 0.077$) and poorer feed efficiency (quadratic, $P = 0.028$).

[1] Appreciation is expressed to Jason Tebay and Dr. Matt Allerson, Holden Farms, for their technical support and expertise in conducting the experiment.

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In conclusion, feeding reducing levels of dietary dEB in nursery diets resulted in poorer growth performance of weanling pigs.

Key words: dietary electrolyte balance, growth performance, nursery pig

Introduction

Electrolytes are key minerals that can be defined as chemical substances that separate when dissolved in fluids to form positive (cation) and negative (anion) ions. These charged ions produce an electrically conductive solution that serves as a medium for cellular signaling, biochemical reactions, transport of substrates across cellular membranes, and the removal of waste products from the body among others. Biologically, there are seven major electrolytes: (1) Na^+; (2) K^+; (3) Mg^{2+}; (4) Ca^{2+}; (5) Cl^-; (6) HPO_4^{2-}; (7) HCO_3^- (Alberts et al. 2002).[3]

Of the seven electrolytes, Mongin (1981)[4] determined that the sum of Na^+, K^+, and Cl^- were the most influential minerals in contributing to the acid-base status of broilers. Based on these findings, an equation was derived in predicating the net acid intake of set animal referred to as dietary electrolyte balance (dEB = Na + K – Cl mEq/kg). Traditionally, the optimal electrolyte balance in the diet for pigs is reported to be around 250 mEq/kg (NRC, 2012)[5] but limited research exists in this particular area. Recently, Guzmán-Pino et al. (2015),[6] reported that nursery pigs fed diets with increasing dEB had poorer ADG and F/G when dEB exceeded 150 mEq/kg. These researchers used $CaCl_2$ to lower the dEB and reported 48.7% improvement in ADG by decreasing dEB from 269 to 16 mEq/kg. Thus, the objective of this study was to determine the influence of dEB on growth performance in nursery pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol for this experiment. The experiment was conducted at a commercial nursery in MN. Pigs were housed in pens (6 × 11 ft) that were equipped with double sided, 5-hole, stainless steel dry feeder and one cup waterer for ad libitum access to feed and water. Feed additions were made by a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that measured feed amounts for each feeder.

A total of 2,880 pigs (PIC 327 × L42; initial BW 11.4 lb) with 30 pigs per pen (60 pigs per feeder) and 12 replications (feeder) per treatment were used in a 35-d trial evaluating the effects of dEB on growth performance of nursery pigs. Pens of pigs were blocked by BW and gender to 1 of 4 treatments in a completely randomized block design. Pigs and feeders were weighed on d 0, 8, 15, 21, and 35 of the trial to determine ADG, ADFI, and F/G.

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[3] Alberts, B., A. Johnson, J. Lewis, M. Raff, K. Roberts, and P. Walter. 2002. Molecular biology of the cell. 4th edition, Garland Science, New York.

[4] Mongin, P. 1981. Recent advances in dietary anion-cation balance: Applications in poultry. Proc. Nutr. Soc. 40:285-294.

[5] Nutrient requirements of swine. 2012. 11th edition, National Research Council, Washington DC.

[6] Guzmán, S. A., D. Solà-Oriol, R. Daving, E. G. Manzanilla, and J. F. Pèrez. 2015. Influence of dietary electrolyte balance on feed preference and growth performance of post-weaned piglets. J. Anim. Sci. 93:2840-2848. doi:10.2527/jas2014-8380

Experimental diets (Tables 1 and 2) were fed in two phases, with the first phase being provided at 3 lb/pig at weaning. The second phase was fed until d 21 post-weaning, when pigs weighed approximately 22 lb. Treatment diets were corn-soybean meal-based with dried whey and other specialty protein sources used in Phase 1 and with decreased amounts in Phase 2.

