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Effects of Standardized Ileal Digestible Threonine to Lysine Ratio on Growth Performance of PIC Line 337 × 1050 Pigs[1]

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Summary

The objective of this research was to evaluate the impact of varying SID Thr:Lys ratios on growth performance, removals, and mortality rates of late-nursery, grower, and finishing PIC 337 × 1050 pigs. In each experiment, pens of pigs were blocked by BW and randomly assigned to 1 of 5 dietary treatments in a randomized complete block design with 19 to 27 pigs per pen and 8, 7, and 7 replications per treatment in Exp. 1, 2, and 3, respectively. In Exp. 1, 987 pigs (initially 26.0 ± 0.70 lb) were used from 26 to 54 lb. In Exp. 2, 875 pigs (initially 95.5 ± 1.17 lb) were used from 95 to 155 lb. In Exp. 3, 824 pigs (initially 224.4 ± 1.85 lb) were used from 224 to 297 lb. Pens were randomly assigned to 1 of 5 dietary treatments with increasing SID Thr:Lys ratios at 53, 58, 62, 65, and 68% in Exp. 1 and 2, and 56.5, 60, 64, 68, and 72.5% in Exp. 3. Diets were corn-soybean meal-based. Diets with the lowest and highest Thr:Lys ratios were blended to achieve the target SID Thr:Lys treatments in each experiment. Between experiments, all pens of pigs were placed on a common diet for 23 (Exp. 1 and 2) and 32 d (Exp. 2 and 3) to provide opportunity for compensatory growth prior to initiation of the next experiment. In Exp. 1 (26 to 54 lb), ADG and final BW increased linearly ($P \leq 0.006$) while ADFI, Thr intake/d, and Thr intake/kg of gain increased quadratically ($P \leq 0.001$). Overall, F/G improved (quadratic, $P \leq 0.001$) as Thr:Lys ratio increased. Additionally, Lys intake/d increased (quadratic, $P < 0.001$) while Lys intake/kg of gain decreased (quadratic, $P < 0.001$) with increasing Thr:Lys ratio. The quadratic polynomial (QP) model predicted greater than 68% SID Thr:Lys was required for ADG from 26 to 54 lb, while a QP model suggested that minimum F/G was achieved at 62.1% SID Thr:Lys. In Exp. 2 (95 to 155 lb), ADG, final BW, Thr intake/d, and Thr intake/kg of gain increased (linear, $P \leq 0.05$) and F/G improved (linear, $P = 0.030$) as dietary Thr:Lys increased. Moreover, Lys intake/kg of gain decreased (linear, $P = 0.023$)

[1] The authors appreciate Swine Vet Center (St. Peter, MN) and Genus PIC (Hendersonville, TN) for providing technical assistance for these studies.

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with increasing Thr:Lys ratio. For model analysis, QP models suggested optimum ADG and F/G were achieved at levels greater than 68% SID Thr:Lys. However, similar fitting broken-line quadratic (BLQ) and broken-line linear (BLL) models predicted no further improvement to F/G and ADG beyond 61 and 67% SID Thr:Lys, respectively. In Exp. 3 (224 to 297 lb), increasing SID Thr:Lys increased (linear, $P \leq 0.001$) Thr intake/d and Thr intake/kg of gain. In addition, increasing SID Thr:Lys ratios tended ($P \leq 0.086$) to quadratically increase ($P \leq 0.086$) ADFI and BW of pigs at the second marketing event. However, no other response criteria were impacted ($P \geq 0.10$) by dietary Thr:Lys. Due to a lack of ADG and F/G responses, prediction models were not developed. In summary, these results suggest the optimal SID Thr:Lys level for 26- to 54-lb pigs is 62.1% for feed efficiency and greater than 68% for ADG. From 95 to 155 lb, the requirement was predicted at or above 61 and 67% SID Thr:Lys for F/G and ADG, respectively. However, with the variation in response criteria in Exp. 3 (224 to 297 lb), we were unable to statistically define a requirement estimate.

