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Using Caloric Efficiency to Estimate the Energy Value of Soybean Meal Relative to Corn and Its Effects on Growth Performance of Nursery Pigs

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Abstract

An experiment was conducted to estimate the energy value of soybean meal (SBM) relative to corn and determine the effects of increasing amounts of SBM in nursery pig diets. A total of 2,233 pigs (PIC 337 × 1050, Hendersonville, TN), initially 24.2 lb body weight (BW), were placed in 92 pens with 20 to 27 mixed gender pigs per pen. After weaning, pigs were fed common diets for 21 d and then assigned to treatments in a randomized complete block design with BW as the blocking factor. Treatment diets consisted of 21, 27, 33, or 39% SBM, obtained by changing the amount of feed-grade amino acids (AA) and corn, and were fed for 21 d. Soybean meal NE value used in diet formulation was 947 kcal/lb. There were 23 replicates per treatment. Pigs were weighed and feed disappearance measured to calculate average daily gain (ADG), average daily feed intake (ADFI), feed efficiency (F/G), and caloric efficiency (CE). Data were analyzed using the GLIMMIX procedure of SAS with block as a random effect and treatment as a fixed effect. Single degree-of-freedom contrasts were constructed to test the linear and quadratic effects of increasing SBM. There was a tendency (*P* = 0.090) for a quadratic response for ADG, with an improvement observed up to 33% SBM. There was a tendency (linear, *P* = 0.092) for a decrease in ADFI as dietary SBM increased. Pigs fed diets with increasing SBM had a tendency (quadratic, *P* = 0.066) for an improvement in F/G up to 33% SBM then returned to control values when 39% SBM was fed. There was an improvement (linear, *P* = 0.001; quadratic, *P* = 0.065) in CE with increasing SBM. Using CE as a means to estimate the energy content of SBM relative to corn, a value of 105.4% of corn energy or 1,277 kcal/lb NE was determined using all 4 data points. When removing the CE value of the 39% SBM treatment due to the quadratic tendency and just using the linear portion of the CE response, SBM was estimated to have 121.1% of corn energy or 1,468 kcal/lb NE. In conclusion, the results of the current study suggest that feeding SBM up to 33% improves ADG, F/G, and CE. The energy value of SBM is estimated between 105 and 121% of corn, much greater than the current suggested value of 78% of corn. This has important ramifications as it increases the value of SBM in diet formulation.

Keywords

caloric efficiency energy, soybean meal, swine

Cover Page Footnote

This research was supported by the United Soybean Board. Appreciation is expressed to New Horizon Farms (Pipestone, MN) for technical support and expertise in conducting the experiment.

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Using Caloric Efficiency to Estimate the Energy Value of Soybean Meal Relative to Corn and Its Effects on Growth Performance of Nursery Pigs[1]

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Summary

An experiment was conducted to estimate the energy value of soybean meal (SBM) relative to corn and determine the effects of increasing amounts of SBM in nursery pig diets. A total of 2,233 pigs (PIC 337 × 1050, Hendersonville, TN), initially 24.2 lb body weight (BW), were placed in 92 pens with 20 to 27 mixed gender pigs per pen. After weaning, pigs were fed common diets for 21 d and then assigned to treatments in a randomized complete block design with BW as the blocking factor. Treatment diets consisted of 21, 27, 33, or 39% SBM, obtained by changing the amount of feed-grade amino acids (AA) and corn, and were fed for 21 d. Soybean meal NE value used in diet formulation was 947 kcal/lb.[3] There were 23 replicates per treatment. Pigs were weighed and feed disappearance measured to calculate average daily gain (ADG), average daily feed intake (ADFI), feed efficiency (F/G), and caloric efficiency (CE). Data were analyzed using the GLIMMIX procedure of SAS with block as a random effect and treatment as a fixed effect. Single degree-of-freedom contrasts were constructed to test the linear and quadratic effects of increasing SBM. There was a tendency ($P = 0.090$) for a quadratic response for ADG, with an improvement observed up to 33% SBM. There was a tendency (linear, $P = 0.092$) for a decrease in ADFI as dietary SBM increased. Pigs fed diets with increasing SBM had a tendency (quadratic, $P = 0.066$) for an improvement in F/G up to 33% SBM then returned to control values when 39% SBM was fed. There was an improvement (linear, $P = 0.001$; quadratic, $P = 0.065$) in CE with increasing SBM. Using CE as a means to estimate the energy content of SBM relative to corn, a value of 105.4% of corn energy or 1,277 kcal/lb NE was determined using all 4 data points. When removing the CE value of the 39% SBM treatment due to the quadratic tendency and just using the linear portion of the CE response, SBM was estimated to have 121.1% of corn energy or 1,468 kcal/lb NE. In conclusion, the results

[1] This research was supported by the United Soybean Board. Appreciation is expressed to New Horizon Farms (Pipestone, MN) for technical support and expertise in conducting the experiment.