Dietary electrolyte balance was determined using the following equation: ((Na*434.98) + (K*255.74) – (Cl*282.06)).[4] Phase 1 diets had dEB's of 84, 137, 190, and 243 mEq/kg. Phase 2 diets had dEB's of 29, 86, 143, and 199 mEq/kg. Limestone was used as the main Ca source in the high dEB diet and was replaced by increasing levels of $CaCl_2$ to form the other experimental diets. The lowest dEB diets were achieved by adding 1.17% and 1.25% $CaCl_2$ in Phase 1 and Phase 2, respectively. The highest dEB diets required additions of 0.55 and 0.80% limestone for Phases 1 and 2, respectively. The two intermediate diets were then balanced to have an equal stepwise increase in dEB. Dietary Ca concentrations were maintained in the three highest dEB diets, but increased in the low dEB diet with the increasing level of $CaCl_2$. After d 21, a common Phase 3 diet (Table 3) was fed to all pigs and was typical of a standard nursery diet fed in commercial production with a dEB of 257 mEq/kg. Phase 1 diets were fed in pellet form, while Phases 2 and 3 were fed in meal form.

Diet samples were taken from 6 feeders per dietary treatment on each weigh day and combined to form a composite sample within each phase. Samples were then stored at -4°F until further analysis. Samples of the diets were analyzed for DM, CP, crude fat, Na, K, Cl, Ca and P (Ward Laboratory, Kearney, NE). All samples for all assays were analyzed in duplicate and were within 10% error of each other. Following chemical analysis, analyzed values for Na, K, and Cl were used to calculate dEB.

Data were analyzed using the PROC GLIMMIX procedure in SAS (SAS Institute, Inc., Cary, NC) with feeder as the experimental unit. Dietary treatments were the fixed effect and block and room served as the random effect in the model. The effects of increasing dietary dEB on performance criteria were determined by linear and quadratic polynomial contrasts. A *P*-value ≤ 0.05 was considered significant and $0.05 < P \leq 0.10$ was considered a tendency.

Results and Discussion

Chemical analysis of experimental diets showed that most nutrients were similar to formulated values for Phase 1 diets (Table 4). Analyzed values for Na and K in Phase 2 diets were consistently higher across dietary treatments; however, Cl levels were lower than formulated values. Although these values varied from formulated values, the range of dEB targeted was ultimately maintained across dietary treatments.

From d 0 to 8 (Phase 1), decreasing dEB decreased (quadratic, $P < 0.05$) ADG, ADFI, and final BW, and worsened (quadratic, $P = 0.042$) F/G. Likewise, from d 8 to 21 (Phase 2), ADG (quadratic, $P = 0.022$) and ADFI (linear, $P = 0.011$) decreased as dEB was decreased, resulting in a worsening of feed efficiency (quadratic, $P < 0.001$).

From d 0 to 21, ADG and ADFI decreased (linear, $P < 0.05$) as dEB decreased resulting in poorer (quadratic, $P < 0.001$) F/G. When a common diet was fed from d 21 to 35

(Phase 3), pigs that were previously fed low dEB diets had improved (linear, $P < 0.001$) ADG and F/G; however, no differences were observed for feed intake.

Overall (d 0 to 35), decreasing dEB in nursery diets from d 0 to 21 caused a reduction in ADG and final BW (linear, $P < 0.001$), which was the result of a tendency for lower ADFI (linear $P = 0.077$) and poorer feed efficiency (quadratic, $P = 0.028$).

In conclusion, feeding diets with reduced dEB in nursery diets resulted in poorer growth performance of weanling pigs. A possible explanation for the poorer growth performance observed in the pigs fed low dEB diets could be attributed to the $CaCl_2$ used to lower dEB. Sensory tests using humans has demonstrated that calcium chloride itself is perceived as bitter and metallic in taste (Lawless et al., 2003; 2004).[7,8] Yen et al. (1981)[9] found that high dietary $CaCl_2$ limited intake in pigs through a Cl-induced metabolic acidosis. In addition, a preference trial conducted by Guzmán-Pino et al. (2015)[6] examining a low (with $CaCl_2$) and high (without $CaCl_2$) dEB diet showed that pigs preferred the high dEB diet. However, when those diets were used in a growth performance trial, performance decreased when pigs were fed levels greater than 150 mEq/kg of the diet. Personal contact with Guzmán-Pino and Davin indicated that a similar unprotected $CaCl_2$ source was used in both experiments as well as the same equation in calculating dEB. The reasons for the observed improvement in growth rate and feed intake in their growth performance trial when pigs were fed low dEB diets are unclear. Therefore, further research is needed to understand the reason that Guzmán-Pino et al. (2015)[6] reported improved performance when $CaCl_2$ was used to lower the dEB of diets, whereas the results of our experiment found the opposite effect.

