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Effects of Feeding Finishing Pig Diets Differing in Ca:P Ratio, Added Phytase and Vitamin D Sources on Growth Performance, Weight Variation, Serum 25(OH)D3, Carcass Characteristics, Bone Characteristics, and Economics

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Effects of Feeding Finishing Pig Diets Differing in Ca:P Ratio, Added Phytase and Vitamin D Sources on Growth Performance, Weight Variation, Serum 25(OH)D_3, Carcass Characteristics, Bone Characteristics, and Economics[1]

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Summary

A total of 2,160 grow-finish pigs (PIC 337 × 1050; initially 71.8 ± 1.4 lb) were used in a 114-d trial to determine the effects of feeding diets differing in Ca:P ratio and added phytase or phytase and 25(OH)D_3 (Hy-D, DSM Nutritional Products, Parsippany, NJ) on growth performance, weight variation, serum 25(OH)D_3, bone characteristics, and economics. Pigs were housed in mixed gender pens with 27 pigs per pen and 20 pens per treatment. The four treatments were structured as a randomized complete block design and consisted of: 1) a high phosphorus (HP) diet formulated to a 1.25:1 Ca to P ratio with STTD P at 115% of NRC[4] requirement estimate without inclusion of phytase; 2) low phosphorus (LP) diet initially formulated to a 1.25:1 Ca to P ratio with STTD P at 80% of NRC requirement without the addition of phytase; 3) HP with phytase (HP+phytase) diet with a 1.1:1 Ca to P ratio with STTD P at 115% of NRC requirement using 0.125% STTD P release from 600 FYT/kg HiPhorius; and 4) Same as diet 3 except 25(OH)D_3 replacing most of the vitamin D_3 in the diet (HP+25(OH)D_3). Diets were fed in meal form with phase 1 fed from 71 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 to 293 lb. Overall, source of vitamin D had no impact on performance, but pigs fed HP diets had improved ($P < 0.05$) ADG, ADFI, and F/G compared to those fed LP diets, and ADFI was greater compared to those fed the HP+phytase diet with 1.1:1 Ca to P ratio. For serum 25(OH)D_3 measured on d 50, pigs fed the HP diets had increased ($P < 0.05$)

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[1] The authors appreciate DSM Nutritional Products, Parsippany, NJ, for providing partial financial support for these studies and New Horizon Farms, Pipestone, MN, for providing technical assistance for these studies.

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

[3] DSM Nutritional Products, Parsippany, NJ.

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

levels of 25(OH)D_3 compared to pigs fed the LP diets, and pigs fed the HP+25(OH)D_3 diets had increased ($P < 0.05$) serum levels of 25(OH)D_3 compared to pigs fed the HP+phytase diets. Pigs fed the HP diets had greater ($P < 0.05$) HCW and percentage lean than those fed LP diets. For economics results, pigs fed HP diets had increased ($P < 0.05$) feed cost, revenue, and income over feed cost (IOFC) compared to those fed LP diets in both a low and high price scenario. For bone analysis, pigs fed HP diets, had greater ($P < 0.05$) bone ash (g) and breaking strength than pigs fed LP or HP+phytase with a reduced Ca to P ratio. In conclusion, when pigs were fed 115% of NRC STTD P requirements, growth performance, HCW, and economics were improved compared to those fed at 80% of the P requirements.

Introduction

Calcium and P play important roles in development and maintenance of the skeletal system, muscle deposition, and many other physiological functions. In addition, vitamin D has an important role in Ca and P metabolism. When formulating diets, Ca and P ingredients should be supplied to meet not only swine nutrient requirements, but also an appropriate ratio for efficient utilization by the pig. Vier et al.[5] observed that the optimal STTD P level for ADG and F/G are well above those suggested by the NRC.

Phytase is an enzyme that when included in swine diets can release P stored in cereal grains to make it available for meeting the pigs' needs. The addition of phytase in pig diets also reduces the inclusion of inorganic sources of phosphorus, which results in decreased diet costs and P excretion. Vitamin D can be supplemented using intermediate molecules of vitamin D metabolism, such as 25(OH)D_3, and positive effects on bone mineralization were observed compared to pigs fed diets deficient in P in recent studies but no evidence for differences in growth performance of the pigs was observed.[6]

Pig growth performance responses can differ when different levels of STTD phosphorus are used in diets, but the effect of replacing vitamin D_3 using intermediate metabolites requires more clarity. Therefore, the objective of this study was to evaluate the effect of feeding finishing pigs diets differing in STTD P levels, Ca:P ratio, the use of phytase, and providing vitamin D by two different sources on growth performance, weight variation, serum 25(OH)D_3, carcass characteristics, bone characteristics, and economics.

