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Modeling the Effects of Standardized Ileal Digestible Tryptophan:Lysine Ratio on Growth Performance of 65- to 275-lb Pigs

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Modeling the Effects of Standardized Ileal Digestible Tryptophan:Lysine Ratio on Growth Performance of 65- to 275-lb Pigs[1,2]

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Summary

The objective of this study was to model the effects of standardized ileal digestible (SID) Trp:Lys ratio on growth performance of 65- to 275-lb pigs. The present experiment, along with three previous experiments from Gonçalves et al. (2014)[6], were used in the analysis. For all studies, dietary treatments consisted of SID Trp:Lys ratios of 14.5, 16.5, 18.0, 19.5, 21.0, 22.5, and 24.5%. The experiments were 21 d in duration and used corn and soybean meal-based diets with 30% dried distillers grains with solubles formulated to be deficient in Lys at the end of each of the experiments. In the current experiment, a total of 975 gilts (337 × 1050; PIC, Hendersonville, TN) were used with initial BW of 234.1 ± 6.8 lb and final BW of 274.9 ± 10.4 (mean ± SD). Pens of pigs were blocked by weight and assigned to one of the seven dietary treatments in a randomized complete block design. There were 6 pens/treatment with 20 to 24 pigs per pen. For 235 to 275 lb-pigs, increasing SID Trp:Lys improved ADG (quadratic, $P < 0.022$), ADFI (linear, $P < 0.001$), and F/G (linear, $P < 0.001$). Data from all experiments were then combined for analysis using linear and non-linear mixed models with random effects of experiment and weight block nested within experiment allowing for heterogeneous variances. Competing models included broken-line linear (BLL), broken-line quadratic (BLQ), and quadratic polynomial (QP). In the combined analysis for ADG, QP was the best fitting model and estimated SID Trp:Lys requirement at 23.5% (95% CI: [22.7, 24.3%]). In the combined analysis for F/G, BLL and BLQ had comparable fit and estimated SID Trp:Lys requirements at 16.9% (95% CI: [16.0, 17.8%]) and 17.0%

[1] The authors thank Ajinomoto Heartland Inc., Chicago, IL, for providing feed-grade amino acids and for partial financial support.

[2] Appreciation is expressed to New Horizon Farms for use of pigs and facilities and to Richard Brobjorg, Scott Heidebrink, Larry Moulton, Marty Heintz, and Craig Steck for technical assistance.

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[6] Gonçalves, M. A. D., M. D. Tokach, S. S. Dritz, K. J. Touchette, N. M. Bello, J. M. DeRouchey, J. C. Woodworth, and R. D. Goodband. 2014. Effects of standardized ileal digestible tryptophan:lysine ratio on growth performance and economics of finishing pigs. Proc Kansas State University Swine Day, SRP1110. Agricultural Experiment Station and Cooperative Extension Service. Manhattan, Kansas. pp. 109-122.

(95% CI: [15.0, 18.9%]), respectively. Thus, the estimated mean requirements for SID Trp:Lys for 65- to 275-lb pigs ranged from 16.9% for optimum mean F/G to 23.5% for maximum mean ADG. Furthermore, 95% of the maximum estimated mean ADG was obtained by feeding 17.6% SID Trp:Lys and 98% of the maximum estimated mean ADG was obtained by feeding 19.8% SID Trp:Lys.

Key words: amino acid ratio, growth, tryptophan, finishing pig

Introduction
With the increasing usage of dried distillers grains with solubles (DDGS) and feed-grade AA in commercial swine diets during the last decade, tryptophan went from being the fourth limiting AA (Naatjes et al., 2014[7]) in corn and soybean meal-based diets to being the second or third limiting AA in diets with DDGS. Tryptophan plays a role in a wide range of functions besides protein synthesis, with one of the most important being the synthesis of serotonin, an important regulator of feed intake (Le Floc'h et al., 2011[8]).