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[7] Lawless, H. T., F. Rapacki, J. Horne, and A. Hayes. 2003. The taste of calcium and magnesium salts and anionic modifications. Food Qual. Prefer. 14:319-325. doi:10.1016/S0950-3293(02)00128-3.

[8] Lawless, H. T., F. Rapacki, J. Horne, A. Hayes, and G. Wang. 2004. The taste of calcium chloride in mixtures with NaCl, sucrose, and citric acid. Food Qual. Prefer. 15:83-89. doi:10.1016/S0950-3293(03)00099-5.

[9] Yen, J. T., W. G. Pond, and R. L. Prior. 1981. Calcium chloride as a regulator of feed intake and weight gain in pigs. J. Anim. Sci. 4:778-782. doi:10.2134/jas1981.524778

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

	Dietary electrolyte balance (mEq/kg)[2]			
Ingredient, %	84	137	190	243
Corn	38.58	39.00	39.14	39.24
Soybean meal, 46.5% CP	17.71	17.68	17.67	17.66
Corn DDGS[3]	5.00	5.00	5.00	5.00
Fish meal	4.50	4.50	4.50	4.50
HP 300[4]	2.50	2.50	2.50	2.50
Spray dried whey	25.00	25.00	25.00	25.00
Choice white grease	3.00	3.00	3.00	3.00
Moncalcium P, 21% P	0.40	0.40	0.40	0.40
Limestone	---	---	0.26	0.55
Calcium chloride	1.17	0.78	0.39	---
Sodium chloride	0.30	0.30	0.30	0.30
L-Lys HCL	0.48	0.48	0.48	0.48
MHA[5]	0.29	0.29	0.29	0.29
L-Thr	0.20	0.20	0.20	0.20
L-Trp	0.05	0.05	0.05	0.05
L-Val	0.10	0.10	0.10	0.10
Choline chloride, 60%	0.04	0.04	0.04	0.04
Phytase[6]	0.04	0.04	0.04	0.04
Zinc oxide	0.39	0.39	0.39	0.39
Selenium, 0.06%	0.05	0.05	0.05	0.05
Trace mineral premix	0.13	0.13	0.13	0.13
Vitamin premix	0.10	0.10	0.10	0.10
Total	100	100	100	100

continued

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

	Dietary electrolyte balance (mEq/kg)[2]			
Ingredient, %	84	137	190	243
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.40	1.40	1.40	1.40
Ile:Lys	55	55	55	55
Leu:Lys	111	111	111	111
Met:Lys	40	40	40	40
Met and Cys:Lys	59	59	59	59
Thr:Lys	64	64	64	64
Trp:Lys	19	19	19	19
Val:Lys	67	67	67	67
ME, kcal/lb	1,570	1,576	1,578	1,580
CP, %	20.99	21.01	21.01	21.02
Na, %	0.39	0.39	0.39	0.39
Cl, %	1.34	1.16	0.97	0.78
K, %	1.14	1.14	1.14	1.14
Ca, %	0.84	0.73	0.73	0.73
P, %	0.67	0.67	0.67	0.67
Available P, %	0.59	0.59	0.59	0.59

[1]Phase 1 diets were fed for 8 d or to approximately 12.5 lb BW.
[2]Dietary electrolyte balance was calculated using the following equation: ((Na*434.98) + (K*255.74) – (Cl*282.06)).
[3]Dried distillers grains with solubles,
[4]Hamlet Protein (Findlay, OH).
[5]Novus International (Saint Charles, MO).
[6]Quantum Blue (AB-Vista Americas, Plantation, FL).

