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Economic Model for Optimum Standardized Total Tract Digestible Phosphorus for Finishing Pigs

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Economic Model for Optimum Standardized Total Tract Digestible Phosphorus for Finishing Pigs

Abstract

An adequate supply of dietary phosphorus (P) is important for pig growth performance and bone mineralization. However, P represents the third most expensive nutrient in swine diets after energy and protein and can greatly affect diet cost. Therefore, the objective of this project was to develop a tool to compare current dietary standardized total tract digestible (STTD) P concentrations to suggested values that yield maximum growth performance while accounting for different financial scenarios. The phosphorus economic tool is a Microsoft Excel-based model that evaluates the user's current dietary STTD P concentrations for a specific production system and market conditions. The tool takes into consideration whether the system is marketing pigs on a fixed time or fixed weight basis. Moreover, the user has the option of an imperial or metric version, as well as the evaluation using two different energy systems: metabolizable energy and net energy. Data from Vier et al. have described the dose response curve to increasing STTD P for late nursery and finishing pigs under commercial conditions. Based on these data, regression equations were developed to predict the STTD P requirement, as a percentage of the diet, for maximum growth rate according to the energy content of the user's diets. For model calculations, non-linear regression equations for average daily gain and feed efficiency are used. The tool calculates profitability indicators utilizing live or carcass weights. For profitability calculations on a carcass basis, a regression equation was developed to account for the effect of STTD P on carcass yield. This tool provides a means for the users to compare their current STTD P concentrations to levels required to achieve maximum growth performance, while considering the financial implications under dynamic productive and economic situations. The model can be accessed at www.ksuswine.org or at the open science framework data repository.

Cover Page Footnote

Appreciation is expressed to Genus PIC for technical assistance.

Authors

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Economic Model for Optimum Standardized Total Tract Digestible Phosphorus for Finishing Pigs[1]

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Summary

An adequate supply of dietary phosphorus (P) is important for pig growth performance and bone mineralization. However, P represents the third most expensive nutrient in swine diets after energy and protein and can greatly affect diet cost. Therefore, the objective of this project was to develop a tool to compare current dietary standardized total tract digestible (STTD) P concentrations to suggested values that yield maximum growth performance while accounting for different financial scenarios. The phosphorus economic tool is a Microsoft Excel-based model that evaluates the user's current dietary STTD P concentrations for a specific production system and market conditions. The tool takes into consideration whether the system is marketing pigs on a fixed time or fixed weight basis. Moreover, the user has the option of an imperial or metric version, as well as the evaluation using two different energy systems: metabolizable energy and net energy. Data from Vier et al.[4] have described the dose response curve to increasing STTD P for late nursery and finishing pigs under commercial conditions. Based on these data, regression equations were developed to predict the STTD P requirement, as a percentage of the diet, for maximum growth rate according to the energy content of the user's diets. For model calculations, non-linear regression equations for average daily gain and feed efficiency are used. The tool calculates profitability indicators utilizing live or carcass weights. For profitability calculations on a carcass basis, a regression equation was developed to account for the effect of STTD P on carcass yield. This tool provides a means for the users to compare their current STTD P concentrations to levels required to achieve maximum growth performance, while considering the financial implications under dynamic productive and economic situations. The model can be accessed at www.ksuswine.org or at the open science framework data repository.

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[1] Appreciation is expressed to Genus PIC for technical assistance.

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[4] Vier, C. M., S. S. Dritz, F. Wu, M. D. Tokach, J. M. DeRouchey, R. D. Goodband, M. A. D. Gonçalves, U. A. D. Orlando, and J. C. Woodworth. 2019. Effects of standardized total tract digestible phosphorus on growth performance of 11- to 23-kg pigs fed diets with or without phytase. J. Anim. Sci. doi:10.1093/jas/skz255.

Introduction

An adequate supply of dietary phosphorus (P) is important for pig growth performance and bone mineralization. It is well established that after the skeleton, the greatest body reserve of P is muscle tissue, with trace amounts found in the adipose tissue.[5] Moreover, the greater the ratio of lean tissue growth, the greater the demand for P to support this growth.[6] Therefore, genetic improvements towards increased pig performance and lean tissue growth over time may result in greater P requirements than in the past. A recent study conducted in a commercial setting has demonstrated that the standardized total tract digestible (STTD) P requirement of a modern genotype is greater than the NRC[7] estimates.[8] This study resulted in the development of non-linear regression equations to predict growth rate, feed efficiency, and carcass yield according to dietary STTD P concentration.

