Kansas Agricultural Experiment Station Research Reports

Volume 3
Issue 7 *Swine Day*

Article 20

2017

Effects of Dietary Ca and P Concentrations on Growth Performance of 13- to 25-lb Pigs

F. Wu
Kansas State University, Manhattan, fangzhou@k-state.edu

M. D. Tokach
Department of Animal Science and Industry, Kansas State University, mtokach@ksu.edu

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

S. S. Dritz
Kansas State University, Manhattan, dritz@k-state.edu

See next page for additional authors

Recommended Citation

Wu, F.; Tokach, M. D.; DeRouchey, J. M.; Dritz, S. S.; Woodworth, J. C.; and Goodband, R. D. (2017) "Effects of Dietary Ca and P Concentrations on Growth Performance of 13- to 25-lb Pigs," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 7. https://doi.org/10.4148/2378-5977.7473

Effects of Dietary Ca and P Concentrations on Growth Performance of 13- to 25-lb Pigs

Abstract

A total of 360 nursery pigs (PIC 1050 × 280, initially 13.3 ± 2.39 lb) were used in a 45-d growth study to determine the effects of feeding 2 standardized total tract digestible (STTD) P and 3 Ca concentrations on growth performance. In a completely randomized design, pens of pigs (10 pigs per pen, 6 pens per treatment) were allotted randomly to 1 of 6 dietary treatments. Dietary treatments were arranged in a 2 × 3 factorial, with 2 levels of STTD P (at or above NRC requirement estimates) and 3 levels of Ca (0.65, 0.90, and 1.20%). Diets formulated to meet NRC P requirement estimates contained 0.45 or 0.40% STTD P in phases 1 and 2, respectively, and diets formulated to exceed NRC P requirements contained 0.56 or 0.52% STTD P in phases 1 and 2, respectively. Diets were provided in 3 phases, with pigs fed experimental diets during phase 1 (d 0 to 10) and phase 2 (d 10 to 24), followed by a common phase 3 diet from d 24 to 45. During the treatment period (d 0 to 24), no Ca × P interactions were observed for ADG and ADFI. Increasing Ca concentration decreased (linear, $P = 0.006$) ADG, but did not affect ADFI. Feeding high concentrations of STTD P tended to increase ($P = 0.084$) ADG, but did not affect ADFI, compared with pigs fed STTD P levels recommended by NRC. An interactive effect between Ca and STTD P was observed for F/G ($P = 0.018$). When diets contained NRC levels of STTD P, pigs fed 1.20% Ca had poorer ($P < 0.05$) F/G than those fed 0.65 or 0.90% Ca; however, when high levels of STTD P were fed, the dietary Ca concentrations did not affect F/G. Day 24 BW decreased (linear, $P = 0.006$) with increasing Ca concentrations, regardless of the STTD P levels in diets. From d 24 to 45, when all pigs received a common phase 3 diet, no interactive or main effects of Ca and STTD P concentrations were observed for ADG, ADFI, or final BW. However, pigs previously fed increasing concentrations of Ca had improved (linear, $P = 0.003$) F/G regardless of dietary STTD P content. As a result of this compensatory gain, no treatment effects were observed for the overall growth performance. In conclusion, excess dietary Ca impairs ADG and F/G of nursery pigs, especially in low P content diets. The STTD P levels estimated by NRC meet the requirement of 13- to 25-lb pigs when diets contain low Ca concentrations but are deficient when diets contain more than 0.90% Ca.

Keywords

calcium, nursery pigs, phosphorus

Cover Page Footnote

Appreciation is expressed to Dr. Brad James, Julie Salyer, and Lorene Parkhurst from Kalmbach Feeds, Inc. (Sycamore, OH), for their technical support and expertise in conducting the experiment.

