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Should Phytase Be Given Release Values for Amino Acids and Energy in Diets for Growing Pigs?

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Abstract

A total of 2,268 mixed gender pigs (PIC; 337 × 1050; initially 62.9 lb) were used from 2 barns in a 55-d growth trial. On d 0 of the trial, pens of pigs were blocked by weight and randomly allotted to 1 of 6 dietary treatments with 27 pigs per pen and 14 pens per treatment (7 pens per barn). Treatments were fed in 2 different phases. Phase 1 diets were fed from d 0 to 29 (62.9 to 112.6 lb) and phase 2 diets were fed from d 29 to 55 (112.6 to 159.7 lb). Treatments consisted of a control with inorganic P from monocalcium P, or 5 diets with 1,500 phytase units (FYT/kg) (Ronozyme HiPhos 2,500; DSM Nutritional Products, Inc., Parsippany, NJ) assuming different supplier- provided nutrient release values (Ca and P; Ca, P, and AA; Ca, P, AA, and half of the suggested net energy (NE); Ca, P, AA, and full NE; or no nutrient release). The assumed release values were 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 19 kcal/lb of NE; and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% digestible Lys, Met, Met + Cys, Thr, Trp, Ile, and Val, respectively. All diets within phase were corn-soybean meal-based and contained a standardized total tract digestibility (STTD) Ca:STTD P ratio of 1.60:1 with all amino acids (AA) set to meet or exceed NRC requirement estimates. Overall (d 0 to 55), there was no evidence for difference in average daily gain (ADG) or average daily feed intake (ADFI). However, pigs fed the diet containing 1,500 FYT/kg assuming no nutrient release had improved ($P < 0.05$) feed efficiency (F/G) compared to pigs fed diets containing 1,500 FYT/kg assuming either Ca and P or Ca, P, AA, and full NE release, with others intermediate. In the economic analysis, there was no evidence for difference ($P > 0.10$) in feed cost per pig or feed cost per lb gain. In conclusion, based on diet formulation, pigs fed either the control diet with inorganic P from monocalcium P or any of the phytase-containing diets should have had similar performance, with the exception of pigs fed the diet formulated to contain 1,500 FYT/kg assuming no release values. However, pigs fed full matrix release values had the poorest ($P < 0.05$) F/G, while pigs fed diets assuming Ca and P in addition to AA and half NE had F/G comparable to the control. This suggests the full matrix release values, especially energy, attributed to the phytase may be too aggressive and resulted in diets contributing fewer nutrients than needed to optimize performance.

Keywords

growing pig, phytase, release value

Cover Page Footnote

Appreciation is expressed to DSM Nutrition Products (Parsippany, NJ) for their expertise; New Horizon Farms, LLP (Pipestone, MN) for the use of their feed mill and animal facilities; and to Marty Heintz, Whitney Adler, and Heath Houselog for technical assistance.

Authors

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Should Phytase Be Given Release Values for Amino Acids and Energy in Diets for Growing Pigs?[1]

Madie R. Wensley, Jason C. Woodworth, Joel M. DeRouchey, Steve S. Dritz,[2] Mike D. Tokach, Robert D. Goodband, and Hilda Calderon Cartagena[3]