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

	Dietary cation anion difference (mEq/kg)[2]			
Ingredient, %	29	86	142	199
Corn	46.92	47.16	47.28	47.41
Soybean meal, 46.5% CP	24.70	24.68	24.67	24.66
Corn DDGS[3]	15.00	15.00	15.00	15.00
LOL Strbase LA S01J[4]	5.00	5.00	5.00	5.00
Fish meal	3.75	3.75	3.75	3.75
Choice white grease	1.00	1.00	1.00	1.00
Dicalcium P, 18.5% P	0.63	0.63	0.63	0.63
Limestone	---	0.20	0.50	0.80
Calcium chloride	1.25	0.83	0.42	---
Sodium chloride	0.35	0.35	0.35	0.35
L-Lys HCL	0.40	0.40	0.40	0.40
L-Thr	0.13	0.13	0.13	0.13
L-Trp	0.03	0.03	0.03	0.03
Zinc oxide	0.25	0.25	0.25	0.25
Iron oxide	0.10	0.10	0.10	0.10
CTC-100[5]	0.20	0.20	0.20	0.20
Vitamin and TM premix	0.30	0.30	0.30	0.30
Total	100	100	100	100

continued

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

	Dietary cation anion difference (mEq/kg)[2]			
Ingredient, %	29	86	142	199
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.35	1.35	1.35	1.35
Ile:Lys	61	61	61	61
Leu:Lys	129	129	129	129
Met:Lys	31	31	31	31
Met and Cys:Lys	57	57	57	57
Thr:Lys	63	63	63	63
Trp:Lys	19	19	19	19
Val:Lys	69	69	69	69
ME, kcal/lb	1,420	1,424	1,425	1,427
CP, %	23.5	23.5	23.6	23.6
Na, %	0.22	0.22	0.22	0.22
Cl, %	0.99	0.79	0.59	0.39
K, %	0.84	0.84	0.84	0.84
Ca, %	0.83	0.79	0.79	0.79
P, %	0.65	0.65	0.65	0.65
Available P, %	0.36	0.36	0.36	0.36

[1]Phase 2 diets were fed from approximately 12.5 lb to approximately 22 lb BW.
[2]Dietary electrolyte balance was calculated using the following equation: ((Na*434.98) + (K*255.74) – (Cl*282.06)).
[3]Dried distillers grains with solubles.
[4]Land O' Lakes, Inc. (Purina Mills, LLC, Shoreview, MN).
[5]Zoetis Animal Health (Florham Park, NJ).

Table 3. Phase 3 diet composition (as-fed basis)[1]

Ingredient, %	
Corn	38.33
Soybean meal, 46.5% CP	31.99
DDGS[2]	25.00
Choice white grease	1.00
Limestone	1.25
Dicalcium P, 18.5% P	1.03
Salt	0.50
L-Lys HCl	0.40
DL-Met	0.11
L-Thr	0.10
Vitamin and TM premix	0.30
Total	100
Calculated analysis	
Standardized ileal digestible (SID) amino acids, %	
Lys	1.35
Met:Lys	35
Met and Cys:Lys	59
Thr:Lys	64
Trp:Lys	18
Val:Lys	74
ME, kcal/lb	1,487
CP, %	25.39
Na, %	0.29
Cl, %	0.47
K, %	1.03
Ca, %	0.83
P, %	0.66
dEB, mEq/kg[3]	257
Available P, %	0.37
Analyzed composition, %	
DM	88.37
CP	22.48
Crude fat	5.90
Ca	0.82
P	0.64

[1]Phase 3 diets were fed from d 21 to 35 post-weaning.
[2]Dried distillers grain with solubles.
[3]Dietary electrolyte balance was calculated using the following equation: ((Na*434.98) + (K*255.74) – (Cl*282.06)).

