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

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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 Cartagena³

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 NRC⁴ 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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² Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.
³ Department of Statistics, College of Arts and Sciences, Kansas State University.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service
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.

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. Digestibility coefficients for P were obtained from NRC and the digestibility coefficients for Ca were obtained from the literature. 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 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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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.

*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.*
Table 1. Composition of experimental diets, phase 1 (as-fed basis)\(^{1,2}\)

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

\(^{1}\)Source:
\(^{2}\)Inorganic P
\(^{3}\)Phytase
\(^{4}\)Corn DDGS = dry distillers grains with solubles
Table 1. Composition of experimental diets, phase 1 (as-fed basis)\(^1,2\)

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>Source: Inorganic P</th>
<th>Phytase(^3)</th>
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<th>Phytase (^3)</th>
<th>Phytase (^3)</th>
<th>Phytase (^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Release: None</td>
<td>CaP</td>
<td>CaPAA</td>
<td>CaPAA + half NE</td>
<td>CaPAA + full NE</td>
<td>None</td>
</tr>
</tbody>
</table>

**Calculated analysis**

**SID\(^4\) amino acids**

- Lysine, %
  - None: 1.04
  - CaP: 1.04
  - CaPAA: 1.04
  - CaPAA + half NE: 1.04
  - CaPAA + full NE: 1.04
  - None: 1.04

- Isoleucine:lysine
  - None: 62
  - CaP: 62
  - CaPAA: 63
  - CaPAA + half NE: 63
  - CaPAA + full NE: 63
  - None: 62

- Leucine:lysine
  - None: 145
  - CaP: 145
  - CaPAA: 145
  - CaPAA + half NE: 145
  - CaPAA + full NE: 145
  - None: 144

- Methionine:lysine
  - None: 31
  - CaP: 30
  - CaPAA: 30
  - CaPAA + half NE: 30
  - CaPAA + full NE: 30
  - None: 31

- Methionine and cysteine:lysine
  - None: 56
  - CaP: 56
  - CaPAA: 56
  - CaPAA + half NE: 56
  - CaPAA + full NE: 56
  - None: 56

- Threonine:lysine
  - None: 62
  - CaP: 62
  - CaPAA: 62
  - CaPAA + half NE: 62
  - CaPAA + full NE: 62
  - None: 62

- Tryptophan:lysine
  - None: 18.6
  - CaP: 18.6
  - CaPAA: 18.5
  - CaPAA + half NE: 18.5
  - CaPAA + full NE: 18.5
  - None: 18.6

- Valine:lysine
  - None: 70
  - CaP: 70
  - CaPAA: 70
  - CaPAA + half NE: 70
  - CaPAA + full NE: 70
  - None: 70

- Histidine:lysine
  - None: 42
  - CaP: 42
  - CaPAA: 42
  - CaPAA + half NE: 42
  - CaPAA + full NE: 42
  - None: 42

**Total lysine, %**

- None: 1.18
  - CaP: 1.18
  - CaPAA: 1.16
  - CaPAA + half NE: 1.16
  - CaPAA + full NE: 1.16
  - None: 1.18

**Metabolizable energy, kcal/lb**

- None: 1,530
  - CaP: 1,531
  - CaPAA: 1,530
  - CaPAA + half NE: 1,531
  - CaPAA + full NE: 1,531
  - None: 1,530

**Net energy, kcal/lb**

- None: 1,152
  - CaP: 1,152
  - CaPAA: 1,152
  - CaPAA + half NE: 1,152
  - CaPAA + full NE: 1,152
  - None: 1,152

**SID lysine:NE, g/Mcal**

- None: 4.09
  - CaP: 4.09
  - CaPAA: 4.10
  - CaPAA + half NE: 4.09
  - CaPAA + full NE: 4.10
  - None: 4.09

**Crude protein, %**

- None: 19.0
  - CaP: 19.1
  - CaPAA: 19.0
  - CaPAA + half NE: 19.0
  - CaPAA + full NE: 19.0
  - None: 19.0

**Calcium, %**

- None: 0.68
  - CaP: 0.57
  - CaPAA: 0.57
  - CaPAA + half NE: 0.56
  - CaPAA + full NE: 0.57
  - None: 0.68