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

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

of the current study suggest that feeding SBM up to 33% improves ADG, F/G, and CE. The energy value of SBM is estimated between 105 and 121% of corn, much greater than the current suggested value of 78% of corn.[3] This has important ramifications as it increases the value of SBM in diet formulation.

Introduction

Soybean meal (SBM) is the primary plant-protein source for swine diets in the United States. The AA profile of SBM is well-balanced and complements the AA profile of grains such as corn and wheat, and these AA are highly digestible for pigs.[3] The energy content of SBM has been reported[3] as 1,642 kcal/lb digestible energy (DE) and 1,494 kcal/lb metabolizable energy (ME), which suggests that SBM has 105% and 97% of corn DE and ME values, respectively. Recently, swine nutritionists have adopted the net energy (NE) system due to the higher correlation to performance relative to DE or ME systems.[4] Using the NE system, SBM contains 947 kcal/lb, which is only 78% of corn energy values.[3] However, recent research shows improvements in feed efficiency of pigs fed increasing levels of SBM,[5,6] which suggests that the NRC[3] underestimates SBM NE.

Calorimetry trials to measure NE involve labor-intensive procedures that require highly specialized equipment. A practical approach to estimate energy values under field conditions has gained acceptance among swine nutritionists. Feeding increasing amounts of an ingredient and using the differences in CE to estimate the energy content of a test ingredient relative to a known ingredient, usually corn, has been reported by others and is sometimes termed productive energy.[7,8] As the inclusion of the ingredient increases, CE should not change if the energy estimate of the test ingredient is accurate. Increases or decreases in CE indicate over- or under-estimation of the energy content. This method may be more predictive of growth performance than systems based on DE or ME because energy estimation from CE calculations are done using growth assays under field conditions. The objective of this study was to determine differences in growth performance of pigs fed increasing amounts of SBM and, by using changes in CE, estimate SBM energy value relative to corn.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments.

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[4] Nitikanchana, S., S.S. Dritz, M.D. Tokach, J.M. DeRouchey, R.D. Goodband, and B.J. White. 2015. Regression analysis to predict growth performance from dietary net energy in growing-finishing pigs. J. Anim Sci. 93:2826-2839. doi:10.2527/jas.2015-9005.

[5] Moran, K., R.D. Boyd, C. Zier-Rush, P. Wilcock, N. Bajjalieh, and E. van Heugten. 2017. Effects of high inclusion of soybean meal and a phytase superdose on growth performance of weaned pigs housed under the rigors of commercial conditions. J. Anim. Sci. 95:5455-5465. doi:10.2527/jas2017.1789.

[6] Cemin, H.S., M.D. Tokach, A.M. Gaines, B.W. Ratliff, S.S. Dritz, J.C. Woodworth, J.M. DeRouchey, and R.D. Goodband. 2019. Effects of soybean meal level and distillers dried grains inclusion on growth performance of late nursery pigs. J. Anim. Sci. in print (Abstr.).

[7] Boyd, R.D., C.E. Zier-Rush, and C.E. Fralick. 2011. Practical method for productive energy (NEm+g) estimation of soybean meal for growing pigs. J. Anim. Sci. 89(E-Suppl. 2):89 (Abstr.).

[8] Gonçalves, M.A.D., S.S. Dritz, C.K. Jones, M.D. Tokach, J.M. DeRouchey, J.C. Woodworth, and R.D. Goodband. 2016. Fact sheets - Ingredient database management: Part I, overview and sampling procedures and Part II, energy. J. Swine Health Prod. 24:216-221.