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-finishing site in southwest Minnesota. The barns were naturally ventilated and double-curtain-sided with totally slatted floors. Each pen was equipped with a 5-hole

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

[6] Williams, H., J. T. Gebhardt, M. D. Tokach, J. C. Woodworth, J. M. DeRouchey, R. D. Goodband, J. R. Bergstrom, C. W. Hastad, Z. Post, M. Rahe, C. Siepker, P. Sitthicharoenchai, S. Ensley. 2022. The effect of different bones and analytical methods on the assessment of bone mineralization to dietary phosphorus, phytase, and vitamin D in finishing pigs. Kansas Agricultural Experiment Station Research Reports: Vol. 8: Iss. 10. doi:10.4148/2378-5977.8376

stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) able to record feed deliveries for individual pens.

Animals and diets

Two groups of pigs (total 2,160 pigs; PIC 337 × 1050; initially 71.8 ± 1.35 lb) were used in a 114-d growth trial. Pigs were housed in mixed gender pens with 27 pigs per pen and 20 pens per treatment. The treatments were structured as a randomized complete block design and consisted of: 1) a high phosphorus (HP) diet formulated to a 1.25:1 Ca to P ratio with STTD P at 115% of NRC requirement without inclusion of phytase; 2) low phosphorus (LP) diet formulated to a 1.25:1 Ca to P ratio with STTD P at 80% of NRC requirement without the addition of phytase; 3) HP with phytase (HP+phytase) diet formulated to a 1.1:1 Ca to P ratio with STTD P at 115% of NRC requirement using 0.125% STTD P release from 600 FYT/kg phytase (HiPhorius, DSM Nutritional Products, Parsippany, NJ); and 4) Diet 3 with 25(OH)D_3 replacing a majority of the vitamin D_3 in the diet (HP+25(OH)D_3). The first 3 treatments had 1,300 IU D_3/kg in the first three diet phases and 650 IU D_3/kg in the last phase. The HP+25(OH)D_3 treatment had 1,000 IU of vitamin D_3 from 25 mcg/kg of 25(OH)D_3 (Hy-D, DSM Nutritional Products, Parsippany, NJ)/kg + 300 IU vitamin D_3/kg in the first three phases and 500 IU vitamin D_3 equivalency/kg from 25(OH)D_3/kg + 150 IU vitamin D_3/kg in the last phase. All treatment diets were manufactured at the New Horizon Farms Feed Mill in Pipestone, MN, and were formulated to meet or exceed NRC requirement estimates for growing-finishing pigs for their respective weight ranges (Tables 1 and 2). Diets were fed in meal form with phase 1 fed from 71 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 to 293 lb. Experimental diets were corn-soybean meal-based and were formulated with a premix containing Rovimix D_3 (DSM Nutritional Products Inc.) as the only source of vitamin D for the HP, LP and HP+phytase treatments; whereas, for treatment HP+25(OH)D_3, a premix containing Rovimix Hy-D and Rovimix D_3 was used to supply the dietary vitamin D requirements. Phytase source was added to the diet by hand-made premixes, which were added in place of corn.