The most practical approach for diet formulation is the expression of the standardized ileal digestible (SID) Trp requirement as a ratio to Lys (Trp:Lys). The NRC (2012) estimates the SID Trp:Lys requirement for finishing pigs from 65- to 275-lb at 17.4%. However, recent studies suggest requirement estimates for finishing pigs ranging from 16.5 to 23.6% SID Trp:Lys (Simongiovanni et al., 2012[9]; Salyer et al., 2013[10]). These studies indicate the requirement may be significantly higher than suggested by NRC (2012).

To accurately determine the SID Trp:Lys requirement, Lys must be limiting. Otherwise, the SID Trp:Lys requirement estimate will be underestimated. Additionally, the AA requirement estimation is likely to depend on the statistical model used and on the response variable selected. The current body of literature lacks a study where results were applied to a wide range of finishing pigs' BW and lacks use of best fitting statistical mixed models to estimate the requirement for the different response variables. Therefore, the objective of this study was to model the effects of SID Trp:Lys requirement for ADG and F/G in 65- to 275-lb pigs.

Procedures
The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. All studies were conducted at a commercial research-finishing barn in southwestern Minnesota. The barn was naturally ventilated and double-curtain-sided. Pens had completely slatted flooring and deep pits for manure

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[7] Naatjes, M., J. K. Htoo, K. Walter, K. H. Tölle, and A. Susenbeth. 2014. Effect of dietary tryptophan to lysine ratio on growth of young pigs fed wheat–barley or corn based diets. Liv. Sci. 163:102–109.
[8] Le Floc'h, N., W. Otten, and E. Merlot. 2011. Tryptophan metabolism, from nutrition to potential therapeutic applications. Amino Acids 41:1195–1205.
[9] Simongiovanni, A., E. Corrent, N. Le Floc'h, and J. van Milgen. 2012. Estimation of the tryptophan requirement in piglets by meta-analysis. Anim. 6:594–602.
[10] Salyer, J. A., M. D. Tokach, J. M. DeRouchey, S. S. Dritz, R. D. Goodband, and J. L. Nelssen. 2013. Effects of standardized ileal digestible tryptophan:lysine in diets containing 30% dried distillers grains with solubles on finishing pig performance and carcass traits. J. Anim. Sci. 91:3244–3252.

storage. Each pen (18 × 10 ft) was equipped with a 4-hole stainless steel dry self-feeder (Thorp Equipment, Thorp, WI) and a cup waterer. The facility was equipped with a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that delivered and recorded daily feed additions and diets as specified. Pigs had ad libitum access to feed and water.

Five representative samples of corn, soybean meal, and DDGS were collected each week for 5 wk and analyzed in duplicate for total amino acids and CP by Ajinomoto Heartland, Inc. (Chicago, IL). The values were then used in diet formulation. Other nutrients and SID amino acid digestibility coefficient values used for diet formulation were obtained from NRC (2012).

Growth performance for three of the four studies used to model the dose response to SID Trp:Lys ratio was previously described by Gonçalves et al. (2014)[11]. The fourth study used similar procedures but at a heavier BW range. A total of 975 gilts (337 × 1050; PIC, Hendersonville, TN) with initial BW of 234.1 ± 6.8 and final BW of 274.9 ± 10.4 lb (mean ± SD) were used in a 21-d growth study. At the beginning of the experiment, pigs were weighed in pens and pens were ranked by average BW and randomly assigned dietary treatments in a randomized complete block design based on average pen BW. There were six pens per treatment with 20 to 24 pigs per pen.

Two experimental corn and soybean meal–based diets with 30% DDGS were formulated (Table 1) to have either a 14.5 or 24.5% SID Trp:Lys ratio, then blended using the robotic feeding system to achieve intermediate SID Trp:Lys ratios. The SID Trp:Lys ratio was increased by adding crystalline L-Trp to the control diet at the expense of corn. The percentage of low and high SID Trp:Lys blended to create the treatment diets were 100:0, 80:20, 65:35, 50:50, 35:65, 20:80, and 0:100 to achieve 14.5, 16.5, 18.0, 19.5, 21.0, 22.5, and 24.5% SID Trp:Lys ratios, respectively. The NRC (2012) model was used to estimate the Lys requirement of pigs at the expected BW at the end of the experiment. The SID Lys as a percentage of the diet was reduced to ensure that lysine was the second limiting amino acid throughout the experiment based on a preliminary study conducted by Gonçalves et al. (2014)[12] in the same commercial research finishing complex. Diets were fed in meal form and were manufactured at the New Horizon Farms feed mill (Pipestone, MN).