Summary

A total of 2,268 mixed gender pigs (PIC; 337 × 1050; initially 62.9 lb) were used from 2 barns in a 55-d growth trial. On d 0 of the trial, pens of pigs were blocked by weight and randomly allotted to 1 of 6 dietary treatments with 27 pigs per pen and 14 pens per treatment (7 pens per barn). Treatments were fed in 2 different phases. Phase 1 diets were fed from d 0 to 29 (62.9 to 112.6 lb) and phase 2 diets were fed from d 29 to 55 (112.6 to 159.7 lb). Treatments consisted of a control with inorganic P from monocalcium P, or 5 diets with 1,500 phytase units (FYT/kg) (Ronozyme HiPhos 2,500; DSM Nutritional Products, Inc., Parsippany, NJ) assuming different supplier-provided nutrient release values (Ca and P; Ca, P, and AA; Ca, P, AA, and half of the suggested net energy (NE); Ca, P, AA, and full NE; or no nutrient release). The assumed release values were 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 19 kcal/lb of NE; and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% digestible Lys, Met, Met + Cys, Thr, Trp, Ile, and Val, respectively. All diets within phase were corn-soybean meal-based and contained a standardized total tract digestibility (STTD) Ca:STTD P ratio of 1.60:1 with all amino acids (AA) set to meet or exceed NRC[4] requirement estimates. Overall (d 0 to 55), there was no evidence for difference in average daily gain (ADG) or average daily feed intake (ADFI). However, pigs fed the diet containing 1,500 FYT/kg assuming no nutrient release had improved ($P < 0.05$) feed efficiency (F/G) compared to pigs fed diets containing 1,500 FYT/kg assuming either Ca and P or Ca, P, AA, and full NE release, with others intermediate. In the economic analysis, there was no evidence for difference ($P > 0.10$) in feed cost per pig or feed cost per lb gain. In conclusion, based on diet formulation, pigs fed either the control diet with inorganic P from monocalcium P or any of the phytase-containing diets should have had similar performance, with the exception of pigs fed the diet

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

formulated to contain 1,500 FYT/kg assuming no release values. However, pigs fed full matrix release values had the poorest ($P < 0.05$) F/G, while pigs fed diets assuming Ca and P in addition to AA and half NE had F/G comparable to the control. This suggests the full matrix release values, especially energy, attributed to the phytase may be too aggressive and resulted in diets contributing fewer nutrients than needed to optimize performance.

Introduction

Phytase is routinely used in swine diets as a means to increase P availability. However, it has also been demonstrated that phytase will act to improve availability of other nutrients such as minerals, amino acids, and energy. While some industry nutritionists will credit phytase with Ca release, others will utilize AA matrix values in their formulation and even fewer utilize the NE release values that phytase suppliers recommend. The primary reason for nutritionists not to use full matrix values is the scarcity of data that repeatedly demonstrates the release values are correct.

A previous trial conducted by Vier et al.[5] utilized 1,500 phytase units/kg (FYT/ kg) (Ronozyme HiPhos 2,500; DSM Nutritional Products, Inc., Parsippany, NJ) and full matrix values (P, Ca, AA, and NE) as suggested by the supplier. Pigs fed diets with phytase in the grower and finishing stages had poorer performance than the control pigs fed diets not containing phytase. Thus, we hypothesized that the full matrix release values attributed to the phytase were too aggressive and resulted in diets contributing fewer nutrients than needed to optimize performance. It was also hypothesized that the poorer performance was due to over-estimation of the phytase release of NE and potentially AA; however, we are unable to confirm this because only the full matrix values were utilized.

Consequently, this trial was designed to determine the impact on performance of pigs when phytase is credited with additional nutrient release above Ca and P. This trial was conducted with pigs from approximately 60 to 165 lb in order to utilize pigs in an energy- and AA-dependent phase of growth, which will allow for more sensitivity in determining treatment differences.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research wean-to-finish site in southwestern Minnesota. Two tunnel-ventilated rooms were used. Pens had completely slatted flooring and deep pits. Each pen was equipped with a 5-hole stainless steel feeder and cup waterer to allow *ad libitum* access to feed and water. The facility was equipped with an automated feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of measuring and recording daily feed additions to individual pens.

[5] Vier, C. M., S. S. Dritz, M. D. Tokach, J. R. Bergstrom, J. C. Woodworth, R. D. Goodband, and J. M. DeRouchey. 2019. Determining the effects of high phytase levels and phytase withdrawal on growth performance and carcass characteristics of growing-finishing pigs. Kansas State University Swine Day Report. *Kansas Agricultural Experiment Station Research Reports*: Vol. 5: Iss. 4.