Pigs were weighed approximately every 14 d to determine ADG, ADFI, and F/G. At the beginning of the study and on d 99, all the pigs were individually weighed to determine body weight variation. One mean BW pig per pen was identified with a tag on d 0 and blood samples were collected into red-top tubes on d 0, 50, and 99 from the same pig, and then when samples were centrifuged, the serum was collected and sent to Heartland Assays (Ames, IA) to determine serum 25(OH)D_3 levels. On d 99, the 3 heaviest pigs in each pen were selected and marketed, but not included in the final pen carcass data. On the last day of the trial, final pen weights were obtained, and the pigs were tattooed with a pen identification number and transported to a U.S. Department of Agriculture-inspected packing plant (JBS Swift, Worthington, MN) for carcass data collection. Carcass measurements included HCW, loin depth, backfat, and percentage lean. The percentage lean calculations were obtained from a proprietary equation used by the packer. Carcass yield was calculated by dividing the pen average HCW by the pen average final live weight obtained at the farm. In addition, one pig per pen was used for bone collection from one front foot per pig. The third metacarpal was used for de-fatted bone ashing and the fourth metacarpal used to determine bone breaking strength at the Kansas State University Swine Laboratory. Feed cost per pig was calculated by diet feed cost times feed intake per phase divided by pigs placed. Feed cost per lb of gain was calculated by dividing total feed cost per pig by total gain per pig. Revenue was calculated by multiplying total gain by carcass yield and carcass price. Income over feed cost was calculated by subtracting feed cost per pig from revenue.

Statistical analysis

Data were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package in R (version 4.1.1 (2021-08-10), R Foundation for Statistical Computing, Vienna, Austria) with pen considered the experimental unit, and treatment as fixed effect. Contrast coefficients were used to evaluate the effects of phosphorus level in the diet (HP vs. LP), Ca:P ratio (HP vs. HP+phytase), and vitamin D source (HP+phytase vs. HP+25(OH)D_3). Pig individual weight data on d 0 and 99 were used to calculate within-pen coefficient of variation which was analyzed in a similar manner to growth data and visualized using the ggplot package in R. Hot carcass weight was used as a covariate for analysis of backfat, loin depth, and lean percentage. All results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

During the grower period, pigs fed the HP diet had increased ($P < 0.05$) ADG, ADFI, and improved F/G compared to those fed the LP diet. Also, pigs fed the HP+phytase diet tended to have decreased ($P = 0.059$) ADFI compared to those fed the HP diet with no impact of vitamin D source observed. In the finisher period, pigs fed the HP diet resulted in increased ($P < 0.05$) ADG and ADFI compared to pigs fed the LP diet, and ADFI also tended to increase ($P = 0.083$) compared to those fed the HP+phytase diet. Overall, pigs fed the HP diet had improved ($P < 0.05$) ADG, ADFI, and F/G compared to those fed the LP diet. Also, pigs fed the diet formulated to 1.1:1 Ca:P ratio with phytase (HP+phytase) had decreased ($P < 0.05$) ADFI compared to those fed the diet formulated to 1.25:1 Ca:P ratio without phytase (HP).

For body weight variation, there was no evidence for difference ($P \geq 0.10$) in coefficient of variation between the treatments at any of the times when individual weights were collected. On d 50, pigs fed the HP diet had increased ($P < 0.05$) serum 25(OH)D_3 compared to pigs fed the LP diets, and pigs fed the HP+25(OH)D_3 diets had increased ($P < 0.05$) serum 25(OH)D_3 compared to pigs fed the HP+phytase diets. Serum 25(OH)D_3 collected on d 99 did not show evidence of differences between treatments. Even though 25(OH)D_3 was numerically highest in pigs fed the HP+25(OH)D_3 diet, there was not a significant difference ($P \geq 0.10$) compared to pigs fed only vitamin D_3, which may have resulted from the lower levels of vitamin D supplementation in the last diet phase.

For carcass characteristics, pigs fed the HP diet had greater ($P < 0.05$) HCW and lean percentage, with a tendency ($P = 0.092$) for reduced backfat compared to those fed the LP diet.

For bone analysis, pigs fed the HP diet had greater ($P < 0.05$) bone ash weight and breaking strength than pigs fed the LP or HP+phytase indicating that higher levels of dietary STTD P had greater bone ash weight and breaking strength, and that pigs fed a 1.25 Ca:P ratio had greater bone mineralization than pigs fed a 1.1:1 Ca:P ratio. However, when looking at bone ash as a percentage of bone composition, no evidence for treatment differences were observed ($P \geq 0.10$).

Pigs fed the HP diet had increased ($P < 0.05$) feed cost, revenue, and IOFC compared to those fed the LP diet in both low and high price scenarios. Feed cost per pig tended to decrease ($P = 0.088$) when feeding HP+25(OH)D_3 compared to pigs fed HP+phytase diet in high price scenario. Pigs fed HP+phytase had reduced ($P < 0.05$) feed cost per pig compared to those fed HP in low and high price scenarios. However, in the low price scenario, feed cost per lb of gain tended to be decreased ($P = 0.064$) for the HP+phytase compared with the HP treatment.