Introduction

Threonine is an essential amino acid for pigs, which has been categorized as the first limiting amino acid for maintenance and development of intestinal tissue.[5] An increase in the Thr requirement of pigs potentially occurs as pigs grow due to increased growth of intestinal tissue coupled with increased production of Thr-rich proteins (i.e., mucin).[6] With improvements in modern swine genetics, it is critical to continuously re-evaluate the established nutrient requirements to optimize genetic potential for growth performance. Therefore, the objective of this study was to evaluate the impact of SID Thr:Lys ratios on growth performance, removals, and mortality rates of PIC 337 × 1050 late-nursery, grower, and finishing pigs.

Procedures

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. A commercial research barn located in south-central Minnesota was used to conduct the study. The barn had slatted concrete flooring, deep pits for manure storage, and was naturally ventilated. Pens contained a 3-hole stainless steel dry self-feeder (Thorp Equipment, Thorp, WI) and a 1-cup waterer to provide *ad libitum* access to feed and water. These experiments were conducted from May to September 2022.

Animals and diets

In Exp. 1, 987 pigs (PIC 337 × 1050; initially 26.0 ± 0.70 lb) were used from 26 to 54 lb. In Exp. 2, 875 pigs (initially 95.5 ± 1.17 lb) were used from 95 to 155 lb. In Exp. 3, 824 pigs (initially 224.4 ± 1.85 lb) were used from 224 to 297 lb. Pens were randomly assigned to 1 of 5 dietary treatments with increasing SID Thr:Lys ratios of 53, 58, 62, 65, or 68% in Exp. 1 and 2, and 56.5, 60, 64, 68, or 72.5% in Exp. 3. Diets were corn-soybean meal-based. Diets containing low and high Thr:Lys ratios were blended to achieve the intermediate SID Thr:Lys treatment levels in Exp. 1 and 2. In Exp. 3, diets

[5] Tolosa A. F., M. D. Tokach, R. D. Goodband, J. C. Woodworth, J. M. DeRouchey, and J. T. Gebhardt. 2022. Evaluation of increasing digestible threonine to lysine in corn-soybean meal diets without and with distillers dried grains with solubles on growth performance of growing-finishing pigs. Transl. Anim. Sci. 6:1-6.

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

containing 56.5, 64, and 72.5% SID Thr:Lys ratios were formulated. The 56.5 and 64% SID Thr:Lys diets were blended to create the 60% SID Thr:Lys treatment, while the 64 and 72.5% diets were blended to create the 68% SID Thr:Lys treatment (Table 1). Threonine was the first-limiting AA, with Lys formulated to be approximately 10% below PIC recommendations in each experiment, while all other AA ratios were maintained above PIC requirement estimates. Treatment diets were fed for 21, 28, and 36 d in Exp. 1, 2, and 3, respectively. Between experiments, all pens of pigs were placed on a common diet for 23 and 32 d, between Exp. 1 and 2, and Exp. 2 and 3, respectively. To determine ADG, ADFI, and F/G, pens of pigs were weighed, and feed disappearance was recorded throughout each experiment. On d 17 and 23 of Exp. 3, the 4 heaviest pigs from each pen were removed and marketed. The remaining pigs were marketed 13 d later at the conclusion of the study.

Statistical analysis

Data were analyzed as a randomized complete block design for a one-way ANOVA using the GLIMMIX procedure of SAS (v. 9.4, SAS Institute, Inc., Cary, NC). Pen was considered the experimental unit, initial body weight served as a blocking factor, and treatment served as the fixed effect in the statistical model. Contrast coefficients were adjusted to account for unequal spacing in treatments. Results were considered significant with $P \leq 0.05$ and marginally significant with $P \leq 0.10$. Dose response curves were evaluated using quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models. The best-fitting model was selected using the Bayesian Information Criterion (BIC) with improved model fits accepted when BIC decreased at least 2.0.