A total of 2,268 mixed sex pigs (PIC; 337 × 1050; initially 62.9 lb) were used from 2 barns in a 55-d growth trial. On d 0 of the trial, pens of pigs were blocked by body weight (BW) and randomly allotted to 1 of 6 dietary treatments with 27 pigs per pen and 14 pens per treatment (7 pens per barn). Diets were fed in 2 different phases. Phase 1 diets were fed from d 0 to 29 (62.9 to 112.6 lb) and phase 2 diets were fed from d 29 to 55 (112.6 to 159.7 lb). Treatments consisted of: A) Control (diet formulated with no added phytase); B) CaP (diet formulated to contain 1,500 FYT/kg assuming release values for Ca and P); C) CaPAA (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, and AA); D) CaPAA + half NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and half of the suggested NE release); E) CaPAA + full NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and the full NE release); and F) None (diet formulated to contain 1,500 FYT/kg assuming no release values).

Ronozyme HiPhos 2500 (DSM Nutritional Products, Inc., Parsippany, NJ) was included in the phytase-containing diets with assumed release values of 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 24 kcal/lb of metabolizable energy (ME), 19 kcal/lb of NE, and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% digestible Lys, Met, Met + Cys, Thr, Trp, Ile, and Val, respectively. Ingredient loading values were obtained either from laboratory results of a previous trial in the same facility or from NRC.[3] Digestibility coefficients for P were obtained from NRC[3] and the digestibility coefficients for Ca were obtained from the literature.[6,7,8] The diets were formulated to contain adequate STTD P across the dietary treatments in all phases based on the estimated requirement previously determined in this facility. The STTD Ca:STTD P ratio for all diets was 1.60:1. Additionally, energy and standard ileal digestible (SID) AA were balanced across treatments.

All dietary treatments were manufactured at the New Horizon Farms Feed Mill in Pipestone, MN, and were formulated to meet or exceed NRC[3] requirement estimates.

For the economic analysis, total feed cost per pig and feed cost per lb of gain were calculated. The total feed cost per pig was calculated by multiplying each pen's overall feed intake by the cost per pound of diet, then dividing these values by the final pen inventory. Feed cost per lb of gain was calculated by dividing total feed cost per pig by total gain per pig. For all economic evaluations, ingredient prices during spring of 2019 were used with corn valued at $3.38/bu ($121/ton), soybean meal at $291/ton, dried distillers grains with solubles (DDGS) at $140/ton, beef tallow at $0.21/lb, L-lysine HCL at $0.72/lb, DL-methionine at $1.30/lb, L-threonine at $1.08/lb, L-tryptophan at $4.50/lb, Ronozyme HiPhos 2500 at $0.95/lb, monocalcium phosphate at $0.38/lb, and limestone at $0.02/lb.

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[6] González-Vega, J. C., C. L. Walk, Y. Liu, and H. H. Stein. 2013. Determination of endogenous intestinal losses of Ca and true total tract digestibility of calcium in canola meal fed to growing pigs. J. Anim. Sci. 91:4807-4816.

[7] González-Vega, J. C., C. L. Walk, and H. H. Stein. 2015. Effects of microbial phytase on apparent and standardized total tract digestibility of calcium in calcium supplements fed to growing pigs. J. Anim. Sci. 93:2255-2264.

[8] Stein, H.H., 2016. Calcium digestibility and requirements for digestible calcium by growing pigs. In 16th Annual Midwest Swine Nutrition Conference Proceedings, Indianapolis, Indiana (September 9, 2016) (pp. 57-61).

Data were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package in R (version 3.5.1 (2018-07-02)) with pen considered the experimental unit, treatment as fixed effect, and weight block as random effect. Results were considered significant at $P \leq 0.05$.