In conclusion, pigs fed the HP diets had improved growth performance, HCW, and economics compared to those fed the LP diets. Feeding a 1.25:1 Ca:P ratio provided greater bone breaking strength than feeding a 1.1:1 ratio. Lastly, feeding the HP+phytase diet could be a strategy to reduce feed cost.

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

	Phase 1		Phase 2	
Item	HP/LP[2]	HP + Phytase/25(OH)D_3[3]	HP/LP[4]	HP + Phytase/25(OH)D_3[3]
Ingredients, %				
Corn	66.01	67.22	73.32	73.64
Soybean meal, 46.5% CP[5]	28.78	28.76	22.65	22.62
Choice white grease	1.50	1.50	1.50	1.50
Limestone	[2]	0.93	[4]	0.87
Monocalcium P, 21% P	[2]	0.40	[4]	0.22
Salt	0.40	0.40	0.40	0.40
L-Lys-HCl	0.30	0.30	0.30	0.30
DL-Met	0.09	0.09	0.06	0.06
L-Trp	---	---	0.01	0.01
Thr[6]	0.12	0.12	0.11	0.11
L-Val	0.02	0.02	0.01	0.01
Tribasic copper chloride	0.03	0.03	0.03	0.03
Vitamin-trace mineral premix[7]	0.15	0.15	0.15	0.15
Phytase[8]	---	0.10	---	0.10
Total	100	100	100	100

continued

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

	Phase 1		Phase 2	
Item	HP/LP[2]	HP + Phytase/25(OH)D_3[3]	HP/LP[4]	HP + Phytase/25(OH)D_3[3]
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.12	1.12	0.97	0.97
Ile:Lys	63	63	62	62
Leu:Lys	132	132	138	138
Met:Lys	32	32	31	31
Met and Cys:Lys	56	56	56	56
Thr:Lys	62	62	62	62
Trp:Lys	18.3	18.3	18.2	18.2
Val:Lys	70	70	70	70
His:Lys	42	42	42	42
Total Lys, %	1.26	1.26	1.09	1.09
NE, kcal/lb	1,141	1,145	1,159	1,164
SID Lys:NE, g/Mcal	4.45	4.44	3.80	3.78
CP, %[5]	19.6	19.7	17.3	17.3
Ca, %	[2]	0.51	[4]	0.44
STTD P, %	[2]	0.36	[4]	0.31

[1] Phase 1 was fed from approximately 71 to 110 lb and phase 2 from 110 to 165 lb.
[2] HP and LP phase 1 treatment diets were combined in this column. HP diet = 1.28% limestone and 1.06% monocalcium P (21% P) to provide a total content of 0.76% Ca and 0.36 STTD P % in the diet. LP diet = 1.14% limestone and 0.48% monocalcium P (21% P) to provide a total content of 0.60% Ca and 0.25 STTD P % in the diet.
[3] HP+phytase and HP+25(OH)D_3 diets were combined in this column. Differences between treatments are explained in footnote 7.
[4] HP and LP phase 2 treatment diets were combined in this column. HP diet = 1.19% limestone and 0.88% monocalcium P (21% P) to provide a total content of 0.68% Ca and 0.31 STTD P % in the diet. LP diet = 1.08% limestone and 0.41% monocalcium P (21% P) to provide a total content of 0.55% Ca and 0.22 STTD P % in the diet.
[5] CP = crude protein.
[6] Thr Pro; CJ America-Bio, Downers Grove, IL.
[7] Vitamin and trace mineral premix containing Rovimix D_3 (DSM Nutritional Products Inc.) as the only source of vitamin D for the HP, LP and HP+D_3 treatments; whereas, for treatment HP+25(OH)D_3 a premix containing Rovimix Hy-D and Rovimix D_3 was used to meet vitamin D requirements.
[8] HiPhorius (DSM Nutritional Products Inc.) was added in a blend of 0.025 lb of the product and 1.975 lb of ground corn to achieve 600 FYT/kg, providing an estimated release of 0.125% STTD P for treatments containing phytase.

