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Cover Page Footnote

Appreciation is expressed to DSM Nutritional Products Inc. for their expertise and partial funding, to New Horizon Farms for use of the feed mill and animal facilities, and to Marty Heintz, Whitney Adler and Bayley Kroupa for technical assistance.

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Determining the Effects of High Phytase Levels and Feeding Duration on Growth Performance and Carcass Characteristics of Growing-Finishing Pigs[1]

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Summary

A total of 1,215 barrows and gilts (PIC; 359 × Camborough; initially 61.5 ± 1.02 lb) were used in a 126-d growth trial to determine the effects of high phytase levels and feeding duration on growth performance and carcass characteristics of growing-finishing pigs. Pens of pigs were randomly assigned to 1 of 3 dietary treatments with 15 pens per treatment and 27 pigs per pen. The experimental diets were fed in four phases and based on corn, distillers dried grains with solubles (DDGS), and soybean meal. The 3 dietary treatments consisted of: 1) Control (diets formulated with no added phytase); 2) Grower phytase (diets formulated with 1,500 phytase units (FYT)/kg added phytase fed from d 0 to 57, then no phytase from d 57 to market); and 3) Grow-finish phytase (diets formulated with 1,500 FYT/kg added phytase fed throughout the entire study). The phytase-containing diets had the addition of 1,500 FYT/kg of Ronozyme HiPhos 2500 (DSM Nutritional Products, Inc., Parsippany, NJ) with assumed release values of 0.146% standardized total tract digestible (STTD) P, 0.166% available P, 0.102% STTD calcium, 24 kcal/lb of metabolizable energy, 19 kcal/lb of net energy, 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. Beef tallow and feed grade amino acids were added to the diets without phytase to balance the net energy and standardized ileal digestible (SID) amino acid concentrations across treatments. During the grower period (d 0 to 57) pigs fed the control diets with no added phytase had increased average daily gain (ADG) compared to pigs fed phytase in the grower period, with pigs fed phytase in the grower and finishing stages intermediate. Pigs fed the phytase-containing diets had poorer feed efficiency (F/G) compared to pigs fed the control diets with no phytase. During the finisher period, ADG and F/G were similar between pigs fed the control and grower phytase treatments, and both

[1] Appreciation is expressed to DSM Nutritional Products Inc. for their expertise and partial funding, to New Horizon Farms for use of the feed mill and animal facilities, and to Marty Heintz, Whitney Adler and Bayley Kroupa for technical assistance.
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were better ($P < 0.05$) than for pigs fed the phytase in grower and finisher. Overall, pigs fed diets with no phytase and pigs that were only fed phytase in the grower period had improved ($P < 0.05$) ADG and F/G than pigs fed the phytase-containing diets fed until market. There was a marginally significant ($P < 0.10$) treatment effect on hot carcass weight (HCW), with pigs fed the control and grower phytase treatments having greater HCW than the pigs fed phytase throughout treatment. No evidence of differences ($P > 0.10$) were observed for other carcass characteristics. In summary, adding 1,500 FYT/kg of phytase and using full matrix values for minerals, amino acids (AA), and energy had detrimental effects on ADG, F/G, and HCW in this study. We speculate that the negative effects on performance of pigs fed added phytase may be due to overestimating the matrix values for energy and AA and further research is warranted.

Introduction

Approximately 60 to 80% of phosphorus (P) in feedstuffs of plant origin is stored in phytic acid, typically in the form of phytate.[4] Pigs poorly utilize the phytate-bound phosphorus because they lack sufficient endogenous phytase to effectively cleave the phosphates from the phytate. Thus, phytate is known as an antinutritional factor[5] in swine diets as it reduces the digestibility of phosphorus. A practical solution to this issue consists of adding an exogenous phytase to swine diets, which has the ability to dephosphorylate the phytate in a stepwise manner and liberate P. As a consequence, P availability to the pig is increased while a need for the inclusion of expensive inorganic sources of P is decreased.[6]