Results and Discussion

Overall (d 0 to 55), there was no evidence for difference in ADG or ADFI. However, pigs fed the diet containing 1,500 FYT/kg assuming no nutrient release had improved ($P < 0.05$) F/G compared to pigs fed diets containing 1,500 FYT/kg assuming either Ca and P or Ca, P, AA, and full NE release, with others intermediate. In the economic analysis, there was no evidence for difference ($P > 0.10$) in feed cost per pig or feed cost per lb gain.

This study has provided valuable insight on the nutrient release values of Ronozyme HiPhos 2500. Based on similar nutrient formulation, pigs fed either the control diet with inorganic P from monocalcium P or any of the phytase-containing diets should have had similar performance, with the exception of pigs fed the diet formulated to contain 1,500 FYT/kg assuming no release values. However, pigs fed full matrix release values had the poorest F/G while pigs fed diets assuming Ca and P in addition to AA and half of the suggested NE release had F/G comparable to the control. This trial confirmed that the full matrix release values, especially energy, attributed to phytase may be too aggressive, and resulted in poorer feed efficiency.

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

	Source:	Inorganic P	Phytase[3]				
Ingredient, %	Release:	None	CaP	CaPAA	CaPAA + half NE	CaPAA + full NE	None
Corn		63.00	64.13	64.48	64.88	65.61	62.88
Soybean meal		22.15	22.07	21.82	21.79	21.74	22.16
Corn DDGS[4]		10.00	10.00	10.00	10.00	10.00	10.00
Beef tallow		2.00	1.60	1.55	1.20	0.50	2.05
Monocalcium P		0.75	---	---	---	---	0.75
Limestone		1.08	1.13	1.13	1.10	1.13	1.08
Sodium chloride		0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine-HCl		0.37	0.37	0.35	0.35	0.35	0.37
DL-Methionine		0.05	0.04	0.04	0.04	0.04	0.05
L-Threonine		0.09	0.09	0.07	0.07	0.07	0.09
L-Tryptophan		0.02	0.02	0.01	0.01	0.01	0.02
Vitamin mineral premix		0.15	0.15	0.15	0.15	0.15	0.15
Phytase		---	0.06	0.06	0.06	0.06	0.06
Total		100	100	100	100	100	100

continued

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

	Source: Inorganic P	Phytase[3]				
Ingredient, % Release:	None	CaP	CaPAA	CaPAA + half NE	CaPAA + full NE	None
Calculated analysis						
SID[5] amino acids						
Lysine, %	1.04	1.04	1.04	1.04	1.04	1.04
Isoleucine:lysine	62	62	63	63	63	62
Leucine:lysine	145	145	145	145	145	144
Methionine:lysine	31	30	30	30	30	31
Methionine and cysteine:lysine	56	56	56	56	57	56
Threonine:lysine	62	62	62	62	62	62
Tryptophan:lysine	18.6	18.6	18.5	18.5	18.5	18.6
Valine:lysine	70	70	70	70	70	70
Histidine:lysine	42	42	42	42	42	42
Total lysine, %	1.18	1.18	1.16	1.16	1.16	1.18
Metabolizable energy, kcal/lb	1,530	1,531	1,530	1,531	1,531	1,530
Net energy, kcal/lb	1,152	1,152	1,152	1,152	1,152	1,152
SID lysine:NE, g/Mcal	4.09	4.09	4.10	4.09	4.10	4.09
Crude protein, %	19.0	19.1	19.0	19.0	19.0	19.0
Calcium, %	0.68	0.57	0.57	0.56	0.57	0.68
STTD Ca,[6] %	0.53	0.54	0.54	0.53	0.54	0.53
Phosphorus, %	0.57	0.41	0.41	0.41	0.41	0.57
STTD P,[7] %	0.33	0.34	0.33	0.33	0.34	0.33
Available phosphorus, %	0.29	0.29	0.29	0.29	0.29	0.29
Calcium:phosphorus	1.18	1.38	1.38	1.35	1.37	1.19
STTD Ca:STTD P	1.60	1.60	1.60	1.60	1.60	1.60