Authors

F. Wu, M. D. Tokach, J. M. DeRouchey, S. S. Dritz, J. C. Woodworth, and R. D. Goodband

Effects of Dietary Ca and P Concentrations on Growth Performance of 13- to 25-lb Pigs[1]

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

Summary

A total of 360 nursery pigs (PIC 1050 × 280, initially 13.3 ± 2.39 lb) were used in a 45-d growth study to determine the effects of feeding 2 standardized total tract digestible (STTD) P and 3 Ca concentrations on growth performance. In a completely randomized design, pens of pigs (10 pigs per pen, 6 pens per treatment) were allotted randomly to 1 of 6 dietary treatments. Dietary treatments were arranged in a 2 × 3 factorial, with 2 levels of STTD P (at or above NRC[3] requirement estimates) and 3 levels of Ca (0.65, 0.90, and 1.20%). Diets formulated to meet NRC[3] P requirement estimates contained 0.45 or 0.40% STTD P in phases 1 and 2, respectively, and diets formulated to exceed NRC[3] P requirements contained 0.56 or 0.52% STTD P in phases 1 and 2, respectively. Diets were provided in 3 phases, with pigs fed experimental diets during phase 1 (d 0 to 10) and phase 2 (d 10 to 24), followed by a common phase 3 diet from d 24 to 45. During the treatment period (d 0 to 24), no Ca × P interactions were observed for ADG and ADFI. Increasing Ca concentration decreased (linear, $P = 0.006$) ADG, but did not affect ADFI. Feeding high concentrations of STTD P tended to increase ($P = 0.084$) ADG, but did not affect ADFI, compared with pigs fed STTD P levels recommended by NRC.[3] An interactive effect between Ca and STTD P was observed for F/G ($P = 0.018$). When diets contained NRC[3] levels of STTD P, pigs fed 1.20% Ca had poorer ($P < 0.05$) F/G than those fed 0.65 or 0.90% Ca; however, when high levels of STTD P were fed, the dietary Ca concentrations did not affect F/G. Day 24 BW decreased (linear, $P = 0.006$) with increasing Ca concentrations, regardless of the STTD P levels in diets. From d 24 to 45, when all pigs received a common phase 3 diet, no interactive or main effects of Ca and STTD P concentrations were observed for ADG, ADFI, or final BW. However, pigs previously fed increasing concentrations of Ca had improved (linear, $P = 0.003$) F/G regardless of dietary STTD P content. As a result of this compensatory gain, no treatment effects were observed for the overall growth performance. In conclusion, excess dietary Ca impairs ADG and F/G of nursery pigs, especially in low P content diets. The STTD P levels estimated by NRC[3] meet the requirement of 13- to 25-lb pigs when diets contain low Ca concentrations but are deficient when diets contain more than 0.90% Ca.

---

[1] Appreciation is expressed to Dr. Brad James, Julie Salyer, and Lorene Parkhurst from Kalmbach Feeds, Inc. (Sycamore, OH), for their technical support and expertise in conducting the experiment.

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

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

Introduction

Appropriate dietary Ca and P concentrations are essential for pig growth performance. The total Ca and STTD P requirements estimated by NRC[3] are 0.86 and 0.45%, respectively, for 13- to 15-lb pigs; and 0.79 and 0.40%, respectively, for 15- to 25-lb pigs. In a previous study, we demonstrated that adding phytase improved pig growth performance when diets contained a STTD P level similar to NRC[3] requirement.[4] This finding suggests that the STTD P requirement may have been slightly underestimated for pigs of this weight range. In addition, we also observed that feeding excess dietary Ca decreased pig growth performance when diets were deficient in P, but not in pigs fed high P diets. Therefore, the objective of this study was to determine the effects of feeding 2 STTD P levels, either at or above the NRC[3] requirement, in combination with 3 different Ca concentrations on growth performance of nursery pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in the experiment. The study was conducted at the Cooperative Research Farm's Swine Research Nursery (Kalmbach Feeds, Inc., Sycamore, OH). Each pen (5 × 6 ft^2) had completely slatted metal floors and was equipped with a 4-hole stainless-steel feeder and a nipple-cup waterer. Pigs were allowed ad libitum access to feed and water throughout the experiment.