It is important to note that after energy and protein, P represents the third most expensive nutrient in swine diets. Therefore, P concentration can impact dietary cost. Also due to the nonlinear nature of the response, the dietary STTD P to support maximal growth will not always result in maximal profitability. The objective of this study was to develop a tool to compare current dietary STTD P concentrations to recommended values that yield maximum growth performance while accounting for financial implications over different scenarios.

Procedures

Model Description

The phosphorus economic tool is a Microsoft Excel-based model and is intended to be used by swine nutritionists. This tool provides a method to evaluate current dietary STTD P concentrations for a specific production system and market conditions. The tool takes into consideration whether the system is marketing pigs on a fixed time (where increased gain is important) or fixed weight basis (where gain is not valued because days are adequate to reach the desired market weight). Moreover, the user has the option of an imperial or metric version, as well as two different energy systems: metabolizable energy (ME) or net energy (NE). The P economic tool is divided into 3 sections: 1) user inputs, with economic and dietary criteria; 2) background model calculations for growth performance, carcass yield predictions, and profitability indexes; and 3) model outputs with recommended STTD P concentration for maximal growth, percentage of maximal growth performance for the current STTD P concentrations, and profitability indexes that contrast the current and estimated STTD P for maximal growth.

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[5] Nielsen, A.J., 1973. Anatomical and chemical composition of Danish Landrace pigs slaughtered at 90 kilograms live weight in relation to litter, sex and feed composition. J. Anim. Sci. 36(3):476-483. doi: 10.2527/jas1973.363476x.

[6] Jongbloed, A. W. 1987. Phosphorus in the feeding of swine: Effect of diet on the absorption and retention of phosphorus by growing pigs. Drukkeri, Deboer, Lelystad, The Netherlands.

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

[8] 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. Anim. Prod. Sci. 57:2424. doi:10.1071/ANv57n12Ab071.

User Inputs

The user has the option to choose either the ME or NE basis according to the energy system used in the production system. Once the energy basis is defined, the user is required to enter the following inputs for calculation of growth performance and economic criteria: pork carcass price ($/lb or $/kg), facility cost ($/pig/d), and the current carcass yield (%). Also, the user is required to select the economic evaluation criteria (live or carcass basis) and the number of dietary phases (the model allows the selection of 2 to 6 phases).

After defining the number of dietary phases, the user is required to enter the body weight (BW) ranges within each phase, along with the energy concentration of each diet (kcal/lb or kcal/kg). Then, the user enters the current dietary STTD P (%) concentrations for each dietary phase and the associated diet costs. The model will then calculate the STTD P concentration to achieve maximum growth based on the BW ranges and the specified energy content of the diets. The user is required to reformulate their diets with the STTD P concentrations suggested by the model and subsequently input the associated dietary costs. This step is required for the economic comparisons between the current STTD P levels provided by the user and the model recommended STTD P levels for maximum growth.

Calculations for Performance and Economics

Energy content of the diet can affect feed intake; therefore, this model calculates the STTD P estimates as a ratio relative to energy. Data from Vier et al.[9] have described the dose response curve to increasing STTD P for late nursery and finishing pigs under commercial conditions. Based on these data, two sets of equations were developed to estimate the STTD P to energy ratio as a function of BW:

$$\text{STTD P:NE, g/Mcal} = 0.0000472912571538526 \times (\text{BW, kg})^2 - 0.0143907820290028 \times (\text{BW, kg}) + 2.0275145422229$$

$$\text{STTD P:ME, g/Mcal} = 0.0000306269361758696 \times (\text{BW, kg})^2 - 0.00966436147205444 \times (\text{BW, kg}) + 1.47675067863161$$

The equation result is then multiplied by the input provided by the user (energy content of the diet) and converted from g/kg to predict the STTD P requirement, as a percentage of the diet, for maximum growth.