The experiment was conducted at New Horizon Farms Nursery Research (Pipestone, MN). A total of 2,233 pigs (PIC; 337 × 1050; Hendersonville, TN) were placed in 92 pens with 20 to 27 mixed gender pigs each and used in a 21-d trial. Each pen (12 × 8 ft) had plastic slatted floors and was equipped with a six-hole stainless steel dry feeder and a pan waterer. Pigs were weaned at approximately 21 d of age, placed in pens based on initial body weight (BW), and fed common diets for approximately 21 d. On d 21, which was considered d 0 of the trial, pens of pigs were blocked by BW (initial BW = 24.2 lb) and allotted to 1 of 4 dietary treatments in a randomized complete block design. Pens of pigs were weighed and feed disappearance was measured weekly to determine ADG, ADFI, F/G, and CE.

Representative samples of corn, SBM, and distillers dried grains with solubles (DDGS) were submitted to the Agricultural Experimental Station Chemical Laboratories (University of Missouri-Columbia, Columbia, MO) for total AA analysis (method 982.30; AOAC International[9]) prior to diet formulation (Table 1). The total AA values for corn and SBM were multiplied by NRC[3] standardized ileal digestibility coefficients and these values used in diet formulation. Corn, SBM, and distillers dried grains were also analyzed (Ward Laboratories, Inc., Kearney, NE) for dry matter (method 935.29; AOAC International[9]), crude protein (method 990.03; AOAC International[9]), neutral detergent fiber (Ankom[10]), and ether extract (Ankom[11]). Other nutrient values were obtained from the NRC.[3]

The four dietary treatments consisted of increasing amounts of SBM (21, 27, 33, or 39% of the diet; Table 2) and there were 23 replicates per treatment. The increasing amounts of SBM were obtained by changing the addition of feed-grade AA and corn. Diets were formulated to meet or exceed the NRC[3] requirement estimates and were not balanced for NE. The NRC[3] NE value was used for SBM (947 kcal/lb) and feed-grade amino acids were assigned NE values of 1,529, 1,876, 1,334, 2,168, 1,962, and 2,162 kcal/lb for L-lysine HCl, DL-methionine, L-threonine, L-tryptophan, L-valine, and L-isoleucine, respectively. Diets contained 1,123, 1,105, 1,088, and 1,071 kcal/lb as SBM increased from 21 to 39% of the diet. Diets were formulated to a common analyzed Ca:analyzed P ratio and were provided at *ad libitum* and in mash form. At the conclusion of the experiment, the energy value of SBM relative to corn was estimated based on CE, which was obtained by multiplying ADFI by kcal of NE per lb of diet and dividing by ADG. In order to obtain an energy estimate, the energy value of SBM was adjusted for the slope of CE to be zero.

Representative diet samples were obtained from each treatment and stored at -20°C until analysis. Samples were analyzed (Ward Laboratories, Inc., Kearney, NE) for dry matter (method 935.29; AOAC International[9]), crude protein (method 990.03; AOAC International[9]), calcium (method 985.01; AOAC International[9]), phosphorus (method 985.01; AOAC International[9]), neutral detergent fiber (Ankom[10]), and ether extract (Ankom[11]).

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[9] AOAC International. 2006. Official methods of analysis AOAC International. 17th ed. AOAC Int., Gaithersburg, MD.

[10] Ankom Technology. 1998. Method for Determining Neutral Detergent Fiber, Ankom 200/220 Fiber Analyzer. Ankom Technology, Fairport, NY.

[11] Ankom Technology. 2004. Rapid Determination of Oil/Fat Utilizing High Temperature Solvent Extraction. ANKOM XT20 Fat Analyzer. Ankom Technology, Fairport, NY.

Data were analyzed as a randomized complete block design. Single degree-of-freedom contrasts were constructed to test the linear and quadratic effects of increasing SBM. Block was included as a random effect and treatment as a fixed effect. Pen was considered the experimental unit. Data were analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Institute Inc., Cary, NC). Results were considered significant at $P \le 0.05$ and a tendency at $0.05 < P \le 0.10$.

Results and Discussion

The analyzed AA profiles of corn, DDGS, and SBM were, in general, within the expected values (Table 1). Soybean meal and DDGS had a similar AA composition to NRC[3] values, whereas corn was slightly lower than NRC,[3] especially in Met and Leu. The chemical analysis of diets was consistent with formulated values (Table 2).