Pens of pigs were weighed and feed disappearance measured at the beginning and on d 21 to determine ADG, ADFI, and F/G. The total grams of SID Trp intake based on formulated values was divided by total BW gain to calculate the g of SID Trp intake per kilogram of gain.

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[11] Gonçalves, M. A. D., M. D. Tokach, S. S. Dritz, K. J. Touchette, N. M. Bello, J. M. DeRouchey, J. C. Woodworth, and R. D. Goodband. 2014. Effects of standardized ileal digestible tryptophan:lysine ratio on growth performance and economics of finishing pigs. Proc. Kansas State University Swine Day, SRP1110. Agricultural Experiment Station and Cooperative Extension Service. Manhattan, Kansas. pp. 109-122.

[12] Gonçalves, M. A. D., M. D. Tokach, S. S. Dritz, K. J. Touchette, J. M. DeRouchey, J. C. Woodworth, and R. D. Goodband. 2014. Validating a dietary approach to determine amino acid: lysine ratios for pigs. Proc. Kansas State University Swine Day, SRP1110. Agricultural Experiment Station and Cooperative Extension Service. Manhattan, Kansas. pp. 83-100.

Diet samples were taken from six feeders per dietary treatment 3 d after the beginning and 3 d before the end of the experiment and stored at -20°C. Then CP and total amino acid analysis was conducted on composite samples from each treatment by Ajinomoto Heartland, Inc. Diet samples were also submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, crude fiber, ash, crude fat, Ca, and P.

For the experiment reported herein, responses measured at the pen level were analyzed using a general linear mixed model and linear and quadratic polynomial contrasts with coefficients adjusted for unequally spaced treatments. Responses were used to evaluate the dose response effect of increasing dietary SID Trp:Lys ratio on ADG, ADFI, F/G, BW, grams of SID Trp intake per day, and grams of SID Trp intake per kg of gain. Heterogeneous residual variances as a function of the response variables were fitted as needed. Model assumptions were checked and considered to be appropriately met. The experimental data were analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc., Cary, NC).

For the combined statistical analysis to characterize the dose response, the data from the three previously described experiments from Gonçalves et al. (2014)[13] along with the experiment reported herein were used in the analysis. Prior to fitting the dose-response estimation models on the combined data, a base model was fitted to estimate and assess variance components of weight block, weight block nested within experiment, and treatment by experiment interaction for each of the response variables. Subsequently, initial BW and initial BW squared were evaluated as covariates for each of the response variables. Linear and non-linear regression models adapted from Robbins et al. (2006)[14] were expanded to accommodate random effects and were fitted to ADG and F/G to further estimate SID Trp:Lys dose responses. Specifically, competing statistical models fitted to the data were: a broken-line linear ascending (BLL) model, a broken-line quadratic ascending (BLQ) model, and a quadratic polynomial (QP). Broken-line regression models were fitted using the NLMIXED procedures of SAS. The optimization technique used was the dual Quasi-Newton algorithm, as specified by default in the NLMIXED procedure. The 95% CI and the dose for optimum performance were calculated using inverse prediction strategy. Competing statistical models were compared using maximum-likelihood-based fit criteria, specifically the Bayesian information criteria (BIC). Results were considered significant at $P \le 0.05$ and a tendency at $P \le 0.10$.

Results and Discussion

The analyzed total amino acids, DM, CP, crude fiber, Ca, P, fat, and ash contents of experimental diets (Table 2) were reasonably consistent with formulated estimates. For 235- to 275 lb-pigs, increasing SID Trp:Lys improved ADG (quadratic, $P < 0.022$), ADFI (linear, $P < 0.001$), and F/G (linear, $P < 0.001$). Final BW and grams of SID Trp per kg gain increased linearly ($P < 0.003$) with increasing SID Trp:Lys ratio.