A total of 360 weaned pigs (PIC 1050 × 280) with initial BW of 13.3 ± 2.39 lb were housed in 36 pens with 10 pigs per pen. Upon arrival, pigs were individually weighed and assigned to pens to achieve balanced pen weights. Pens of pigs were then allotted to 1 of 6 dietary treatments (Tables 1 and 2) in a completely randomized manner. The dietary treatments were arranged in a 2 × 3 factorial, with 2 levels of STTD P (at or above NRC[3] requirement estimates) and 3 levels of total Ca (0.65, 0.90, and 1.20%). Diets formulated to meet NRC[3] P requirement contained 0.45 and 0.40% STTD P in phases 1 and 2, respectively; diets formulated to exceed NRC[3] P requirement (>NRC) contained 0.56 and 0.52% STTD P in phases 1 and 2, respectively. Pigs were fed in 3 phases, with the experimental diets provided in phase 1 (d 0 to 10) and 2 (d 10 to 24). A common phase 3 diet was then fed to all pigs from d 24 to 45. Phase 1 diets were prepared in pellet form and phases 2 and 3 diets were provided in meal form. Pigs and feeders were weighed on d 0, 10, 24, and 45 to determine ADG, ADFI, and F/G.

The Ca and P content for ingredients used in diet formulation were from a previous study[4] conducted in the same research facility. Complete diet samples were obtained and delivered to Kansas State University Swine Laboratory and stored at -4°F until analysis. Feed samples were analyzed for DM, CP, ether extract, Ca, and P at Ward Laboratories, Inc. (Kearney, NE). Concentrations of Ca and P were also analyzed at Cumberland Valley Analytical Services Inc. (Maugansville, MD) and Midwest Laboratories (Omaha, NE). The means of analyzed nutrient values are presented in Tables 1 and 2.

Data were analyzed using the GLIMMIX procedure of SAS version 9.4 (SAS Institute,

[4] F. Wu, M.D. Tokach, J.M. DeRouchey, S.S. Dritz, J.C. Woodworth and R.D. Goodband. 2017. Effects of dietary Ca and P concentrations and addition of phytase on growth performance of nursery pigs. *Kansas Agricultural Experiment Station Research Reports*: Vol. 3: Iss. 7. http://newprairiepress.org/kaesrr/vol3/iss7/.

Inc., Cary, NC) in a completely randomized design with pen as the experimental unit. The treatment effects were analyzed as a 2 × 3 factorial, with main effects of Ca and P and their interaction. Four single degree-of-freedom contrasts were performed to test the linear and quadratic effects of increasing Ca and their interactions with P concentration. Means were reported as least-squares means and were separated by the PDIFF option with a Tukey–Kramer adjustment. Results were considered significant at $P < 0.05$ and marginally significant at $0.05 < P < 0.10$.

Results and Discussion

Analyzed Ca and P concentrations of dietary treatments were similar to calculated values and followed similar patterns as the designed treatment structure (Tables 1 and 2).

During phase 1 (d 0 to 10), no Ca × P interactions were observed for any growth responses. Calcium and STTD P concentrations did not affect ADG or d 10 BW. However, increasing Ca concentration increased (linear, $P = 0.014$) ADFI and worsened ($P = 0.014$) F/G. Feeding pigs 0.56% STTD P tended to worsen ($P = 0.088$) F/G compared with those fed diets containing 0.45% STTD P, with the response being driven by a poor F/G of pigs fed 0.90 or 1.20% Ca with 0.56% STTD P.