Pigs fed diets with increasing SBM had a tendency (quadratic, $P = 0.090$) for an improvement in ADG up to 33% followed by a decrease in ADG when 39% SBM was fed (Table 3). There was a tendency (linear, $P = 0.092$) for a decrease in ADFI as dietary SBM increased. The changes in ADG and ADFI resulted in a tendency (quadratic, $P = 0.066$) for an improvement in F/G up to 33% SBM. There was an improvement (linear, $P = 0.001$; quadratic, $P = 0.065$) in CE with increasing SBM.

In our study, there was an improvement in ADG when increasing SBM up to 33% of the diet; however, pigs fed 39% SBM had reduced ADG. The differences between treatments were relatively small and did not result in statistical differences in final BW. The reason for the negative impact of the highest SBM addition on ADG is unclear. Although the available literature generally does not agree with this finding, as most of the studies[5,6,12,13] find improvements or no change in ADG with increasing SBM, the current experiment evaluated higher SBM levels than most of the previous research. It could be hypothesized that the high level of crude protein (25.6%) in the diet with 39% SBM provided excess nitrogen which needs to be metabolized and excreted by the animal.[14] The excess nitrogen represents an energy cost that may ultimately translate to decreased growth performance; however, this was not evident with lower CP levels.

Improvements in feed efficiency with increasing SBM levels seem to be more consistently reported in the literature and agree with our findings. Energy is the most expensive component of any swine diet, thus it is critical to accurately determine the energy value of feed ingredients. Direct measurement of NE is a procedure that requires highly specialized equipment. Therefore, the estimation of the energy value of a test ingredient based on CE relative to a known ingredient such as corn is suggested as a practical approach, and is sometimes termed productive energy.[7,8] Other than the practical advantage, the estimates using CE are conducted under field conditions and may be more predictive of growth performance than other energy values. Our diets were

[12] Johnston, M.E., R.D. Boyd, C. Zier-Rush, and C.E. Fralick. 2010. Soybean meal level modifies the impact of high immune stress on growth and feed efficiency in pigs. J. Anim. Sci. 88(E-Suppl. 3):57-58. (Abstr.).

[13] Rocha, G.C., R.D. Boyd, J.A.S. Almeida, Y. Liu, T.M. Che, R.N. Dilger, and J.E. Pettigrew. 2013. Soybean meal level in diets for pigs challenged with porcine reproductive and respiratory syndrome (PRRS) virus. J. Anim. Sci. 92(E-Suppl. 2):31. (Abstr.).

[14] Van Milgen, J., and J.Y. Dourmad. 2015. Concept and application of ideal protein for pigs. J. Anim. Sci. Biotechnol. 6:15. doi:10.1186/s40104-015-0016-1.

formulated using the NRC[3] NE value for SBM and resulted in dietary NE of 1,123, 1,105, 1,088, and 1,071 kcal/lb as SBM increased from 21 to 39% of the diet. Thus, if NE of SBM provided by NRC[3] is correct, F/G should become worse as SBM level increases in the diet. The improvement in CE observed in the current study suggests that the NE value of SBM is underestimated. Our findings suggest that the energy value of SBM is 105.4% of corn energy or 1,277 kcal/lb NE. It is important to note that, while CE response was significantly linear ($P = 0.001$), there was also tendency ($P = 0.065$) for a quadratic response. Therefore, it could be hypothesized that the CE value of 39% SBM treatment should not be considered for the energy estimation because the assay should only include the linear portion of the response.[15] Removing the 39% SBM diet and using the linear portion of the dataset results in an energy estimate of 121.1% of corn energy or 1,468 kcal/lb NE. Both energy estimates, 105.4 or 121.1%, are significantly greater than the NRC[3] NE value.

The benefits of SBM on growth performance, especially for health-challenged pigs, have also been hypothesized to be driven by bioactive components such as isoflavones and saponins, which have anti-inflammatory, antioxidant, and anti-viral properties (Smith and Dilger[16]; Smith et al.[17]). However, the known available research is inconsistent regarding the effects of isoflavones on growth performance of pigs. Kuhn et al.[18] compared SBM and soy protein concentrate, an ingredient with markedly lower isoflavones relative to SBM, in a wean-to-finish study and observed higher plasma isoflavones in pigs fed SBM but no evidence for differences in growth performance. Greiner et al.[19,20] evaluated increasing levels of dietary isoflavones and observed improvements in performance of PRRS positive pigs, mostly during periods of peak viremia. Smith et al.[14] fed diets based on soy protein concentrate or enzyme-treated SBM supplemented or not with isoflavones and observed changes in activation of the adaptive immune system, although no impact on growth performance was observed.