Table 2. Composition of experimental phases 3 and 4 diets (as-fed basis)[1]

	Phase 3		Phase 4	
Item	HP/LP[2]	HP + Phytase/25(OH)D_3[2]	HP/LP[2]	HP + Phytase/25(OH)D_3[3]
Ingredients, %				
Corn	78.82	79.12	81.46	81.79
Soybean meal, 46.5% CP[4]	17.33	17.30	14.86	14.80
Choice white grease	1.50	1.50	1.50	1.50
Limestone	[2]	0.83	[3]	0.80
Monocalcium P, 21% P	[2]	0.13	[3]	---
Salt	0.40	0.40	0.40	0.40
L-Lys-HCl	0.30	0.30	0.30	0.30
DL-Met	0.03	0.03	0.02	0.02
L-Trp	0.01	0.01	0.02	0.02
Thr[4]	0.11	0.11	0.12	0.18
L-Val	0.01	0.01	0.01	0.01
Tribasic copper chloride	0.03	0.03	0.03	0.03
Vitamin-trace mineral premix[4]	0.15	0.15	0.08	0.08
Phytase[4]	---	0.10	---	0.10
Total	100	100	100	100
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.84	0.84	0.78	0.78
Ile:Lys	61	61	60	60
Leu:Lys	144	144	148	148
Met:Lys	29	29	29	29
Met and Cys:Lys	56	56	56	56
Thr:Lys	63	63	65	71
Trp:Lys	18.1	18.1	18.3	18.3
Val:Lys	70	70	70	70
His:Lys	42	43	43	43
Total Lys, %	0.95	0.95	0.88	0.88
NE, kcal/lb	1,175	1,179	1,183	1,189
SID Lys:NE, g/Mcal	3.24	3.23	2.99	2.98
CP, %[4]	15.1	15.2	14.2	14.2
Ca, %	[2]	0.39	[3]	0.35
STTD P, %	[2]	0.28	[3]	0.25

[1] Phase 3 was fed from approximately 165 to 220 lb and phase 4 from 220 to 293 lb.
[2] HP and LP phase 3 treatment diets were combined in this column. HP diet = 1.13% limestone and 0.79% monocalcium P (21% P) to provide a total content of 0.62% Ca and 0.28 STTD P % in the diet. LP diet = 1.02% limestone and 0.32% monocalcium P (21% P) to provide a total content of 0.50% Ca and 0.19 STTD P % in the diet.
[3] HP and LP phase 4 treatment diets were combined in this column. HP diet = 1.07% limestone and 0.61% monocalcium P (21% P) to provide a total content of 0.56% Ca and 0.24 STTD P % in the diet. LP diet = 0.99% limestone and 0.24% monocalcium P (21% P) to provide a total content of 0.46% Ca and 0.17 STTD P % in the diet.
[4] See Table 1, footnotes 4-8, for treatment details.

Table 3. Effects of feeding finishing pig diets differing in Ca:P, phytase addition, and vitamin D sources on growth performance, weight variation, serum 25(OH)D_3, carcass characteristics, economics, and bone characteristics[1]