During phase 2 (d 10 to 24), Ca × P interactions were observed for ADG ($P = 0.088$) and F/G ($P = 0.002$), but not for ADFI or BW. Pigs fed 1.20% Ca had decreased ($P < 0.05$) ADG and poorer ($P < 0.05$) F/G compared with those fed 0.65 and 0.90% Ca when diets contained 0.40% STTD P; however, this detrimental effect of high Ca was not observed in pigs fed 0.52% STTD P. Average daily feed intake was not affected by dietary Ca or STTD P concentrations. Day 24 BW was decreased (linear, $P = 0.006$) by increasing Ca concentrations regardless of the STTD P levels in diets.

When combining the treatment periods (d 0 to 24), no Ca × P interactions were observed for ADG and ADFI. Increasing Ca concentration decreased (linear, $P = 0.006$) ADG, but had no effect on ADFI. Similarly, feeding >NRC[3] levels of STTD P tended to increase ($P = 0.084$) ADG, but did not affect ADFI, compared with pigs fed NRC[3] levels of STTD P. Concentrations of Ca and STTD P had an interactive effect on F/G ($P = 0.018$). When diets contained NRC[3] levels of STTD P, pigs fed 1.20% Ca had poorer ($P < 0.05$) F/G than those fed 0.65 and 0.90% Ca; however, when >NRC[3] levels of STTD P were fed, the dietary Ca concentrations did not affect F/G.

High Ca concentration has been demonstrated to decrease P digestibility and absorption by forming a Ca-P complex.[5,6] In a previous study,[4] we observed that feeding excess Ca (1.05 vs. 0.58%) decreased pig growth performance when diets were deficient in P, but not in adequate P diets (0.45% STTD P during phases 1 and 2). Results from the present study suggest that feeding high Ca diets worsens F/G independent of STTD P concentrations in phase 1. However, in phase 2, the detrimental effects of high Ca on

[5] Liu, J., D. W. Bollinger, D. R. Ledoux, and T. L. Veum. 1998. Lowering the dietary calcium to total phosphorus ratio increases phosphorus utilization in low-phosphorus corn-soybean meal diets supplemented with microbial phytase for growing-finishing pigs. J. Anim. Sci. 76:808–813.

[6] Stein, H. H., O. Adeola, G. L. Cromwell, S. W. Kim, D. C. Mahan, and P. S. Miller. 2011. Concentration of dietary calcium supplied by calcium carbonate does not affect the apparent total tract digestibility of calcium, but reduces digestibility of phosphorus by growing pigs. J. Anim. Sci. 89:2139–2144.

ADG and F/G were only observed in pigs fed 0.40% STTD P (NRC) but not for pigs that received 0.52% STTD P (> NRC). It is possible that 0.40% STTD P just met, or was marginally below, the requirement of pigs during phase 2, which resulted in a P deficiency when high Ca was added to the diets. This marginal deficiency in STTD P was also supported by the observation that feeding high levels of STTD P (>NRC) tended to improve ADG from d 0 to 24.

From d 24 to 45, all pigs received a common phase 3 diet. No interactive or main effects of Ca and STTD P concentrations were observed for ADG, ADFI, or final BW. However, pigs previously fed increasing dietary Ca had improved (linear, $P = 0.003$) F/G regardless of the STTD P content previously fed in phases 1 and 2 diets. As a result of this compensatory gain, overall (d 0 to 45) growth responses were not affected by the Ca and P concentrations fed during phases 1 and 2.

In summary, feeding excess dietary Ca impairs ADG and F/G of nursery pigs, especially when diets contain low P content. The STTD P levels estimated by NRC[3] meet the requirement of 13- to 25-lb pigs when diets contain low Ca concentrations; however, caution is needed when NRC[3] P requirement estimates are applied to diets containing more than 0.90% Ca.