Another important consideration is that the responses in performance could have been driven by underestimation of the requirements of amino acids. Our diets were formulated to meet the NRC[3] AA requirement estimates; nevertheless, if any of these estimates are not accurate, by increasing the inclusion of SBM we could have potentially corrected an AA deficiency. However, most of the AA ratios were much greater than those recommended by the NRC,[3] thus the authors believe the responses to SBM are unlikely to be driven by changes in AA ratios.

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[15] Littell, R.C., P.R. Henry, A.J. Lewis, and C.B. Ammerman. 1997. Estimation of relative bioavailability of nutrients using SAS procedures. J. Anim. Sci. 75:2672-2683. doi:10.2527/1997.75102672x.

[16] Smith, B.N., and R.N. Dilger. 2018. Immunomodulatory potential of dietary soybean-derived isoflavones and saponins in pigs. J. Anim. Sci. 96:1288-1304. doi:10.1093/jas/sky036.

[17] Smith, B.N., A. Morris, M.L. Oelschlager, J. Connor, and R.N. Dilger. 2019. Effects of dietary soy isoflavones and soy protein source on response of weanling pigs to porcine reproductive and respiratory syndrome viral infection. J. Anim. Sci. in print. doi:10.1093/jas/skz135.

[18] Kuhn, G., U. Hennig, C. Kalbe, C. Rehfeldt, M.Q. Ren, S. Moors, and G.H. Degen. 2004. Growth performance, carcass characteristics and bioavailability of isoflavones in pigs fed soy bean based diets. Arch. Anim. Nutr. 58:265-276. doi:10.1080/00039420412331273295.

[19] Greiner, L.L., T.S. Stahly, and T.J. Stable. 2001a. The effect of dietary soy daidzein on pig growth and viral replication during a viral challenge. J Anim. Sci. 79:3113-3119. doi:10.2527/2001.79123113x.

[20] Greiner, L.L., T.S. Stahly, and T.J. Stabel. 2001b. The effect of dietary soy genistein on pig growth and viral replication during a viral challenge. J. Anim. Sci. 79:1272-1279. doi:10.2527/2001.7951272x.

In conclusion, nursery pigs fed diets with increasing SBM tended to have improved performance up to 33% of the diet. The results of the current study suggest that the energy value of SBM may be estimated to range between 105 and 121% of corn energy, or 1,277 and 1,468 kcal/lb NE, which indicates that the NRC[3] potentially underestimates the SBM NE value. This has important ramifications as it increases the value of SBM in diet formulation. However, it is unclear if the benefit of SBM is entirely driven by energy or if other components, such as isoflavones, could be partially responsible for the response observed in this study.

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Table 1. Proximate and total amino acid analysis of corn, distillers dried grains with solubles (DDGS), and soybean meal (as-fed basis)[1]

Item, %	Corn	DDGS	Soybean meal
Dry matter	87.8	90.8	88.8
Crude protein	6.3	28.7	48.0
Neutral detergent fiber	7.0	27.9	5.4
Ether extract	3.6	8.8	1.1
Calcium	0.07	0.08	0.42
Phosphorus	0.23	0.88	0.64
Amino acids			
Alanine	0.45	1.86	2.06
Arginine	0.30	1.27	3.42
Aspartic acid	0.44	1.79	5.39
Cysteine	0.16	0.60	0.73
Glutamic acid	1.11	3.64	8.44
Glycine	0.26	1.11	2.00
Histidine	0.19	0.78	1.27
Isoleucine	0.24	1.09	2.33
Leucine	0.71	3.19	3.71
Lysine	0.25	1.08	3.09
Methionine	0.13	0.50	0.66
Phenylalanine	0.31	1.69	2.52
Proline	0.56	2.07	2.41
Serine	0.29	1.26	1.91
Threonine	0.23	1.10	1.81
Tryptophan	0.06	0.22	0.73
Tyrosine	0.18	1.03	1.66
Valine	0.31	1.45	2.44

[1]A representative sample of each ingredient was obtained, homogenized, and submitted to the Agricultural Experimental Station Chemical Laboratories (University of Missouri-Columbia, Columbia, MO) for amino acid analysis and Ward Laboratories (Kearney, NE) for proximate analysis prior to diet formulation.