The main beneficial effect of phytase is an improvement in the availability of phytate-bound P and its utilization by the pig. However, phytate carries an electro-negative charge when it reaches the digestive tract. This allows phytate to bind and form stable insoluble complexes with protein, fat, and minerals; preventing their absorption.[7] Phytase may also enhance the digestibility and absorption of these nutrients through a dissociation of such complexes.[6] The improvements in the utilization of nutrients other than P are known as extra-phosphoric effects of phytase. Use of higher levels of phytase to totally dissociate nutrients from phytate is thought to maximize these extra phosphoric effects; however, little data are available that show the impacts of higher levels of phytase when considering the potential release of AA and energy in addition to P. Additionally, to our knowledge, no data show the overall impact of high levels of phytase fed to pigs throughout the growing and finishing phases, compared to only fed in the growing phase, when a higher nutrient-dense diet is required to maximize performance.

Therefore, the objective of the present study was to investigate the effects of feeding high levels of phytase and the impact of phytase feeding duration on growth performance, carcass characteristics, and economics of growing-finishing pigs.

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[4] Eeckhout, W. and De Paepe, M., 1994. Total phosphorus, phytate-phosphorus and phytase activity in plant feedstuffs. *Animal Feed Science and Technology*, *47*(1-2), pp.19-29.

[5] Swick, R.A. and Ivey, R. 1992. The value of improving phosphorus retention. *Feed Manag* 43: 8-17.

[6] Selle, P.H. and Ravindran, V., 2008. Phytate-degrading enzymes in pig nutrition. Livestock Science, 113(2-3), pp.99-122.

[7] Woyengo, T.A. and Nyachoti, C.M., 2013. Anti-nutritional effects of phytic acid in diets for pigs and poultry–current knowledge and directions for future research. Canadian Journal of Animal Science, 93(1), pp.9-21.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This experiment was conducted at a commercial research-finishing site in southwestern Minnesota. The barn was naturally ventilated and double-curtain-sided. 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 a computerized feeding system (FeedPro, Feedlogic Corp., Willmar, MN) capable of measuring and recording daily feed additions to individual pens.

A total of 1,215 barrows and gilts (PIC; 359 × Camborough; initially 61.5 ± 1.02 lb) were used in a 126-d growth trial. At placement (35 lb), pigs were fed a common diet containing 0.66% total calcium (Ca) and 0.42% STTD P until the initiation of the trial. On d 0, pens of pigs were weighed and ranked by average body weight (BW). Pens were then randomly assigned to 1 of 3 dietary treatments in a randomized complete block design, with BW used as a blocking factor. There were 27 pigs per pen and 15 replicate pens per treatment. The 3 dietary treatments consisted of: 1) Control (diets formulated with no added phytase); 2) Added phytase in the grower phase (diets formulated to contain 1,500 FYT fed from d 0 to 57, then switched to control diets until market); and 3) Phytase throughout (diets formulated to contain 1,500 FYT fed from d 0 until market).

The experimental diets were fed in four phases and based on corn, distillers dried grains with solubles, and soybean meal (Tables 1 and 2). Phase 1 diets were fed from d 0 to 29 (61.5 to 112 lb); phase 2 diets were fed from d 29 to 57 (112 to 163 lb); phase 3 diets were fed from d 57 to 85 (163 to 217 lb); and phase 4 diets were fed from d 85 to 126 (217 to 298 lb). The added phytase diets contained 1,500 FYT/kg of Ronozyme HiPhos 2500 (DSM Nutritional Products, Inc., Parsippany, NJ) with assumed release values of 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 24 kcal/lb of metabolizable energy, 19 kcal/lb of net energy, and 0.0217, 0.0003, 0.00886, 0.0224, 0.0056, 0.0122, and 0.0163% standardized ileal digestible (SID) 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.[8] Digestibility coefficients for P were obtained from NRC (2012) and the digestibility coefficients for Ca were obtained from the literature.[9,10,11] The diets were formulated to contain adequate STTD P across the dietary treatments in all phases based on the estimated requirement

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

[9] 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.