[13] Gonçalves, M. A. D., M. D. Tokach, S. S. Dritz, K. J. Touchette, N. M. Bello, J. M. DeRouchey, J. C. Woodworth, and R. D. Goodband. 2014. Effects of standardized ileal digestible tryptophan:lysine ratio on growth performance and economics of finishing pigs. Proc. Kansas State University Swine Day, SRP1110. Agricultural Experiment Station and Cooperative Extension Service. Manhattan, Kansas. pp. 109-122.

[14] Robbins, K. R., A. M. Saxton, and L. L. Southern. 2006. Estimation of nutrient requirements using broken-line regression analysis. J. Anim. Sci. 84: E155–E165.

For the combined analysis across all four experiments evaluating the ADG dose response curve, the QP was the best fitting model (BIC: 1655.4) whereas BLL and BLQ did not have an adequate model fit (BIC: 1668.7 and 1659.8, respectively). The estimated maximum response for ADG was 23.5% (95% CI: [22.7, 24.3%]) SID Trp:Lys for QP model (Fig. 1) and described by the following equation:

QP equation for ADG, lb: $[-0.329 + 6.3 \times (\text{Trp:Lys}) - 13.5 \times (\text{Trp:Lys})^2 + 0.015 \times (\text{Initial BW, kg}) - 0.000098 \times (\text{Initial BW, kg})^2] \times 2.2046$

where the Trp:Lys variable is in a ratio (i.e., 0.180) rather than percentage format (i.e., 18.0%).

For F/G, BLL and BLQ had comparable fit (BIC: 1316.3 and 1316.1, respectively) whereas the QP model did not have an adequate fit (BIC: 1322.6). The estimated SID Trp:Lys breakpoint for F/G were 16.9 (95% CI: [16.0, 17.8%]) and 17.0% (95% CI: [15.0, 18.9%]) for BLL and BLQ, respectively (Fig. 2):

BLL equation for F/G: if SID Trp:Lys < 16.9%, equation is $1/[0.599 - 1.0 \times (0.169 - \text{Trp:Lys}) - 0.004 \times (\text{Initial BW, kg}) + 0.000017 \times (\text{Initial BW, kg})^2]$, otherwise F/G is predicted at minimum for doses greater than 16.9%.

BLQ equation for F/G: if SID Trp:Lys < 17.0%, equation is $1/[0.6014 - 0.603 \times (0.170 - \text{Trp:Lys}) - 20.0 \times (0.170 - \text{Trp:Lys})^2 - 0.004 \times (\text{Initial BW, kg}) + 0.000017 \times (\text{Initial BW, kg})^2]$, otherwise F/G is predicted at minimum for doses greater than 17.0%.

Target performance levels based on the best fitting models for ADG and F/G are listed in Table 4. Note that at 96% of the optimum performance, the SID Trp:Lys ratio for ADG and F/G is approximately 18% and 15%, respectively, whereas at 99% of the optimum performance, the SID Trp:Lys ratio for ADG and F/G is approximately 21% and 16 %, respectively.

The equations of the best fitting models presented herein provide an opportunity for nutritionists to determine the economic return at each level of nutrient addition. As an illustration, by using these equations for 160- to 200-lb pigs and assuming corn at $3.50/bu, SBM at $325/ton, L-Trp at $10/lb, and revenue per lb of live gain at $0.60, the minimum feed cost per lb of gain is at 16.5% SID Trp:Lys whereas the maximum income over feed cost is at 21.5% SID Trp:Lys.

The estimated mean requirements for SID Trp:Lys for 65- to 275-lb pigs ranged from 16.9% for F/G to 23.5% for maximum mean ADG. Furthermore, 95% of the maximum estimated ADG was obtained by feeding 17.6% SID Trp:Lys and 98% of the maximum estimated ADG was obtained by feeding 19.8% SID Trp:Lys.