Table 2. Composition of experimental diets (as-fed basis)

	Soybean meal, %			
Ingredient, %	21	27	33	39
Corn	60.07	54.68	49.21	43.70
Soybean meal	21.00	27.00	33.00	39.00
DDGS[1]	15.00	15.00	15.00	15.00
Calcium carbonate	1.08	1.08	1.08	1.08
Monocalcium phosphate, 21.5% P	0.65	0.55	0.50	0.40
Sodium chloride	0.50	0.50	0.50	0.50
L-Lysine HCl	0.643	0.456	0.255	0.053
DL-Methionine	0.225	0.170	0.110	0.045
L-Threonine	0.295	0.215	0.135	0.040
L-Tryptophan	0.095	0.060	0.020	---
L-Valine	0.225	0.115	---	---
L-Isoleucine	0.040	---	---	---
Vitamin trace-mineral premix[2]	0.150	0.150	0.150	0.150
Phytase[3]	0.050	0.050	0.050	0.050
Total	100.0	100.0	100.0	

continued

Table 2. Composition of experimental diets (as-fed basis)

	Soybean meal, %			
Ingredient, %	21	27	33	39
Calculated analysis				
SID[4] amino acids, %				
Lysine	1.30	1.30	1.30	1.30
Isoleucine:lysine	55	61	69	78
Leucine:lysine	112	124	137	149
Methionine:lysine	37	34	32	30
Methionine and cysteine:lysine	57	57	57	57
Threonine:lysine	65	65	65	65
Tryptophan:lysine	22.1	22.1	22.0	23.4
Valine:lysine	76	76	76	85
Histidine:lysine	33	37	42	47
Net energy,[5] kcal/lb	1,123	1,105	1,088	1,071
Crude protein, %	19.2	21.3	23.4	25.6
Neutral detergent fiber, %	11.9	11.7	11.5	11.3
Calcium, %	0.69	0.70	0.72	0.74
STTD P,[6] %	0.45	0.45	0.45	0.45
Analyzed values, %				
Dry matter	87.7	88.1	88.2	88.5
Crude protein	20.0	21.4	24.2	25.9
Neutral detergent fiber	9.2	9.8	9.8	9.3
Ether extract	2.9	3.0	2.8	2.6
Calcium	0.64	0.69	0.71	0.76
Phosphorus	0.55	0.50	0.53	0.54

[1]DDGS = distillers dried grains with solubles.
[2]Provided per lb of premix: 2,425,000 IU vitamin A; 607,000 IU vitamin D; 45,455 IU vitamin E; 758 mg vitamin K; 9.70 mg vitamin B12; 13,182 mg niacin; 6,970 mg pantothenic acid; 1,818 mg riboflavin; 31 mg biotin; 303 mg folic acid; 545 mg vitamin B6; 33.3 g Zn from zinc sulfate; 30.3 g Fe from ferrous sulfate; 12.1 g Mn from manganese oxide; 4.5 g Cu from copper sulfate; 0.23 g I from calcium iodate; and 0.09 g Se from sodium selenite.
[3]Optiphos 2000 (Huvepharma, Inc., Peachtree City, GA) provided 2,000 FTU per lb of diet.
[4]SID = standardized ileal digestible.
[5]Net energy values were obtained from the NRC (National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.).
[6]STTD P = standardized total tract digestible phosphorus.

Table 3. Effects of increasing soybean meal on growth performance and caloric efficiency of nursery pigs[1]

	Soybean meal, %					Probability, $P <$	
Item[2]	21	27	33	39	SEM	Linear	Quadratic
BW, lb							
d 0	24.2	24.2	24.2	24.2	0.329	0.894	0.993
d 21	49.1	49.1	49.3	48.5	0.606	0.263	0.180
d 0 to 21							
ADG, lb	1.18	1.18	1.20	1.16	0.016	0.207	0.090
ADFI, lb	1.82	1.81	1.80	1.77	0.026	0.092	0.579
F/G	1.54	1.53	1.50	1.53	0.012	0.361	0.066
CE, kcal/lb gain	1,725	1,695	1,634	1,643	13.01	0.001	0.065

[1]A total of 2,233 pigs (initially 24.2 lb) were used in a 21-d study with 19 to 27 pigs per pen and 23 replicates per treatment.
[2]BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio. CE = caloric efficiency.