[10] 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.

[11] 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).

previously determined in this facility.[12] All diets were balanced for a STTD Ca:STTD P ratio of 1.55:1. Beef tallow and feed grade amino acids were added to the diets without phytase to balance the net energy, SID lysine, and the amino acid ratios across treatments.

Experimental diets were manufactured at the New Horizon Farms Feed Mill (Pipestone, MN) and fed in meal form. Representative samples of treatment diets were taken from 6 feeders per dietary treatment 3 d after the beginning and 3 d before the end of each phase and stored at -4°F. After blending, subsamples were analyzed in duplicates for dry matter, crude protein, crude fiber, ash, ether extract, Ca, P, and average values were reported (Table 6; Ward Laboratories, Inc., Kearney, NE). A composite sample of phase 1 and 2 diets (grower) and phase 3 and 4 diets (finisher) was analyzed for phytase activity in duplicate (New Jersey Feed Laboratory Inc., Trenton, NJ).

Pens of pigs were weighed, and feed disappearance was recorded approximately every 14 d to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). On d 99, the 2 heaviest pigs in each pen were selected, weighed, and sold according to standard farm procedures. On d 126, final pen weights were taken, and pigs were individually tattooed with the specific pen identity on the shoulder to allow carcass measurements to be recorded on a pen basis. These pigs were transported to a commercial packing plant in southwestern Minnesota (JBS Swift and Company, Worthington, MN) for processing and carcass data collection. Carcass measurements included HCW, loin depth, backfat depth, and percentage lean. Percentage carcass yield was calculated by dividing the average pen HCW by the average final live weight at the farm.

For the economic analysis, total feed cost per pig, cost per lb of gain, gain value, and income over feed cost (IOFC) were calculated. The total feed cost per pig was calculated by multiplying ADFI by feed cost per lb and number of days the diet was fed in each respective period, then taking the sum of these values for each period. Cost per lb of gain was calculated by dividing total feed cost per pig by total gain per pig. Gain value per pig was calculated by multiplying carcass gain by an assumed carcass value of $58.23 per cwt. To calculate IOFC, total feed cost was subtracted from gain value. For all economic evaluations, prices of ingredients during spring of 2018 were used with corn valued at $3.25/bu ($116/ton), soybean meal at $290/ton, DDGS at $130/ton, beef tallow at $0.21/lb, L-lysine HCL at $0.69/lb, DL-methionine at $1.20/lb, L-threonine at $0.89/lb, L-tryptophan at $3.90/lb, Ronozyme HiPhos 2500 at $0.77/lb, monocalcium phosphate at $0.23/lb, and limestone at $0.03/lb.

Data were analyzed as a randomized complete block design, with pen as the experimental unit and BW the blocking factor. The study was structured as a one-way treatment structure with dietary treatment as the factor level. Because carcass characteristics were recorded on an individual pig basis, a random effect of block by treatment was used to identify the pen as the experimental unit. Pairwise comparisons

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[12] Vier C. M., Wu F., Menegat M. B., Cemin H., Dritz S. S., Tokach M. D., Gonçalves M. A. D., Orlando U. A. D., Woodworth J. C., Goodband R. D., DeRouchey J. M. 2017. Effects of standardised total tract digestible phosphorus on performance, carcass characteristics, and economics of 24 to 130 kg pigs. Animal Production Science 57, 2424-2424. https://doi.org/10.1071/ANv57n12Ab071.

were conducted, and means were reported as least-square means. Statistical models were fitted using GLIMMIX procedure of SAS (Version 9.3, SAS Institute Inc., Cary, NC). Results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 \leq P \leq 0.10$.