**STTD Ca, %**

- None: 0.53
  - CaP: 0.54
  - CaPAA: 0.54
  - CaPAA + half NE: 0.53
  - CaPAA + full NE: 0.54
  - None: 0.53

**Phosphorus, %**

- None: 0.57
  - CaP: 0.41
  - CaPAA: 0.41
  - CaPAA + half NE: 0.41
  - CaPAA + full NE: 0.41
  - None: 0.57

**STTD P, %**

- None: 0.33
  - CaP: 0.34
  - CaPAA: 0.33
  - CaPAA + half NE: 0.33
  - CaPAA + full NE: 0.34
  - None: 0.33

**Available phosphorus, %**

- None: 0.29
  - CaP: 0.29
  - CaPAA: 0.29
  - CaPAA + half NE: 0.29
  - CaPAA + full NE: 0.29
  - None: 0.29

**Calcium:phosphorus**

- None: 1.18
  - CaP: 1.38
  - CaPAA: 1.38
  - CaPAA + half NE: 1.35
  - CaPAA + full NE: 1.37
  - None: 1.19

**STTD Ca:STTD P**

- None: 1.60
  - CaP: 1.60
  - CaPAA: 1.60
  - CaPAA + half NE: 1.60
  - CaPAA + full NE: 1.60
  - None: 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)\textsuperscript{1,2}

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

continued
Table 2. Composition of experimental diets, phase 2 (as-fed basis)\textsuperscript{1,2}

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

\textsuperscript{1}Diets were fed for 26 d from approximately 113 to 160 lb.

\textsuperscript{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).

\textsuperscript{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.

\textsuperscript{4}DDGS = dried distillers grains with solubles.

\textsuperscript{5}Standardized ileal digestibility.

\textsuperscript{6}Standardized total tract digestibility of calcium.

\textsuperscript{7}Standardized total tract digestibility of phosphorus.
Swine Day 2019

Table 3. Effects of different nutrient release values of Ronozyme HiPhos 2500 phytase on pig growth performance and economics¹

<table>
<thead>
<tr>
<th>Ingredient, % Release</th>
<th>Source: Inorganic P²</th>
<th>Phytase³,⁴</th>
<th>Probability, P &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
<td>CaP</td>
<td>CaPAA + half NE</td>
</tr>
<tr>
<td>Body weight, lb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d 0</td>
<td>62.9</td>
<td>62.8</td>
<td>62.9</td>
</tr>
<tr>
<td>d 55</td>
<td>159.7</td>
<td>160.7</td>
<td>159.8</td>
</tr>
<tr>
<td>Overall (d 0 to 55)⁵</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>ADG, lb</td>
<td>1.83</td>
<td>1.84</td>
<td>1.83</td>
</tr>
<tr>
<td>ADFI, lb</td>
<td>3.69</td>
<td>3.79</td>
<td>3.69</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td>2.02&lt;sub&gt;ab&lt;/sub&gt;</td>
<td>2.06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.02&lt;sub&gt;ab&lt;/sub&gt;</td>
</tr>
<tr>
<td>Removed, %</td>
<td>1.3</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>1.3</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Economics

<table>
<thead>
<tr>
<th></th>
<th>Gain/pig, lb</th>
<th>Feed cost/pig, $</th>
<th>Feed cost/lb gain, $</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>96.8</td>
<td>18.87</td>
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<tr>
<td></td>
<td>97.9</td>
<td>18.78</td>
<td>0.192</td>
</tr>
<tr>
<td></td>
<td>96.9</td>
<td>18.36</td>
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<tr>
<td></td>
<td>95.6</td>
<td>18.13</td>
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<tr>
<td></td>
<td>96.3</td>
<td>18.43</td>
<td>0.191</td>
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<tr>
<td></td>
<td>97.4</td>
<td>18.80</td>
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<td></td>
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<td>0.0018</td>
</tr>
<tr>
<td></td>
<td>0.703</td>
<td></td>
<td>0.201</td>
</tr>
</tbody>
</table>

¹A 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.

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

³Treatments 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).

⁴Ronozyme 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.

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

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

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