Results and Discussion

Experiment 1

In 26- to 54-lb pigs, ADG and final BW increased (linear, $P \leq 0.006$) with increasing Thr:Lys ratio. Meanwhile, ADFI, Thr intake/d, and Thr intake/kg of gain increased, and F/G improved (quadratic, $P \leq 0.001$) as Thr:Lys ratio increased. Additionally, Lys intake/d increased (quadratic, $P < 0.001$) while Lys intake/kg of gain decreased (quadratic, $P < 0.001$) with increasing Thr:Lys ratio. There was no difference between dietary treatments on the percentage of removals, mortalities, or total removals ($P > 0.10$).

A QP model predicted the requirement at levels greater than 68% SID Thr:Lys for ADG, while a QP model suggested that 62.1% SID Thr:Lys was required to achieve minimum F/G (Figures 1 and 2).

Experiment 2

In 95- to 155-lb pigs, ADG, final BW, Thr intake/d and Thr intake/kg of gain increased (linear, $P \leq 0.036$) as dietary Thr:Lys increased, while F/G improved (linear, $P = 0.030$). Moreover, Lys intake/kg of gain decreased (linear, $P = 0.023$) with increasing Thr:Lys. There was no difference between treatments on the percentage of removals, mortalities, or total removals ($P > 0.10$).

Quadratic polynomial models suggested optimum ADG and F/G were achieved at dietary levels greater than 68% SID Thr:Lys. Similar fitting BLQ and BLL models predicted no further improvement to F/G and ADG beyond 61 and 67% SID Thr:Lys, respectively (Figures 3 and 4).

Experiment 3

In 224- to 297-lb pigs, increasing SID Thr:Lys ratio increased (linear, $P \leq 0.001$) Thr intake/d and Thr intake/kg of gain. In addition, increasing SID Thr:Lys ratios marginally increased (quadratic, $P \leq 0.086$) ADFI and BW of pigs at the second marketing event. However, no other response criteria were significantly impacted by dietary Thr:Lys ($P \geq 0.10$). Additionally, there was no difference across Thr:Lys treatments on the percentage of removals, mortalities, or total removals ($P > 0.10$). Models were not analyzed for Exp. 3 due to lack of observed significant differences for ADG or F/G.

In summary, these results suggest the optimal SID Thr:Lys level for 26- to 54-lb pigs is 62.1% for feed efficiency and greater than 68% for ADG. For pigs from 95 to 155 lb, the requirement was predicted to be at or above 65 and 67% SID Thr:Lys for F/G and ADG, respectively. However, statistical differences across dietary SID Thr:Lys levels for 224- to 297-lb pigs were not detected, thus models to establish requirements for growth performance criteria were not conducted.

Table 1. Diet composition (as-fed basis)[1,2]