Results and Discussion

Chemical analysis of experimental diets (Table 3) showed that values were reasonably consistent with formulated estimates. Average values of analyzed Ca and P concentrations were slightly more variable compared to the formulated values but were all within 10% of formulated values. This variation is still within the acceptable analytical variation based on the AAFCO's sample program.[13] The analyzed phytase activity were reasonably consistent with formulated estimates. Control diets with no added phytase had 50 and 80 FYT/kg in the grower and finisher diets, respectively. The phytase-containing diets had 1,710 and 1,790 FYT/kg, in the grower and finisher diets, respectively.

During the grower period, which corresponds to phases 1 and 2 (d 0 to 57), there was a significant ($P < 0.05$) treatment effect on ADG (Table 4). Pigs fed the control diets with no added phytase had increased ADG compared to pigs fed phytase in the grower period, with pigs in the phytase throughout growing and finishing treatment intermediate. This was mainly due to a significant ($P < 0.05$) treatment effect on F/G, which was the best for pigs fed the control diets with no phytase compared to pigs fed the phytase-containing diets. There was no evidence ($P > 0.10$) of differences in ADFI between treatments. During the finisher period, which corresponds to phases 3 and 4 (d 58 to 126), ADG was similar between pigs fed the control diets and pigs fed the diets with phytase in the grower period. This ADG was greater ($P < 0.05$) than that of pigs fed phytase in both the grower and finisher periods. This was driven by an improvement in feed efficiency, which was similar between the control and grower phytase treatment and better ($P < 0.05$) than the F/G of pigs receiving phytase in both the grower and finisher. There was no evidence ($P > 0.10$) of differences in ADFI between treatments.

Overall, there was a significant ($P < 0.05$) treatment effect on ADG and F/G. Average daily gain was similar between pigs fed diets with no phytase and pigs who were fed phytase only in the grower phases, and greater than ADG of pigs fed phytase-containing diets until market. Likewise, F/G was comparable between the control and pigs fed phytase in the grower phases, and better than the pigs fed phytase throughout treatment. No evidence ($P > 0.10$) of differences between treatments was observed for ADFI.

There was a marginally significant ($P < 0.10$) treatment effect on HCW, which was similar between the control and phytase fed only in the grower phase treatments, and greater for pigs fed phytase in the grower and finisher phase. No evidence of differences ($P > 0.10$) were observed for carcass yield, backfat, fat-free lean, and loin depth.

Feed cost per pig was similar between pigs fed diets with no phytase and those who were fed the phytase-containing diets in the grower phase. This feed cost per pig was greater

[13] AAFCO. 2015. AAFCO Official Publication. Am. Assoc. Feed Control Off., Champaign, IL.

($P < 0.05$) than for pigs fed diets with phytase in the grower and finisher. Feed cost per lb of gain was similar between pigs fed the phytase in the grower phase or grower and finisher, and lower ($P < 0.05$) than for pigs fed diets without phytase. Gain value per pig was greater ($P < 0.05$) for pigs in the control and those fed phytase in the grower phase compared to pigs fed phytase in the grower and finisher. No evidence of difference ($P > 0.10$) was observed for IOFC.

Several studies have reported potential improvements in growth performance of nursery pigs in response to high (greater than 1,000 FYT/kg) dietary phytase levels. The addition of phytase above levels used for P-release, however, has been less consistent in growing-finishing pigs. In many of these studies, phosphorus was the only nutrient replaced by phytase. Results from the present study, where phosphorus, calcium, amino acids, and energy were replaced by phytase, suggest that growing-finishing pigs fed diets containing high levels of phytase until market had poorer performance compared to pigs fed diets without the inclusion of phytase.

Inconsistent results have been observed regarding the effects of phytase on the digestibility of AA. Improved apparent ileal digestibility of some AA in response to the addition of phytase in diets has been reported,[14,15] however, other studies did not observe the same results.[16,17] Similarly, contradictory results have been reported regarding the effects of phytase on energy digestibility.[16] In our study, matrix values were assigned not only to digestible P, but also to digestible Ca, energy, and AA. We speculate that the detrimental effects in performance of pigs supplemented with phytase may be due to an overestimation of the matrix values for energy and AA.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

[14] Kemme, P. A., A. W. Jongbloed, Z. Mroz, J. Koguta, and A. C. Beynen. 1999. Digestibility of nutrients in growing–finishing pigs is affected by *Aspergillus niger* phytase, phytate and lactic acid levels: 1. Apparent ileal digestibility of amino acids. Livest. Prod. Sci. 58:107–117. https://doi.org/10.1016/S0301-6226(98)00203-6.