Table 1. Diet composition for 235- to 275-lb pigs (as-fed basis)[1]

	SID Trp:Lys	
Item	Low (14.5%)	High (24.5%)
Ingredient, %		
Corn	63.53	63.45
Soybean meal (46% CP)	3.43	3.43
DDGS[1]	30.00	30.00
Corn oil	0.50	0.50
Limestone	1.40	1.40
Salt	0.35	0.35
Trace mineral premix[2]	0.050	0.050
Vitamin premix[3]	0.050	0.050
L-lysine HCl	0.415	0.415
L-threonine	0.055	0.055
L-tryptophan	-	0.072
Phytase[4]	0.025	0.025
Ractopamine HCl, 2.25 g/lb	0.200	0.200
Total	100	100

continued

Table 1. Diet composition for 235- to 275-lb pigs (as-fed basis)[1]

	SID Trp:Lys	
Item	Low (14.5%)	High (24.5%)
Lys	0.71	0.71
Ile:lys	64	64
Leu:lys	203	203
Met:lys	35	35
Met & cys:lys	66	66
Thr:lys	68	68
Trp:lys	14.5	24.5
Val:lys	78	78
His:lys	47	47
Trp:BCAA[5]	4.8	8.1
Trp:LNAA[6]	3.9	6.6
ME, kcal/lb	1,517	1,518
NE, kcal/lb	1,143	1,144
SID lysine:ME, g/Mcal	2.81	2.81
SID lysine:NE, g/Mcal	2.12	2.12
CP, %	16.0	16.0
Ca, %	0.55	0.55
P, %	0.37	0.37
STTD P, %	0.30	0.30
Available P, %	0.30	0.30

[1] Diets were fed from 234.1 to 274.9 lb BW. Corn, dried distillers grains with solubles (DDGS), and soybean meal were analyzed for CP and total amino acid content and NRC (2012) SID digestibility values were used in the diet formulation.

[2] Provided: 33 ppm Mn from manganese oxide, 110 ppm Fe from iron sulfate, 110 ppm Zn from zinc oxide, 16.5 ppm Cu from copper sulfate, 0.33 ppm I from ethylenediamin dihydroiodide, and 0.30 ppm Se from sodium selenite.

[3] Provided per lb of diet: 2,400 IU vitamin A; 375 IU vitamin D_3; 12.0 IU vitamin E; 1.20 mg vitamin K; 7.5 mg pantothenic acid; 13.5 mg niacin; 2.1 mg riboflavin and 9 μg vitamin B_{12}.

[4] OptiPhos 2000 (Huvepharma, Peachtree City, GA) provided 227 phytase units (FTU) per lb of diet and a release of 0.14% in available P was considered.

[5] Dietary Trp as a ratio to branched-chain amino acids (BCAA; isoleucine, leucine, valine) on an SID basis.

[6] Dietary Trp as a ratio to large neutral amino acids (LNAA; isoleucine, leucine, valine, phenylalanine, and tyrosine) on an SID basis.

Table 2. Chemical analysis of the diets (as-fed-basis)[1]