Table 1. Diet formulation, phase 1 (as-fed basis)

	Phase 1 (d 0 to 10)					
STTD[1] P:	NRC (0.45%)			>NRC (0.56%)		
Ca, %:	0.65	0.90	1.20	0.65	0.90	1.20
Ingredients, %						
Corn	46.66	45.54	44.14	46.04	44.92	43.53
Soybean meal	21.33	21.40	21.50	21.38	21.45	21.55
HP 300[2]	3.75	3.75	3.75	3.75	3.75	3.75
Fish meal	2.50	2.50	2.50	2.50	2.50	2.50
Dried whey	20.00	20.00	20.00	20.00	20.00	20.00
Beef tallow	2.60	3.00	3.50	2.80	3.20	3.70
Monocalcium P (21% P)	0.63	0.63	0.63	1.25	1.25	1.25
Limestone	0.30	0.95	1.75	0.04	0.70	1.49
Salt	0.50	0.50	0.50	0.50	0.50	0.50
L-Lys HCl	0.48	0.48	0.48	0.48	0.48	0.48
DL-Met	0.24	0.24	0.24	0.24	0.24	0.24
L-Thr	0.21	0.21	0.21	0.21	0.21	0.21
L-Trp	0.03	0.03	0.03	0.03	0.03	0.03
L-Val	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.09	0.09	0.09	0.09	0.09	0.09
Vitamin premix	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin E (20,000 IU)	0.05	0.05	0.05	0.05	0.05	0.05
Choline chloride	0.04	0.04	0.04	0.04	0.04	0.04
Zinc oxide	0.39	0.39	0.39	0.39	0.39	0.39
Selenium premix	0.02	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00	100.00

continued

Table 1. Diet formulation, phase 1 (as-fed basis)

	Phase 1 (d 0 to 10)					
STTD[1] P:	NRC (0.45%)			>NRC (0.56%)		
Ca, %:	0.65	0.90	1.20	0.65	0.90	1.20
Calculated composition						
Standardized ileal digestible (SID) AA, %						
Lys	1.40	1.40	1.40	1.40	1.40	1.40
Ile:Lys	55	55	55	55	55	55
Leu:Lys	109	108	108	109	108	107
Met:Lys	38	38	38	38	38	38
Met and Cys:Lys	58	58	57	58	57	57
Thr:Lys	64	63	63	64	63	63
Trp:Lys	18	18	18	18	18	18
Val:Lys	70	70	70	70	70	70
Total Lys, %	1.53	1.53	1.53	1.53	1.53	1.53
CP, %	20.89	20.83	20.76	20.86	20.80	20.73
NE, kcal/lb	1,182	1,182	1,182	1,182	1,182	1,182
Ca, %	0.65	0.90	1.20	0.65	0.90	1.20
STTD Ca,[3] %	0.51	0.67	0.87	0.53	0.69	0.88
P, %	0.66	0.65	0.65	0.78	0.78	0.77
STTD P, %	0.45	0.45	0.45	0.56	0.56	0.56
Available P,[4] %	0.42	0.42	0.42	0.55	0.55	0.55
Analyzed composition, %						
DM	90.42	90.09	90.91	89.84	90.15	89.82
CP	21.30	21.00	20.90	21.10	20.90	21.10
Fat	5.10	5.30	6.00	5.10	5.90	6.00
Ca[5]	0.66	0.80	1.23	0.66	0.82	1.27
P[5]	0.64	0.66	0.66	0.78	0.80	0.73

[1] STTD = standardized total tract digestible.
[2] Hamlet Protein, Inc., Findlay, OH.
[3] Standardized total tract digestibility coefficients for Ca content of feed ingredients were from Stein (2016).[7]
[4] Determined using availability coefficients from NRC (1998).
[5] Averaged across analyzed values from Ward Laboratories, Inc. (Kearney, NE), Cumberland Valley Analytical Services Inc. (Maugansville, MD), and Midwest Laboratories (Omaha, NE).

[7] Stein, H. H. 2016. Calcium digestibility and requirements for digestible calcium by growing pigs. 16th Annual Midwest Swine Nutrition Conference Proceedings. p. 57-61.