This model also utilizes average daily gain (ADG) and gain-to-feed (G:F) predicted equations developed by Vier et al.[8]

$$\text{ADG, g} = 651.36 + 531.33 \times (\text{STTD P as \% of NRC}) - 216.90 \times (\text{STTD P as \% of NRC})^2$$

$$\text{G:F, g/kg} = 338.34 + 108.98 \times (\text{STTD P as \% of NRC}) - 46.7864 \times (\text{STTD P as \% of NRC})^2$$

[9] Vier, C. M., S. S. Dritz, F. Wu, M. D. Tokach, J. M. DeRouchey, R. D. Goodband, M. A. D. Gonçalves, U. A. D. Orlando, and J. C. Woodworth. 2019. Effects of standardized total tract digestible phosphorus on growth performance of 11- to 23-kg pigs fed diets with or without phytase. J. Anim. Sci. (*Submitted*).

The phase duration is determined based on the initial and final BW and the calculated ADG (Table 1). The equations to predict ADG and G:F previously described were developed based on the overall finisher performance. Therefore, to calculate feed intake within each dietary phase, first a weighted average of the feed efficiency based on the phase duration is determined. This overall feed efficiency is then used with the KSU Feed Budget Calculator (access at ksuswine.org) to obtain the feed intake per dietary phase. In the fixed time scenario, the predicted final BW is included in the feed budget calculator to account for the extra feed intake.

Data developed from a reference population (PIC 337 growing finishing pigs, provided by U. A. D. Orlando, Genus PIC) are used to calculate the predicted carcass yield as influenced by changes in body weight. The predicted carcass yield is then adjusted based on the current carcass yield provided by the user. Furthermore, data from Vier et al.[8] suggested that carcass yield decreases as the concentration of STTD P increases. The estimated regression equation to predict carcass yield according to STTD P concentration is as follows:

$$\text{Carcass yield, \%} = 73.859 - 1.19192 \times (\text{STTD P as \% of NRC})$$

Therefore, the predicted carcass yield is adjusted based on a weighted average of the STTD P concentrations within dietary phases compared to a reference carcass yield (yield at 100% of NRC[7] STTD P estimates).

Fixed weight scenario calculations on a carcass basis are based on the user's predicted hot carcass weight. Due to the negative impact of STTD P on carcass yield, pigs would have to be fed to a heavier final BW in the fixed weight carcass basis situation to achieve a carcass weight similar to the user's input. Economic variables are then calculated based on the sum of costs across phases (Table 1).

Results and Discussion

Application of the Model

Two examples using this model are presented in Tables 2 and 3. In both examples, a six-phase feeding program (55 to 75, 75 to 111, 111 to 142, 142 to 185, 185 to 235, and 235 to 285 lb) was used. In example 1, diets were corn-soybean meal based, and the STTD P levels were achieved with monocalcium phosphate and added phytase. In the second example, the diets contained corn, soybean meal, and distillers dried grains with solubles (DDGS) with added phytase. Phases 1–4 had the inclusion of 25% DDGS, which was reduced to 22.5 in phase 4 and 10.0% in phases 5 and 6.

In both simulations, diets were formulated similar to NRC[8] STTD P estimates across dietary phases. Therefore, diets contained 0.32, 0.30, 0.28, 0.26, 0.23, and 0.21% STTD P in example 1. Diets in example 2 contained 0.33, 0.30, 0.27, 0.26, 0.23, and 0.21% STTD P. The NE system was used, with diets containing 1,113, 1,125, 1,138, 1,151, 1,163, and 1,167 kcal NE/lb of diet in example 1; and 1,100, 1,111, 1,126, 1,138, 1,156, and 1,163 kcal NE/lb of diet in example 2. The model estimated the STTD P concentration for maximal growth at 0.40, 0.37, 0.34, 0.31, 0.28, and 0.25% for phases 1 to 6, respectively.

For scenario building in example 1, the following inputs were used: 1) facility cost of $0.12/pig/d; 2) current carcass yield of 73.4%; 3) current diet costs of $181.93, $175.17, $167.76, $160.81, $156.04, and $153.56 per ton; and 4) diet costs of reformulated diets to STTD P for maximal growth of $183.29, $176.36, $168.87, $161.75, $156.89, and $154.18 per ton. For scenario building in example 2, the following inputs were used: 1) facility cost of $0.12/pig/d; 2) current carcass yield of 73.4%; 3) current diet costs of $173.65, $166.98, $160.96, $155.51, $153.23, and $152.78 per ton; and 4) diet costs of reformulated diets to STTD P for maximal growth of $174.03, $167.22, $161.15, $155.65, $153.32, and $152.92 per ton.