	SID Trp:Lys, %						
Item	14.5	16.5	18.0	19.5	21.0	22.5	24.5[3]
Proximate analysis, %							
DM	91.89 (88.54)[2]	91.63 (88.54)	92.03 (88.54)	91.74 (88.54)	91.71 (88.54)	91.70 (88.54)	---
CP	14.7 (16.0)	14.1 (16.0)	15.0 (16.0)	15.0 (16.0)	14.7 (16.0)	15.1 (16.0)	---
Crude fiber	3.0 (4.1)	3.2 (4.1)	3.2 (4.1)	3.3 (4.1)	3.2 (4.1)	3.2 (4.1)	---
Ca	0.69 (0.55)	0.76 (0.55)	0.72 (0.55)	0.70 (0.55)	0.78 (0.55)	0.66 (0.55)	---
P	0.43 (0.37)	0.42 (0.37)	0.44 (0.37)	0.44 (0.37)	0.43 (0.37)	0.43 (0.37)	---
Fat	5.3 (5.4)	5.3 (5.4)	5.4 (5.4)	5.3 (5.4)	5.1 (5.4)	5.0 (5.4)	---
Ash	3.82 (3.72)	3.91 (3.72)	3.69 (3.72)	3.76 (3.72)	3.81 (3.72)	3.62 (3.72)	---
Amino acids, %							
Lys	0.82 (0.87)	0.79 (0.87)	0.80 (0.87)	0.79 (0.87)	0.80 (0.87)	0.84 (0.87)	---
Ile	0.62 (0.57)	0.58 (0.57)	0.60 (0.57)	0.58 (0.57)	0.59 (0.57)	0.58 (0.57)	---
Leu	1.62 (1.69)	1.59 (1.69)	1.66 (1.69)	1.61 (1.69)	1.63 (1.69)	1.61 (1.69)	---
Met	0.29 (0.3)	0.28 (0.30)	0.29 (0.30)	0.29 (0.30)	0.29 (0.30)	0.29 (0.30)	---
Met + cys	0.60 (0.59)	0.56 (0.59)	0.58 (0.59)	0.55 (0.59)	0.57 (0.59)	0.56 (0.59)	---
Thr	0.60 (0.63)	0.57 (0.63)	0.58 (0.63)	0.58 (0.63)	0.59 (0.63)	0.59 (0.63)	---
Trp	0.14 (0.13)	0.13 (0.15)	0.15 (0.16)	0.15 (0.17)	0.16 (0.18)	0.17 (0.19)	---
Val	0.77 (0.70)	0.72 (0.70)	0.75 (0.70)	0.73 (0.70)	0.73 (0.70)	0.72 (0.70)	---
His	0.40 (0.41)	0.38 (0.41)	0.40 (0.41)	0.38 (0.41)	0.39 (0.41)	0.39 (0.41)	---
Phe	0.74 (0.73)	0.70 (0.73)	0.73 (0.73)	0.71 (0.73)	0.72 (0.73)	0.71 (0.73)	---

[1] Diet samples were taken from six feeders per dietary treatment 3 d after the beginning of the trial and 3 d to the end of the trial and stored at -20°C, then CP and amino acid analysis was conducted on composite samples by Ajinomoto Heartland Inc. Samples of the diets were also submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CF, Ca, P, ash, and crude fat.
[2] Values in parentheses indicate those calculated from diet formulation and are based on values from NRC, 2012 (Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.) with the exception of CP and total AA content from corn, soybean meal, and DDGS, which were analyzed to diet formulation by Ajinomoto Heartland Inc. (Chicago, IL).
[3] Sample for 24.5% SID Trp:Lys ratio was lost.

Table 3. Least squares mean estimates (and corresponding SEM) for growth performance of 235- to 275- lb finishing pigs fed dietary treatments of standardized ileal digestible tryptophan:lysine (SID Trp:Lys) ratio ranging from 14.5 to 24.5%[1]

	SID Trp:Lys, %								Probability, $P <$	
	14.5	16.5	18.0	19.5	21.0	22.5	24.5	SEM	Linear	Quadratic
d 0 BW, lb	234.3	234.3	234.1	234.3	234.1	234.1	234.1	2.8	0.823	0.999
ADG, lb	1.67	1.95	1.93	1.99	2.00	1.94	2.08	0.07	0.001	0.022
ADFI, lb	4.98	5.35	5.33	5.39	5.47	5.32	5.54	0.10	0.001	0.073
F/G	2.98	2.75	2.77	2.70	2.73	2.74	2.66	0.08	0.001	0.160
d 21 BW, lb	269.6	275.1	275.1	276.2	276.0	274.7	277.8	2.7	0.003	0.140
SID Trp, g/kg gain	2.33	2.85	3.09	3.39	3.70	3.85	4.38	0.065	0.001	0.415

[1] A total of 975 gilts (PIC 337 × 1050) with initial BW of 234.1 ± 6.8 lb (mean ± SD) were used with 20 to 24 pigs per pen and six pens per treatment.