[1]Diets were fed for 26 d from approximately 63 to 113 lb.
[2]Treatments consisted of: A) Control (diet formulated with no added phytase); B) CaP (diet formulated to contain 1,500 phytase units (FYT/kg) assuming release values for Ca and P); C) CaPAA (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, and AA); D) CaPAA + half NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and half of the suggested NE); E) CaPAA + full NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and full NE); and F) None (diet formulated to contain 1,500 FYT/kg assuming no release values).
[3]Ronozyme HiPhos 2500 phytase (DSM Nutritional Products, Inc., Parsippany, NJ) was included at 1,500 FYT/kg with assumed release values of 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 24 kcal/lb of ME, 19 kcal/lb of NE; and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% digestible Lys, Met, Met + Cys, Thr, Trp, Ile, and Val, respectively.
[4]DDGS = dried distillers grains with solubles.
[5]Standardized ileal digestibility.
[6]Standardized total tract digestibility of calcium.
[7]Standardized total tract digestibility of phosphorus.

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

	Source:	Inorganic P	Phytase[3]				
Ingredient, %	Release:	None	CaP	CaPAA	CaPAA + half NE	CaPAA + full NE	None
Corn		69.54	70.79	71.09	71.55	72.23	69.42
Soybean meal		15.55	15.46	15.21	15.18	15.13	15.55
Corn DDGS[4]		10.00	10.00	10.00	10.00	10.00	10.00
Beef tallow		2.00	1.55	1.55	1.15	0.50	2.05
Monocalcium P		0.80	---	---	---	---	0.80
Limestone		1.10	1.13	1.13	1.11	1.13	1.10
Sodium chloride		0.35	0.35	0.35	0.35	0.35	0.35
L-Lysine-HCl		0.39	0.39	0.37	0.37	0.37	0.39
DL-Methionine		0.02	0.02	0.02	0.01	0.01	0.02
L-Threonine		0.09	0.09	0.07	0.06	0.06	0.09
L-Tryptophan		0.03	0.03	0.02	0.02	0.02	0.03
Vitamin mineral premix		0.15	0.15	0.15	0.15	0.15	0.15
Phytase		---	0.06	0.06	0.06	0.06	0.06
Total		100	100	100	100	100	100

continued

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

Source:	Inorganic P	Phytase[3]				
Ingredient, % Release:	None	CaP	CaPAA	CaPAA + half NE	CaPAA + full NE	None
Calculated analysis						
SID[5] amino acids						
Lysine, %	0.89	0.89	0.89	0.89	0.89	0.89
Isoleucine:lysine	60	60	61	61	61	60
Leucine:lysine	151	152	152	152	152	151
Methionine:lysine	29	30	29	29	29	29
Methionine and cysteine:lysine	56	56	56	56	56	56
Threonine:lysine	62	62	62	62	62	62
Tryptophan:lysine	18.7	18.8	18.7	18.7	18.7	18.7
Valine:lysine	70	70	70	70	70	70
Histidine:lysine	42	42	42	42	42	42
Total lysine, %	1.02	1.02	0.99	1.00	1.00	1.02
Metabolizable energy, kcal/lb	1,532	1,533	1,533	1,532	1,534	1,532
Net energy, kcal/lb	1,169	1,169	1,169	1,169	1,169	1,169
SID lysine:NE, g/Mcal	3.45	3.45	3.45	3.45	3.45	3.45
Crude protein, %	16.4	16.5	16.3	16.4	16.4	16.4
Calcium, %	0.66	0.53	0.53	0.53	0.53	0.66
STTD Ca,[6] %	0.52	0.51	0.51	0.51	0.51	0.52
Phosphorus, %	0.55	0.38	0.38	0.38	0.38	0.55
STTD P,[7] %	0.32	0.32	0.32	0.32	0.32	0.32
Available phosphorus, %	0.29	0.28	0.28	0.28	0.28	0.29
Calcium:phosphorus	1.20	1.40	1.40	1.38	1.39	1.20
STTD Ca:STTD P	1.60	1.60	1.60	1.60	1.60	1.60