For the calculation of feed costs as previously presented, the pricing of the main ingredients used was: corn ($0.063/lb), soybean meal ($0.134/lb), DDGS ($0.060/lb), monocalcium phosphate ($0.226/lb), and phytase ($1.00/lb). To evaluate the model performance, carcass pricing was modified from moderate-priced ($0.65/lb) to high-priced ($0.82/lb).

Scenario Results

Approximately 98.9 and 99.7% of the maximum ADG and G:F can be captured using the current dietary STTD P concentrations in both examples. The economics at these STTD P concentrations were calculated and compared with the economics at STTD P concentrations needed to achieve maximum growth.

In example 1, increasing STTD P to greater than current levels resulted in an increase in total feed cost and total feed and facility cost both in a fixed weight and fixed time basis. Revenue per pig was the same on a fixed weight basis. In a fixed time scenario, due to improvements in growth performance, pigs fed increased STTD P reached a greater final BW compared to pigs fed diets with the current STTD P levels. Therefore, revenue per pig increased on a fixed time basis even with the negative impact of increasing STTD P on carcass yield.

Regardless of a moderate or high carcass price, it was not economical to increase the STTD P concentration to achieve maximal growth when the system is not constrained by space (time) limitations. Increasing STTD P above current levels resulted in a reduction in income over feed cost (IOFC) of $0.40 and income over feed and facility costs (IOFFC) of $0.31/pig. If the system is working on a fixed time, it is economical to increase the STTD P levels. The IOFC and IOFFC were $0.11 and $0.30/pig higher in a moderate and high carcass price situation, respectively.

In example 2, increasing STTD P to greater than current levels resulted in an increase in total feed cost and total feed and facility cost on a fixed time and fixed weight basis. Similar to example 1, revenue per pig was similar between the current diets and diets for maximum growth as there was time to raise pigs to the same desired carcass weight. Regardless of a moderate or high carcass price, IOFC and IOFFC were decreased with increasing STTD P when the system is on a space long situation. However, when the system is marketing on a fixed time or on a space short situation, increasing STTD P in diets containing corn, soybean meal, DDGS, and phytase resulted in improvements of $0.36/pig in IOFC and IOFFC in a scenario with moderate carcass price. Considering a scenario with high carcass price, increasing the STTD P resulted in an improvement of $0.57/pig in IOFC and IOFFC.

As illustrated, a key concept is understanding if pigs are marketed on a fixed time or fixed weight basis. A greater response to increasing STTD P is observed for growth rate compared to feed efficiency, and the fixed time or fixed weight situations change the relative value of the growth rate. Most pig production systems fluctuate between a fixed time and fixed weight scenario based on pig flow, growth seasonality, and pig space availability. Due to ingredient prices and differences in formulation, profit per pig was greater in example 2 compared to example 1 on a fixed time basis. However, it is worth noting that increasing STTD P to greater than current levels, to a concentration needed to achieve maximum growth in a fixed time basis, increased the income per pig in both examples. Due to the fixed constraint on the number of days available for growth, the growth rate value is greater in a fixed time scenario. However, in most fixed weight scenarios where adequate growing space is available, it will not be economical to increase the STTD P above the suggested NRC[8] dietary requirement. In this situation, pigs can stay in the barn at a fixed space cost per day until they reach the desired market weight. Therefore, the value of faster weight gain is lower than if on a fixed time basis.

Model Limitations

Currently, the model only estimates performance and economics according to STTD P levels for mixed gender pigs. The BW range used to develop the regression equations used in this model is 56- to 285-lb (26- to 130-kg). Model predictions outside this BW range are not recommended and should be used with caution. In addition, the model does not predict the STTD P level that yields the greatest profitability. It only compares the economics between the current STTD P levels and the STTD P levels needed for maximum growth.

Summary

The model described herein is intended to be used by swine nutritionists. This tool provides a method to evaluate current dietary STTD P concentrations for a specific production system and market conditions. It can be used to compare current dietary STTD P concentrations to recommended values that yield maximum growth performance while accounting for financial implications over different scenarios. To evaluate the performance of the model, two examples are presented considering different dietary formulations and different economic scenarios created by modifying carcass pricing in fixed time and fixed weight situations.