Table 4. Standardized ileal digestible (SID) Trp:Lys ratio at different target performance levels of 65- to 275-lb pigs

	Percent of optimum performance, %					
Item	95%	96%	97%	98%	99%	100%
ADG						
QP[1]	17.6%	18.3%	18.9%	19.8%	20.8%	23.5%
F/G						
BLL[2]	13.9%	14.5%	15.1%	15.7%	16.3%	16.9%
BLQ[3]	14.4%	14.7%	15.2%	15.7%	16.2%	17.0%

[1] QP equation for ADG, lb: $[-0.329 + 6.3 \times (\text{Trp:Lys}) - 13.5 \times (\text{Trp:Lys})^2 + 0.015 \times (\text{Initial BW, kg}) - 0.000098 \times (\text{Initial BW, kg})^2] \times 2.2046$.

[2] BLL equation for F/G: if SID Trp:Lys < 16.9%, equation is $1/[0.599 - 1.0 \times (0.169 - \text{Trp:Lys}) - 0.004 \times (\text{Initial BW, kg}) + 0.000017 \times (\text{Initial BW, kg})^2]$, otherwise F/G is predicted at minimum for doses greater than 16.9%.

[3] BLQ equation for F/G: if SID Trp:Lys < 17.0%, equation is $1/[0.6014 - 0.603 \times (0.170 - \text{Trp:Lys}) - 20.0 \times (0.170 - \text{Trp:Lys})^2 - 0.004 \times (\text{Initial BW, kg}) + 0.000017 \times (\text{Initial BW, kg})^2]$, otherwise F/G is predicted at minimum for doses greater than 17.0%.

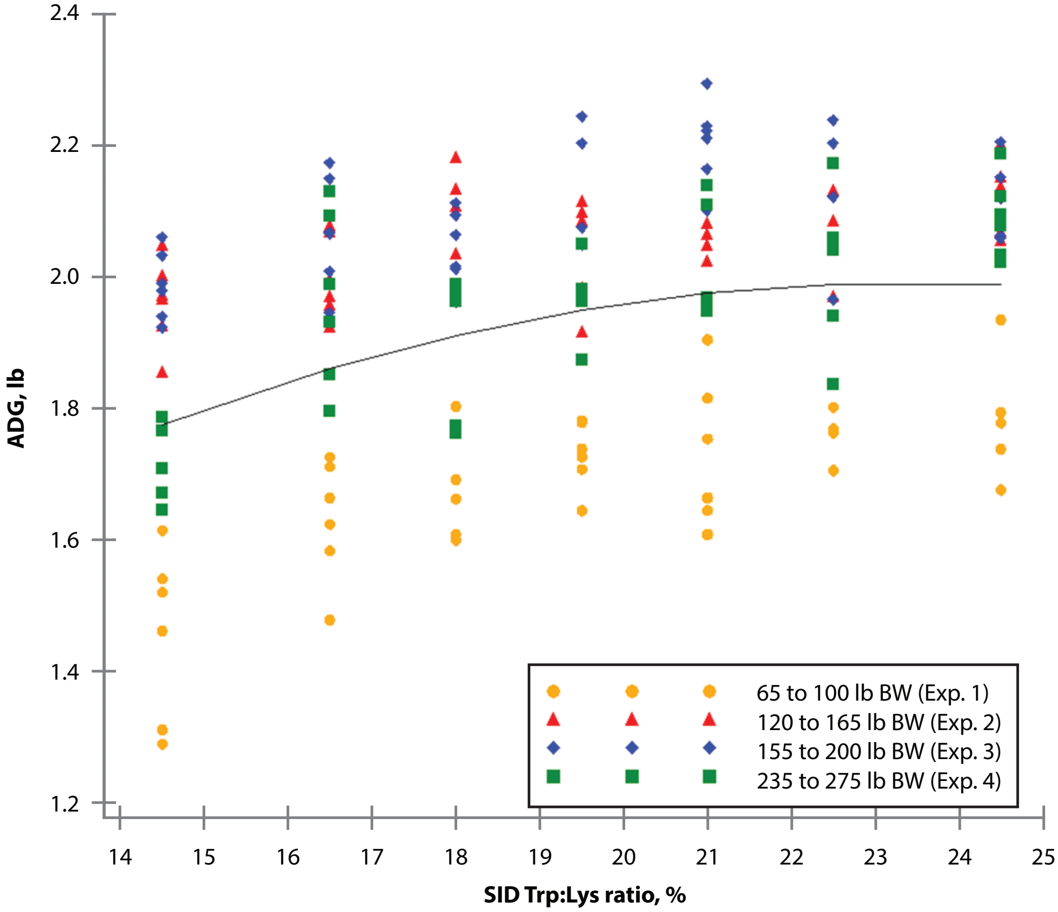

Figure 1. Quadratic polynomial (QP) regression of the ADG response to increasing standardized ileal digestible (SID) Trp:Lys in 65- to 275-lb pigs. The maximum ADG was achieved at 23.5% (95% CI: [22.7, 24.3%]) SID Trp:Lys in the QP model.