	Exp. 1		Exp. 2		Exp. 3		
Item	**Low**	**High**	**Low**	**High**	**Low**	**Medium**	**High**
Ingredient, %							
Corn	64.86	64.67	78.39	78.17	84.72	84.66	84.64
Soybean meal	30.00	30.00	18.70	18.8	13.25	13.25	13.20
Choice white grease	1.45	1.45	---	---	---	---	---
Monocalcium P, 21% P	0.87	0.87	0.45	0.45	---	---	---
Limestone	1.00	1.02	1.18	1.18	1.00	1.00	1.00
Sodium chloride	0.61	0.61	0.55	0.55	0.56	0.56	0.56
L-Lys-HCl	0.36	0.36	0.28	0.28	0.21	0.21	0.21
DL-Met	0.23	0.23	0.11	0.11	0.05	0.05	0.05
L-Thr	0.03	0.20	---	0.12	---	---	---
Thr biomass[3]	---	---	---	---	---	0.06	0.13
L-Trp	0.02	0.02	0.01	0.01	0.01	0.01	0.01
L-Val	0.13	0.13	0.04	0.04	0.01	0.01	0.01
Vitamin premix with phytase[4]	0.25	0.25	0.15	0.15	0.10	0.10	0.10
Trace mineral premix	0.15	0.15	0.15	0.15	0.10	0.10	0.10
Copper sulfate	0.06	0.06	---	---	---	---	---
Total	100	100	100	100	100	100	100
Calculated analysis[1]							
SID AA, %							
Lys, %	1.15	1.15	0.81	0.81	0.63	0.63	0.63
Ile:Lys	56	56	59	59	63	63	63
Leu:Lys	119	119	131	131	149	149	149
Met and Cys:Lys	59	59	59	59	59	59	59
Thr:Lys	53	68	53	68	56.5	64.0	72.5
Trp:Lys	20	20	19.2	19.2	19.0	19.0	19.0
Val:Lys	70	70	70	70	73	73	73
His:Lys	36	36	37	37	40	40	40
NE, kcal/lb	1,111	1,111	1,121	1,121	1,142	1,142	1,142
SID Lys:NE, g/Mcal	4.70	4.70	3.28	3.28	2.50	2.50	2.50
CP, %[5]	18.7	18.8	14.2	14.3	12.0	12.0	12.1
Ca, %	0.69	0.70	0.64	0.64	0.47	0.47	0.47
STTD P, %	0.44	0.44	0.33	0.33	0.26	0.26	0.26

[1]Calculated analysis is based off nutrient profiles for ingredients listed in 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.)
[2]Low and high Thr:Lys diets were blended to create treatment diets at 58, 62, and 65% SID Thr:Lys in Exp. 1 and 2. In Exp. 3, the low and medium diets were blended to create the 60% SID Thr:Lys treatment, and the medium and high diets were blended to create the 68% SID Thr:Lys treatment.
[3]THR Pro; CJ America-Bio, Downers Grove, IL.
[4]Axtra PHY (Dupont, Wilmington, DE) provided 325, 195, and 236 phytase units (FTU/lb) for an estimated release of 0.13, 0.12, and 0.14% STTD P, in Exp. 1, 2, and 3, respectively.
[5]CP = crude protein.

Table 2. Effects of increasing SID Thr:Lys on growth performance of 26- to 54-lb PIC 337 × 1050 pigs, Exp. 1[1,2]

	SID Thr:Lys, %						*P* =	
Item	53	58	62	65	68	SEM	Linear	Quadratic
BW, lb								
d 0	26.4	25.8	26.0	25.6	26.3	0.70	0.532	0.109
d 21	51.0	52.2	53.1	52.9	53.9	0.90	0.006	0.775
d 0 to 21								
ADG, lb	1.16[b]	1.21[ab]	1.24[ab]	1.25[ab]	1.29[a]	0.024	0.003	0.951
ADFI, lb	1.87[ab]	1.72[c]	1.72[c]	1.74[bc]	1.92[a]	0.047	0.599	< 0.001
F/G	1.61[a]	1.43[b]	1.40[b]	1.38[b]	1.49[ab]	0.046	0.002	< 0.001
Thr intake, g/d	5.34[c]	5.39[c]	5.76[bc]	6.10[b]	7.05[a]	0.157	< 0.001	< 0.001
Thr intake, g/kg gain	10.18[b]	9.86[b]	10.30[b]	10.70[b]	12.05[a]	0.333	< 0.001	0.001
Lys intake, g/d	10.09[ab]	9.29[c]	9.29[c]	9.35[bc]	10.36[a]	0.250	0.644	< 0.001
Lys intake, g/kg gain	19.20[a]	17.00[b]	16.61[b]	16.48[b]	17.74[ab]	0.544	0.002	< 0.001
Removals and mortality								
Removals, %	1.51	2.51	2.53	1.53	3.59	1.332	0.430	0.990
Mortality, %	0.28	0.28	0.29	0.00	0.00	0.437	0.997	0.998
Total, %	2.01	3.02	3.03	1.53	3.59	1.332	0.720	0.969

[ab]Means within row with different superscripts differ ($P < 0.05$).
[1]A total of 987 pigs (initial BW = 26.0 ± 0.70 lb) were used in a 21-d growth performance study with 22 to 27 pigs per pen and 8 replicates per treatment.
[2]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio.