[15] Adedokun, S. A., A. Owusu-Asiedu, D. Ragland, P. Plumstead and O. Adeola. 2015. The efficacy of a new 6-phytase obtained from buttiauxella spp. Expressed in Trichoderma reesei on digestibility of amino acids, energy, and nutrients in pigs fed a diet based on corn, soybean meal, wheat middlings, and corn distillers' dried grains with solubles. J. Anim. Sci. 93:168–175. doi:10.2527/jas.2014-7912.

[16] Traylor, S.L., Cromwell, G.L., Lindemann, M.D. and Knabe, D.A., 2001. Effects of level of supplemental phytase on ileal digestibility of amino acids, calcium, and phosphorus in dehulled soybean meal for growing pigs. Journal of animal science, 79(10), pp.2634-2642.

[17] She, Y., Sparks, J.C. and Stein, H.H., 2018. Effects of increasing concentrations of an Escherichia coli phytase on the apparent ileal digestibility of amino acids and the apparent total tract digestibility of energy and nutrients in corn-soybean meal diets fed to growing pigs. Journal of animal science, p.sky152.

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

Item	Phase 1		Phase 2	
	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase
Ingredient, %				
Corn	60.92	63.54	68.59	71.23
Soybean meal, 46.5% crude protein	24.57	24.16	17.13	16.72
Distillers dried grains with solubles	10.00	10.00	10.00	10.00
Beef tallow	1.50	---	1.50	---
Monocalcium phosphate, 21% P	0.90	0.15	0.75	---
Limestone	1.08	1.11	1.00	1.03
Sodium chloride	0.35	0.35	0.35	0.35
L-Lysine HCl	0.37	0.35	0.39	0.37
DL-Methionine	0.06	0.05	0.03	0.02
L-Threonine	0.09	0.07	0.09	0.06
L-Tryptophan	0.02	0.01	0.03	0.02
Phytase[2]	---	0.06	---	0.06
Vitamin and trace mineral premix	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00

continued

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

Item	Phase 1		Phase 2	
	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lysine	1.10	1.10	0.93	0.93
Isoleucine:lysine	63	63	61	62
Leucine:lysine	142	143	149	150
Methionine:lysine	31	30	30	29
Methionine and cysteine:lysine	56	56	56	56
Threonine:lysine	62	62	62	62
Tryptophan:lysine	18.8	18.8	18.9	18.9
Valine:lysine	70	70	70	70
Total lysine, %	1.25	1.23	1.06	1.04
Net energy, kcal/lb	1,134	1,134	1,157	1,157
SID lysine:net energy, g/Mcal	4.40	4.40	3.65	3.65
Crude protein, %	20.0	20.0	17.1	17.1
Calcium, %	0.72	0.60	0.62	0.51
STTD Ca,[3] %	0.57	0.57	0.49	0.50
Phosphorus, %	0.62	0.46	0.55	0.39
STTD P,[4] %	0.37	0.37	0.32	0.32
Available phosphorus, %	0.32	0.34	0.28	0.30
Calcium:phosphorus	1.16	1.31	1.14	1.29
STTD Ca:STTD P	1.55	1.55	1.55	1.55

[1]Phase 1 diets were fed from d 0 to 29 (61.5 to 112 lb) and phase 2 diets were fed from d 29 to 56 (112 to 163 lb).
[2]Phytase (Ronozyme HiPhos, DSM Nutritional Products, 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 metabolizable energy, 19 kcal/lb of net energy, 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.
[3]Standardized total tract digestible calcium.
[4]Standardized total tract digestible phosphorus.