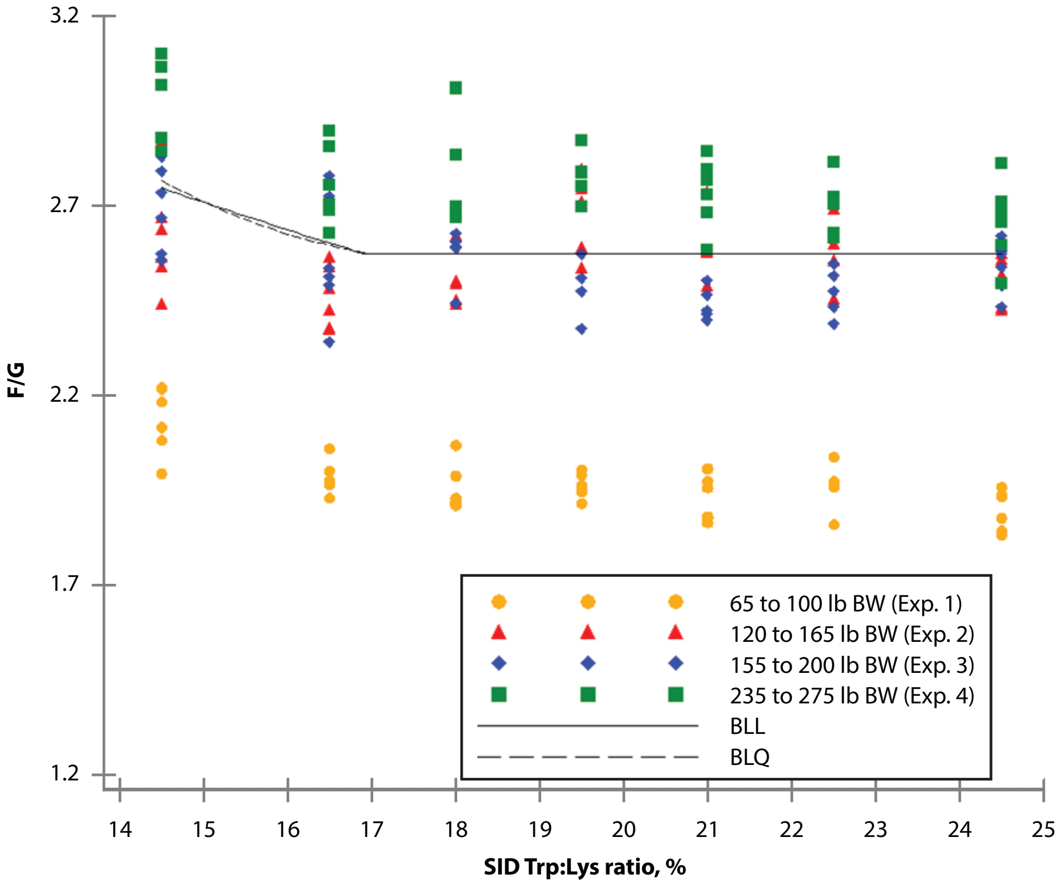

Figure 2. Broken-line linear (BLL) and broken-line quadratic (BLQ) regressions of the F/G response to increasing standardized ileal digestible (SID) Trp:Lys in 65- to 275-lb pigs. The minimum F/G was achieved at 16.9 (95% CI: [16.0, 17.8%]) and 17.0% (95% CI: [15.0, 18.9%]) SID Trp:Lys in the BLL and BLQ models, respectively.