Table 4. Chemical analysis of Phase 1 experimental diets[1]

	dEB, mEq/kg			
Item, %	84	137	190	243
DM	90.54	90.73	91.22	90.81
CP	20.95	20.85	21.10	20.95
Crude fat	4.60	4.80	4.70	4.70
Na	0.36	0.43	0.45	0.39
K	1.26	1.26	1.28	1.25
Cl	1.36	1.21	0.99	0.80
Ca	1.02	0.98	0.95	0.90
P	0.75	0.67	0.72	0.72
dEB, mEq/kg[2]	95	168	244	264

[1]Complete diet samples were submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CP, crude fat, Na, Cl, K, Ca, and P.
[2]Dietary electrolyte balance was calculated using the following formula: ((Na*434.98) + (K*255.74) – (Cl*282.06)).

Table 5. Chemical analysis of Phase 2 experimental diets[1]

	dEB, mEq/kg[2]			
Item, %	29	86	142	199
DM	88.16	88.71	88.71	88.36
CP	21.00	23.15	23.55	21.35
Crude fat	5.20	5.10	5.30	5.20
Na	0.33	0.35	0.30	0.30
K	0.93	0.94	1.06	1.00
Cl	1.11	1.13	0.85	0.77
Ca	1.33	1.57	1.40	1.59
P	0.68	0.86	0.87	0.82
dEB, mEq/kg[2]	68	74	162	169

[1]Complete diet samples were submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CP, crude fat, Na, Cl, K, Ca, and P.
[2]Dietary electrolyte balance was calculated using the following equation: ((Na*434.98) + (K*255.74) – (Cl*282.06)).

Table 6. Evaluation of dietary electrolyte balance on nursery pig performance[1]

	mEq/kg					Probability, P <	
Phase 1:	84	137	190	243			
Phase 2:	29	86	142	199	SEM	Linear	Quadratic
BW, lb							
d 0	11.4	11.4	11.5	11.4	0.12	0.773	0.448
d 8	12.4	12.3	12.6	12.8	0.10	0.001	0.035
d 21	20.7	21.6	22.1	22.5	0.19	0.001	0.177
d 35	34.3	34.7	35.1	35.3	0.26	0.001	0.552
d 0 to 8							
ADG, lb	0.12	0.11	0.13	0.16	0.011	0.001	0.001
ADFI, lb	0.19	0.18	0.18	0.21	0.008	0.008	0.004
F/G	1.70	1.93	1.50	1.32	0.106	0.001	0.042
d 8 to 21							
ADG, lb	0.62	0.69	0.71	0.74	0.012	0.001	0.022
ADFI, lb	0.79	0.80	0.80	0.83	0.013	0.011	0.469
F/G	1.27	1.16	1.13	1.13	0.013	0.001	0.001
d 0 to 21							
ADG, lb	0.43	0.47	0.48	0.52	0.007	0.001	0.807
ADFI, lb	0.55	0.56	0.56	0.59	0.008	0.003	0.103
F/G	1.30	1.21	1.15	1.14	0.013	0.001	0.001
d 21 to 35							
ADG, lb	0.97	0.94	0.93	0.91	0.010	0.001	0.376
ADFI, lb	1.32	1.32	1.33	1.31	0.016	0.891	0.461
F/G	1.36	1.41	1.43	1.43	0.014	0.001	0.124
d 0 to 35							
ADG, lb	0.64	0.65	0.66	0.68	0.007	0.001	0.736
ADFI, lb	0.86	0.86	0.86	0.88	0.010	0.077	0.594
F/G	1.32	1.28	1.26	1.25	0.009	0.001	0.028

[1]A total of 2,880 pigs (PIC 327 × 1050; initial BW 11.4 lb) with 30 pigs per pen (60 pigs per feeder) and 12 replications per treatment were used in a 35-d growth performance trial. All experimental diets were fed in two phases (d 0 to 8, and d 8 to 21) with a common diet fed from d 21 to 35.