Table 2. Diet formulation, Phases 3 and 4 (as-fed basis)[1]

	Phase 3		Phase 4	
Item	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase
Ingredient, %				
Corn	73.86	76.43	83.23	85.65
Soybean meal, 46.5% crude protein	12.06	11.50	12.89	12.64
Distillers dried grains with solubles	10.00	10.00	---	---
Beef tallow	1.45	---	1.45	---
Monocalcium phosphate, 21% P	0.65	---	0.75	---
Limestone	0.95	1.04	0.73	0.77
Sodium chloride	0.35	0.35	0.35	0.35
L-Lysine HCl	0.39	0.38	0.30	0.28
DL-Methionine	0.01	---	0.02	0.01
L-Threonine	0.10	0.08	0.10	0.08
L-Tryptophan	0.03	0.03	0.03	0.02
Phytase[2]	---	0.06	-	0.06
Vitamin and trace mineral premix	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00

continued

Table 2. Diet formulation, Phases 3 and 4 (as-fed basis)[1]

	Phase 3		Phase 4	
Item	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lysine	0.81	0.81	0.73	0.73
Isoleucine:lysine	59	60	60	62
Leucine:lysine	157	158	151	153
Methionine:lysine	29	28	30	29
Methionine and cysteine:lysine	57	57	58	58
Threonine:lysine	64	64	66	66
Tryptophan:lysine	18.9	18.7	19.5	19.5
Valine:lysine	70	70	70	70
Total lysine, %	0.93	0.91	0.83	0.81
Net energy, kcal/lb	1,171	1,171	1,183	1,183
SID lysine:net energy, g/Mcal	3.14	3.14	2.80	2.80
Crude protein, %	15.1	15.0	13.4	13.4
Calcium, %	0.56	0.48	0.51	0.39
STTD Ca,[3] %	0.44	0.48	0.40	0.41
Phosphorus, %	0.50	0.37	0.47	0.31
STTD P,[4] %	0.29	0.31	0.26	0.27
Available phosphorus, %	0.25	0.29	0.21	0.23
Calcium:phosphorus	1.11	1.31	1.08	1.26
STTD Ca:STTD P	1.55	1.55	1.55	1.55

[1]Phase 3 diets were fed from d 57 to 85 (163 to 217 lb) and phase 4 diets were fed from d 85 to 126 (217 to 298 lb).
[2]Phytase (Ronozyme HiPhos, DSM Nutritional Products, 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 metabolizable energy, 19 kcal/lb of net energy, 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.
[3]Standardized total tract digestible calcium.
[4]Standardized total tract digestible phosphorus.

Table 3. Analyzed composition of experimental diets (as-fed-basis)[1,2]

Item, %	Phase 1		Phase 2		Phase 3		Phase 4	
	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase	No added phytase	1,500 FTU/kg phytase
Dry matter	89.16	88.94	88.38	88.12	88.36	88.30	88.14	88.26
Crude protein	20.08	19.85	19.78	18.00	14.60	15.13	13.78	14.00
Crude fiber	2.78	3.00	2.45	2.63	2.90	3.03	2.10	2.30
Ether extract	4.30	3.48	4.30	3.28	4.53	3.33	3.95	3.08
Ash	4.60	3.74	4.42	3.72	3.70	2.64	3.18	3.07
Calcium	0.73	0.42	0.63	0.63	0.63	0.31	0.50	0.41
Phosphorus	0.55	0.43	0.53	0.42	0.45	0.34	0.46	0.31

[1]Representative samples of treatment diets were taken from 6 feeders per dietary treatment 3 d after the beginning and 3 d before the end of the phase and stored at -4°F. After blending, subsamples were submitted to Ward Laboratories, Inc. (Kearney, NE) and were analyzed for dry matter, crude protein, crude fiber, ash, ether extract, calcium, and phosphorus.