	Treatments							
	HP[2]	LP[3]	HP+phytase[4]	HP+25(OH)D_3[5]				
STTD P:	115% NRC	80% NRC	115% NRC	115% NRC				
Ca:P:	1.25:1	1.25:1	1.1:1	1.1:1				
Phytase, FYT/kg:	0	0	600	600		*P=*[6]		
Item Vitamin D, IU/kg:	1,300	1,300	1,300	300 + 1,000 IU from 25(OH)D_3	SEM	P level	Vit. D	Ca:P
BW, lb								
d 0	71.7	71.8	71.6	71.7	1.35	0.714	0.714	0.794
d 29	127.3	125.2	126.9	127.1	1.45	0.009	0.736	0.596
d 57	182.5	176.9	181.5	181.2	1.64	<0.001	0.776	0.392
d 86	238.9	231.5	237.7	236.8	1.97	<0.001	0.521	0.421
d 114	292.5	284.0	290.4	289.2	2.58	0.001	0.627	0.396
Grower period, (d 0 to 29)								
ADG, lb	1.94	1.85	1.93	1.92	0.022	<0.001	0.660	0.349
ADFI, lb	4.65	4.51	4.57	4.51	0.089	0.001	0.199	0.059
F/G	2.39	2.44	2.37	2.35	0.028	0.009	0.267	0.224
Finisher period, (d 29 to 57)								
ADG, lb	2.01	1.93	1.99	1.97	0.047	0.038	0.658	0.506
ADFI, lb	5.99	5.80	5.86	5.80	0.086	0.016	0.441	0.083
F/G	2.98	3.01	2.96	2.95	0.042	0.385	0.890	0.505
Overall, (d 0 to 114)								
ADG, lb	1.98	1.89	1.96	1.94	0.018	<0.001	0.526	0.264
ADFI, lb	5.29	5.13	5.19	5.13	0.068	<0.001	0.177	0.020
F/G	2.68	2.72	2.65	2.64	0.026	0.026	0.428	0.193
CV, %[7]								
d 0	15.1	15.4	15.4	14.6	0.50	0.647	0.256	0.652
d 99	9.4	9.3	9.6	9.5	0.31	0.814	0.723	0.676
25(OH)D_3, ng/mL[8]								
d 0	23.8	22.2	23.8	23.3	1.32	0.368	0.756	0.996
d 50	61.1	50.2	53.9	70.2	3.43	0.020	0.001	0.123
d 99	54.5	48.4	55.1	65.2	4.48	0.331	0.109	0.926
Carcass characteristics								
HCW, lb	214.9	209.1	213.9	214.6	1.96	0.001	0.709	0.551
Yield, %	73.0	72.8	73.1	73.0	0.37	0.630	0.815	0.807
Backfat, in.[9]	0.62	0.64	0.64	0.64	0.009	0.092	0.961	0.064
Loin depth, in.[9]	2.58	2.55	2.56	2.59	0.029	0.127	0.264	0.363
Lean, %[9]	57.1	56.7	56.7	56.8	0.15	0.044	0.502	0.054
Total removals, %	6.7	7.0	6.7	8.5	1.36	0.624	0.624	0.624

continued

Table 3. Effects of feeding finishing pig diets differing in Ca:P, phytase addition, and vitamin D sources on growth performance, weight variation, serum 25(OH)D_3, carcass characteristics, economics, and bone characteristics[1]

	Treatments							
	HP[2]	LP[3]	HP+phytase[4]	HP+25(OH)D_3[5]				
STTD P:	115% NRC	80% NRC	115% NRC	115% NRC				
Ca:P:	1.25:1	1.25:1	1.1:1	1.1:1				
Phytase, FYT/kg:	0	0	600	600		*P*=[6]		
Item Vitamin D, IU/kg:	1,300	1,300	1,300	300 + 1,000 IU from 25(OH)D_3	SEM	P level	Vit. D	Ca:P
Economics, $/pig marketed								
Low ingredients prices[10]								
Feed cost	48.97	47.25	47.69	46.94	0.667	<0.001	0.109	0.007
Feed cost/lb gain[11]	0.227	0.228	0.224	0.223	0.0023	0.414	0.778	0.064
Revenue[12]	93.04	89.06	91.91	90.85	1.410	0.001	0.387	0.346
IOFC[13]	44.09	41.82	44.25	43.79	1.136	0.019	0.629	0.865
High ingredients prices[14]								
Feed cost	80.55	78.05	78.68	77.33	1.106	0.002	0.088	0.019
Feed cost/lb gain[11]	0.373	0.376	0.369	0.368	0.0038	0.145	0.626	0.161
Revenue[12]	138.77	132.83	137.09	135.51	2.103	0.001	0.387	0.346
IOFC[13]	58.26	54.83	58.45	57.95	1.613	0.014	0.719	0.888
Bone analysis								
Bone ash, g	9.99	8.47	8.97	9.22	0.219	<0.001	0.396	<0.001
Bone ash, %[15]	58.9	58.3	58.9	59.7	0.96	0.558	0.422	0.994
Breaking strength, lb[16]	634	502	537	550	25.5	<0.001	0.701	0.005

[1] A total of 2,160 pigs (initial BW of 71.8 lb ± 1.36 lb) were used in two groups with 27 pigs per pen and 20 replicates per treatment. Treatments were assigned in a randomized complete block design to compare the impact on pigs fed diets differing in Ca:P and added phytase (HiPhorius, DSM Nutritional Products, Parsippany, NJ) or phytase and 25(OH)D_3 (Hy-D, DSM Nutritional Products, Parsippany, NJ) 25 mcg 25(OH)D_3 estimated to provide 1,000 IU/kg vitamin D_3 equivalency) on growth performance, serum 25(OH)D_3, and bone characteristics.