Table 1. Input equations used in model development

Indicator[1]	Calculation
Phase duration,[2,3] d (fixed weight live basis)	= [(Final BW, lb – Initial BW, lb)/2.2046]/(calculated ADG, g/1000)
Gain per phase, lb	= (Calculated ADG, g/1000) × (Phase duration, d) × 2.2046
Calculated HCW,[4] lb	= (∑ gain per phase, lb + Initial BW, lb) × (Predicted carcass yield, %/100)
Feed cost per phase, $/pig	= Feed budget by phase, lb/pig × (diet cost, $/ton)/2000
Feed and facility cost per phase, $/pig	= (Feed cost per phase, $/pig) + (Phase duration, d × facility cost, $/pig/d)
Revenue per pig, $/pig (live basis)	= (∑ gain per phase, lb + Initial BW, lb) × Live price, $/lb
Revenue per pig, $/pig (carcass basis)	= (Calculated HCW, lb) × (Carcass price, $/lb)
Income over feed cost, $/pig	= (Revenue per pig, $/pig) - (∑ feed cost per phase, $/pig)
Income over feed and facility cost, $/pig	= (Revenue per pig, $/pig) - (∑ feed and facility cost per phase, $/pig)

[1]BW = body weight. ADG = average daily gain. HCW = hot carcass weight.
[2]Calculation of phase duration for fixed time is based on user predicted duration in each phase.
[3]Final BW for fixed weight carcass basis = (Calculated HCW for current performance, lb) × (Predicted carcass yield, %/100)
[4]Calculation of HCW for fixed weight is based on user predicted HCW.

Table 2. Overall growth performance and economics of user-defined STTD P levels compared with model recommended STTD P levels for maximal growth in a six-phase feeding program with varying pig carcass pricing on a fixed time and fixed weight marketing basis: Example 1[1]

	Carcass price, $/lb					
	0.65			0.82		
		Maximum growth			Maximum growth	
Item[2]	Current	Fixed weight	Fixed time	Current	Fixed weight	Fixed time
Growth performance, % of maximum						
ADG	98.9	100	100	98.9	100	100
F/G	99.7	100	100	99.7	100	100
Economics, $/pig						
Total feed cost	46.42	46.82	47.04	46.42	46.82	47.04
Total feed and facility cost	59.39	59.70	60.01	59.39	59.70	60.01
Total revenue	135.71	135.71	136.43	171.78	171.78	172.69
IOFC	89.29	88.90	89.40	125.36	124.96	125.65
IOFFC	76.32	76.01	76.43	112.38	112.07	112.68

[1]Example 1 consisted of a six-phase feeding program (55 to 75, 75 to 111, 111 to 142, 142 to 185, 185 to 235, and 235 to 285 lb) with corn-soybean meal-based diets that contained the inclusion of monocalcium phosphate and phytase. Price of ingredients were: corn ($0.063/lb), soybean meal ($0.134/lb), monocalcium phosphate ($0.226/lb), and phytase ($1.00/lb).
[2]ADG = average daily gain. F/G = feed-to-gain ratio. IOFC = income over feed cost. IOFFC = income over feed and facility cost. STTD = standardized total tract digestible.

Table 3. Overall growth performance and economics of user-defined STTD P levels compared with model recommended STTD P levels for maximal growth in a six-phase feeding program with varying pig carcass pricing on a fixed time and fixed weight marketing basis: Example 2[1]

	Carcass price, $/lb					
	0.65			0.82		
		Maximum growth			Maximum growth	
Item[2]	Current	Fixed weight	Fixed time	Current	Fixed weight	Fixed time
Growth performance, % of maximum						
ADG	98.9	100	100	98.9	100	100
F/G	99.7	100	100	99.7	100	100
Economics, $/pig						
Total feed cost	45.23	45.39	45.63	45.23	45.39	45.63
Total feed and facility cost	58.20	58.27	58.61	58.20	58.27	58.61
Total revenue	135.72	135.72	136.49	171.78	171.78	172.75
IOFC	90.49	90.33	90.85	126.56	126.39	127.12
IOFFC	77.52	77.44	77.88	113.58	113.51	114.15

[1]Example 2 consisted of a six-phase feeding program (55 to 75, 75 to 111, 111 to 142, 142 to 185, 185 to 235, and 235 to 285 lb) with corn-soybean meal-DDGS-based diets that contained the inclusion of phytase. Price of ingredients were: corn ($0.063/lb), soybean meal ($0.134/lb), distillers dried grains with solubles ($0.060/lb), and phytase ($1.00/lb).

[2]ADG = average daily gain. F/G = feed-to-gain ratio. IOFC = income over feed cost. IOFFC = income over feed and facility cost. STTD = standardized total tract digestible.