[2]A composite sample of phase 1 and 2 diets (grower) and phase 3 and 4 diets (finisher) was analyzed for phytase activity in duplicate (New Jersey Feed Laboratory Inc., Trenton, NJ). Control diets with no added phytase had 50 and 80 FYT/kg in the grower and finisher diets, respectively. The phytase-containing diets had 1,710 and 1,790 FYT/kg, in the grower and finisher diets, respectively.

Table 4. Effects of feeding 1,500 FTY/kg of phytase on growth performance, carcass characteristics, and economics of growing-finishing pigs[1]

	Treatment[2,3]				
Item[4]	Control	Phytase grower	Phytase grower and finisher	SEM[5]	Probability, $P =$[6]
Grower period (d 0 to 57)					
ADG, lb	1.81[a]	1.75[b]	1.78[a,b]	0.017	0.011
ADFI, lb	3.73	3.74	3.76	0.045	0.570
F/G	2.06[b]	2.13[a]	2.11[a]	0.012	<0.001
Finisher period (d 57 to 126)					
ADG, lb	2.03[a]	2.06[a]	1.95[b]	0.023	0.006
ADFI, lb	6.02	6.05	5.97	0.060	0.575
F/G	2.97[b]	2.95[b]	3.07[a]	0.033	0.002
Overall period (d 0 to 126)					
ADG, lb	1.92[a]	1.92[a]	1.87[b]	0.018	0.016
ADFI, lb	4.93	4.96	4.92	0.046	0.651
F/G	2.57[b]	2.60[b]	2.64[a]	0.019	0.001
BW, lb					
d 0	61.4	61.4	61.5	1.02	0.780
d 57	164.3[a]	161.4[b]	162.6[a,b]	1.95	0.017
d 126	301.0[a]	299.7[a]	293.8[b]	2.61	0.030
Carcass characteristics					
HCW, lb	220.2[a]	220.8[a]	215.8[b]	20.48	0.097
Yield, %	72.63	72.82	72.27	0.337	0.406
Backfat, mm	15.98	16.66	16.46	-	0.509
Loin depth, mm	70.98	71.69	71.22	-	0.797
Fat-free lean, %	58.63	57.30	57.36	-	0.717
Economics, $/pig					
Feed cost	53.41[a]	52.60[a]	50.86[b]	0.492	<0.001
Feed cost/lb gain[7]	0.221[a]	0.218[b]	0.216[b]	0.0016	0.003
Gain value[8]	101.63[a]	102.17[a]	98.53[b]	1.078	0.019
IOFC[9]	48.06	48.86	47.21	0.812	0.285

[1]A total of 1,215 pigs (PIC; 359 × Camborough; initial pen average BW of 61.5 lb) were used in a 126-d growth trial with 27 pigs per pen and 15 pens per treatment.
[2]Treatments consisted of: 1) Control (diets formulated with no added phytase); 2) Phytase grower (phytase-containing diet fed until phase 2 when pigs reached approximately 165 lb and then control diet with no phytase; 3) Phytase throughout (diets formulated to contain 1,500 phytase units (FYT) throughout the entire study).
[3]The phytase-containing diets had the inclusion of 1,500 FYT/kg of Ronozyme HiPhos 2500 (DSM Nutritional Products, Inc., Parsippany, NJ) with assumed release values of 0.146% STTD P, 0.166% available P, 0.102% STTD Ca, 24 kcal/lb of metabolizable energy, 19 kcal/lb of net energy, 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]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio. BW= body weight. HCW = hot carcass weight. IOFC = income over feed cost.
[5]SEM for backfat were 0.392, 0.385, and 0.479; SEM for fat-free lean were 0.287, 0.283, 0, and 0.352; and SEM for loin depth were 0.668, 0.652, 0.813 for control, phytase throughout, and phytase withdrawal, respectively.
[6]Means with different superscripts within a row differ.
[7]Feed cost/lb gain = total feed cost divided by total gain per pig.
[8]Gain value = (HCW × $0.5823) – (d 0 BW × 0.75 × $0.5823).
[9]Income over feed cost = gain value – feed cost.