[2] High phosphorus diet (HP) contained 1,300 IU vitamin D_3/kg diet in grower stepped-down to 650 IU in last phase, 1.25:1 analyzable Ca-to-analyzable P with STTD P at 115% of NRC 2012 requirement (0.36%, 0.31%, 0.28%, and 0.24% STTD P in phase 1, phase 2, phase 3, and phase 4, respectively) without phytase.

[3] Low phosphorus diet (LP) contained 1,300 IU vitamin D_3/kg diet in grower stepped-down to 650 IU in last phase, 1.25:1 analyzable Ca-to-analyzable P with STTD P at 80% of NRC 2012 requirement (0.25%, 0.22%, 0.19%, and 0.17% in phase 1, phase 2, phase 3, and phase 4, respectively) without phytase.

[4] High phosphorus diet with phytase (HP+phytase) contained 1,300 IU vitamin D_3/kg diet in grower stepped-down to 650 IU in last phase, 1.1:1 analyzable Ca-to-analyzable P with STTD P at 115% of NRC 2012 requirement (0.36%, 0.31%, 0.28%, and 0.24% STTD P in phase 1, phase 2, phase 3, and phase 4, respectively) using 0.125% STTD P from 600 FYT/kg HiPhorius.

[5] High phosphorus diet with 25(OH)D_3 (HP+25(OH)D_3) contained 1,000 IU 25(OH)D_3 + 300 IU vitamin D_3/kg diet in grower stepped-down to 500 IU 25(OH)D_3 + 150 vitamin D_3 in last phase, 1.1:1 analyzable Ca-to-analyzable P with STTD P at 115% NRC 2012 requirement (0.36%, 0.31%, 0.28%, and 0.24% STTD P in phase 1, phase 2, phase 3, and phase 4, respectively) using 0.125% STTD P from 600 FYT/kg HiPhorius.

[6] Contrast coefficients were used to compare the effect of STTD P level (HP vs. LP), vitamin D_3 source (HP+phytase vs. HP+25(OH)D_3), and Ca:P (HP vs. HP+phytase).

[7] Pigs were weighed individually to calculate variation of final BW.

[8] A sample of blood was taken from 1 pig per pen at three different times during the trial by jugular venipuncture. Blood samples were spun down to obtain serum and sent to Heartland Assays (Ames, IA, to determine serum levels of 25(OH)D_3.

[9] Adjusted using HCW as covariate.

[10] Market price for the low revenue calculation: corn = $3.00/bushel ($107/ton); soybean meal = $300/ton; L-Lys HCl = $0.65/lb; DL-Met = $1.70/lb; Thr Pro = $0.80/lb; L-Trp = $3.00; L-Val = $2.50/lb; HiPhorius = $8.16/lb; VTM D_3 = $1.89/lb; and VTM 25(OH)$D_3$ = $2.10/lb.

[11] Feed cost/lb gain = total feed cost per pig divided by total gain per pig.

[12] Revenue = (total gain × carcass yield) × carcass price.

[13] Income over feed cost = revenue – feed cost.

[14] Market price for the high revenue calculation: corn = $6.00/bushel ($214/ton); soybean meal = $400/ton; L-Lys HCl = $0.80/lb; DL-Met = $2.50/lb; Thr Pro = $0.80/lb; L-Trp = $5.00; L-Val = $4.00/lb; HiPhorius = $8.16/lb; VTM D_3 = $1.89/lb; and VTM 25(OH)$D_3$ = $2.10/lb.

[15] One pig per pen (20 pens per treatment) was sent to JBS packing plant (Worthington, MN) and the right 3rd metacarpals were collected to determine bone ash weight and percentage bone ash. After cleaning, bones were placed in Soxhlet extractors containing petroleum ether for 7 days as a means of removing water and fat. Bones were then dried at 221°F (105°C)for 7 days, and then ashed in a muffle furnace at 1,112°F (600°C) for 24 h.

[16] Bone breaking strength is reported as the maximum compressive load on each bone with an Instron (Instron 5569, NV Lab, Norwood, MA).