Table 2. Diet formulation, phase 2 and 3 (as-fed basis)[1]

	Phase 2						Phase 3
STTD[2] P:	NRC (0.40%)			>NRC (0.52%)			0.37%
Ca, %:	0.65	0.90	1.20	0.65	0.90	1.20	0.77
Ingredients, %							
Corn	57.76	56.63	55.23	57.01	55.87	54.50	62.60
Soybean meal	24.88	24.96	25.05	24.93	25.01	25.10	32.23
Fish meal	3.50	3.50	3.50	3.50	3.50	3.50	-
Dried whey	10.00	10.00	10.00	10.00	10.00	10.00	-
Beef tallow	1.00	1.40	1.90	1.25	1.65	2.15	1.00
Monocalcium P (21% P)	0.61	0.61	0.61	1.29	1.29	1.29	1.25
Limestone	0.38	1.03	1.83	0.09	0.75	1.53	1.10
Salt	0.60	0.60	0.60	0.60	0.60	0.60	0.60
L-Lys HCl	0.40	0.40	0.40	0.40	0.40	0.40	0.40
DL-Met	0.18	0.18	0.18	0.18	0.18	0.18	0.18
L-Thr	0.17	0.17	0.17	0.17	0.17	0.17	0.17
L-Trp	0.03	0.03	0.03	0.03	0.03	0.03	-
L-Val	0.10	0.10	0.10	0.10	0.10	0.10	0.07
Trace mineral premix	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Vitamin premix	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Selenium premix	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

continued

Table 2. Diet formulation, phase 2 and 3 (as-fed basis)[1]

	Phase 2						Phase 3
STTD[2] P:	NRC (0.40%)			>NRC (0.52%)			0.37%
Ca, %:	0.65	0.90	1.20	0.65	0.90	1.20	0.77
Calculated composition							
Standardized ileal digestible (SID) AA, %							
Lys	1.30	1.30	1.30	1.30	1.30	1.30	1.28
Ile:Lys	57	57	57	57	57	57	59
Leu:Lys	116	116	115	116	116	115	121
Met:Lys	37	37	36	37	37	36	36
Met and Cys:Lys	58	57	57	57	57	57	58
Thr:Lys	63	63	63	63	63	63	63
Trp:Lys	19	19	19	19	19	19	17
Val:Lys	70	69	69	69	69	69	69
Total Lys, %	1.44	1.44	1.44	1.44	1.44	1.44	1.43
CP, %	20.70	20.64	20.58	20.66	20.61	20.54	21.19
NE, kcal/lb	1,142	1,142	1,142	1,142	1,142	1,142	1,109
Ca, %	0.65	0.90	1.20	0.65	0.90	1.20	0.77
STTD[2] Ca, %	0.49	0.65	0.85	0.51	0.67	0.86	0.54
P, %	0.62	0.62	0.62	0.76	0.75	0.75	0.61
STTD[2] P, %	0.40	0.40	0.40	0.52	0.52	0.52	0.37
Available P,[3] %	0.36	0.36	0.36	0.50	0.50	0.50	0.32
Analyzed composition, %							
DM	89.96	89.24	89.83	89.61	90.05	89.35	88.60
CP	21.20	21.10	21.30	21.10	21.70	21.20	21.30
Fat	4.00	4.20	4.50	4.20	4.50	4.90	4.00
Ca[4]	0.73	0.97	1.33	0.72	0.93	1.24	0.76
P[4]	0.64	0.63	0.66	0.79	0.81	0.76	0.65

[1] Phase 2 diets were fed from d 10 to 24 and phase 3 diet were fed from d 24 to 45.
[2] STTD = standardized total tract digestible.
[3] Determined using availability coefficients from NRC (1998).
[4] Averaged across analyzed values from Ward Laboratories, Inc. (Kearney, NE), Cumberland Valley Analytical Services Inc. (Maugansville, MD), and Midwest Laboratories (Omaha, NE).