[1]Diets were fed for 26 d from approximately 113 to 160 lb.
[2]Treatments consisted of: A) Control (diet formulated with no added phytase); B) CaP (diet formulated to contain 1,500 phytase units (FYT/kg) assuming release values for Ca and P); C) CaPAA (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, and AA); D) CaPAA + half NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and half of the suggested NE); E) CaPAA + full NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and full NE); and F) None (diet formulated to contain 1,500 FYT/kg assuming no release values).
[3]Ronozyme HiPhos 2500 phytase (DSM Nutritional Products, Inc., Parsippany, NJ) was included at 1,500 FYT/kg with assumed release values of 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 24 kcal/lb of ME, 19 kcal/lb of NE; and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% digestible Lys, Met, Met + Cys, Thr, Trp, Ile, and Val, respectively.
[4]DDGS = dried distillers grains with solubles.
[5]Standardized ileal digestibility.
[6]Standardized total tract digestibility of calcium.
[7]Standardized total tract digestibility of phosphorus.

Table 3. Effects of different nutrient release values of Ronozyme HiPhos 2500 phytase on pig growth performance and economics[1]

Source:	Inorganic P[2]	Phytase[3,4]						
Ingredient, % Release:	None	CaP	CaPAA	CaPAA + half NE	CaPAA + full NE	None	SEM	Probability, *P* <
Body weight, lb								
d 0	62.9	62.8	62.9	62.9	62.9	62.8	1.34	0.999
d 55	159.7	160.7	159.8	158.5	159.2	160.2	2.09	0.853
Overall (d 0 to 55)[5]								
ADG, lb	1.83	1.84	1.83	1.80	1.82	1.84	0.023	0.768
ADFI, lb	3.69	3.79	3.69	3.67	3.76	3.66	0.052	0.222
Feed efficiency	2.02[ab]	2.06[a]	2.02[ab]	2.04[ab]	2.07[a]	1.99[b]	0.015	0.002
Removed, %	1.3	1.0	2.3	2.3	2.6	1.0	0.841	0.358
Mortality, %	1.3	1.0	1.0	0.8	0.8	0.8	0.594	0.970
Economics								
Gain/pig, lb	96.8	97.9	96.9	95.6	96.3	97.4	1.12	0.703
Feed cost/pig,[6] $	18.87	18.78	18.36	18.13	18.43	18.80	0.289	0.193
Feed cost/lb gain,[7] $	0.195	0.192	0.190	0.190	0.191	0.193	0.0018	0.201

[1]A total of 2,268 mixed sex pigs (PIC; 337 × 1050; initially 62.9 lb) were used in a 55-d growth study to determine the impact on performance when phytase is credited with additional nutrient release above P and Ca. There were 27 pigs per pen and 14 pens per treatment.

[2]Inorganic P was added to the diet by increasing monocalcium P.

[3]Treatments consisted of: A) Control (diet formulated with no added phytase); B) CaP (diet formulated to contain 1,500 phytase units (FYT/kg) assuming release values for Ca and P); C) CaPAA (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, and AA); D) CaPAA + half NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and half of the suggested NE); E) CaPAA + full NE (diet formulated to contain 1,500 FYT/kg assuming release values for Ca, P, AA, and full NE); and F) None (diet formulated to contain 1,500 FYT/kg assuming no release values).

[4]Ronozyme HiPhos 2500 phytase (DSM Nutritional Products, Inc., Parsippany, NJ) was included at 1,500 FYT/kg with assumed release values of 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 24 kcal/lb of ME, 19 kcal/lb of NE; and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% digestible Lys, Met, Met + Cys, Thr, Trp, Ile, and Val, respectively.

[5]ADG = average daily gain. ADFI = average daily feed intake.

[6]Feed cost/pig = (pen feed intake × cost per lb of diet)/final pen inventory.

[7]Feed cost/lb gain = feed cost per pig ÷ gain per pig.