Table 3. Effects of Ca and P concentrations on growth performance of nursery pigs[1]

	Treatment							Probability, %				
STTD[2] P:	NRC[3]			>NRC[4]					Main effect		Ca	
Ca, %:	0.65	0.90	1.20	0.65	0.90	1.20	SEM	Ca × P	Ca	P	Linear	Quadratic
BW, lb												
d 0	13.3	13.3	13.3	13.3	13.3	13.3	0.03	0.944	0.843	0.812	0.562	0.976
d 10	15.0	14.9	15.0	14.9	14.7	14.7	0.13	0.790	0.494	0.140	0.455	0.358
d 24	25.5	25.3	23.7	25.8	25.3	25.1	0.43	0.190	0.018	0.104	0.006	0.544
d 45	55.6	56.3	54.6	55.9	55.7	55.5	0.79	0.643	0.480	0.754	0.383	0.402
d 0 to 10 (phase 1)												
ADG, lb	0.17	0.16	0.16	0.16	0.14	0.14	0.013	0.878	0.507	0.138	0.418	0.404
ADFI, lb	0.24	0.24	0.25	0.22	0.23	0.26	0.010	0.554	0.022	0.431	0.014	0.188
F/G	1.42	1.49	1.54	1.39	1.68	1.91	0.123	0.286	0.045	0.088	0.014	0.776
d 10 to 24 (phase 2)												
ADG, lb	0.75[a]	0.74[a]	0.62[b]	0.78[a]	0.75[a]	0.74[a]	0.025	0.088[5]	0.008	0.011	0.003	0.372
ADFI, lb	0.97	1.01	0.98	1.01	0.97	0.96	0.030	0.405	0.700	0.860	0.434	0.760
F/G	1.30[b]	1.37[b]	1.59[a]	1.31[b]	1.29[b]	1.29[b]	0.040	0.002[6]	0.004	0.001	0.001	0.298
d 0 to 24												
ADG, lb	0.51	0.50	0.43	0.52	0.50	0.49	0.018	0.203	0.020	0.084	0.006	0.623
ADFI, lb	0.67	0.69	0.68	0.68	0.66	0.67	0.020	0.558	0.988	0.752	0.877	0.995
F/G	1.32[b]	1.38[b]	1.58[a]	1.32[b]	1.33[b]	1.36[b]	0.039	0.018[6]	0.001	0.007	<0.001	0.365
d 24 to 45 (phase 3)												
ADG, lb	1.43	1.48	1.46	1.42	1.45	1.45	0.023	0.944	0.293	0.394	0.336	0.215
ADFI, lb	2.16	2.15	2.08	2.15	2.12	2.12	0.040	0.684	0.382	0.990	0.175	0.817
F/G	1.50	1.46	1.43	1.52	1.46	1.46	0.019	0.724	0.007	0.315	0.003	0.225
d 0 to 45												
ADG, lb	0.94	0.95	0.91	0.94	0.94	0.94	0.018	0.532	0.424	0.622	0.361	0.349
ADFI, lb	1.36	1.36	1.33	1.36	1.34	1.34	0.025	0.757	0.588	0.938	0.310	0.907
F/G	1.45	1.44	1.47	1.46	1.42	1.43	0.017	0.490	0.370	0.328	0.988	0.162

[1] A total of 360 barrows and gilts (PIC 1050 × 280, Hendersonville, TN) with initial BW of 13.3 ± 2.39 lb were used in a 45-d trial with 10 pigs per pen and 6 replications (pen) per treatment.
[2] STTD = standardized total tract digestible.
[3] NRC = STTD P levels formulated to meet NRC[3] requirement estimates (0.45% for phase 1 and 0.40% for phase 2).
[4] >NRC = STTD P levels formulated to exceed NRC[3] requirement estimates (0.56% for phase 1 and 0.52% for phase 2).
[ab] Means with different superscripts within a row differ ($P < 0.05$).
[5] Linear Ca × P interaction: $P = 0.070$; quadratic Ca × P interaction: $P = 0.196$.
[6] Linear Ca × P interaction: $P < 0.01$; quadratic Ca × P interaction: $P > 0.10$.