Table 3. Effects of increasing SID Thr:Lys on growth performance of 95- to 155-lb PIC 337 × 1050 pigs, Exp. 2[1,2]

	SID Thr:Lys, %						*P* =	
Item	53	58	62	65	68	SEM	Linear	Quadratic
BW, lb								
d 0	95.4	95.4	95.5	95.5	95.5	1.17	0.841	0.958
d 28	151.1	151.3	152.0	153.9	154.3	1.76	0.036	0.507
d 0 to 28								
ADG, lb	1.98	2.00	2.01	2.09	2.08	0.037	0.028	0.676
ADFI, lb	4.61	4.52	4.63	4.64	4.69	0.068	0.212	0.321
F/G	2.32[a]	2.27[ab]	2.30[ab]	2.22[b]	2.26[ab]	0.025	0.030	0.584
Thr intake, g/d	9.51	10.23	11.20	11.76	12.43	0.163	< 0.001	0.324
Thr intake, g/kg gain	10.59	11.30	12.29	12.41	13.21	0.130	< 0.001	0.711
Lys intake, g/d	17.96	17.66	18.04	18.10	18.29	0.266	0.210	0.337
Lys intake, g/kg gain	19.97	19.50	19.80	19.09	19.41	0.214	0.023	0.613
Removals and mortality								
Removals, %	0.00	0.00	0.00	0.00	0.58	0.576	0.992	0.993
Mortality, %	0.53	1.09	0.53	0.54	1.06	0.860	0.816	0.934
Total, %	0.59	1.19	0.59	0.60	1.73	0.993	0.614	0.730

[ab]Means within row with different superscripts differ ($P < 0.05$).
[1]A total of 875 pigs (initial BW = 95.5 ± 1.17 lb) were used in a 28-d growth performance study with 21 to 27 pigs per pen and 7 replicates per treatment.
[2]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio.

Table 4. Effects of increasing SID Thr:Lys ratio growth performance of 224- to 297-lb PIC 337 × 1050 pigs, Exp. 3[1,2]

	SID Thr:Lys, %						*P* =	
Item:	**56.5**	**60**	**64**	**68**	**72.5**	**SEM**	**Linear**	**Quadratic**
BW, lb								
d 0	224.7	224.1	223.7	224.4	224.4	1.85	0.916	0.434
d 36[3]	294.4	294.8	296.2	296.2	294.8	3.26	0.788	0.543
Marketing								
First marketing (d 17)[4]	283.5	277.5	281.0	281.6	280.2	3.29	0.819	0.620
Second marketing (d 23)[4]	293.3	294.6	297.1	297.3	287.7	3.71	0.434	0.086
Average[5]	292.3	291.8	293.4	293.9	291.1	2.22	0.926	0.246
d 0 to 36								
ADG, lb	2.21	2.20	2.26	2.29	2.18	0.044	0.935	0.144
ADFI, lb	6.47	6.56	6.57	6.65	6.40	0.099	0.778	0.083
F/G	2.93	2.99	2.91	2.91	2.94	0.036	0.666	0.750
Thr intake, g/d	10.43[d]	11.57[c]	12.39[b]	13.13[a]	13.23[a]	0.183	< 0.001	< 0.001
Thr intake, g/kg gain	10.39[d]	11.63[c]	12.07[c]	12.69[b]	13.40[a]	0.147	< 0.001	0.039
Lys intake, g/d	19.69	19.91	19.96	20.20	19.46	0.304	0.789	0.096
Lys intake, g/kg gain	19.60	20.04	19.46	19.53	19.70	0.238	0.654	0.772
Removals and mortality								
Removals, %	0.00	0.00	0.80	0.00	0.38	0.974	0.990	1.000
Mortality, %	0.00	0.43	0.90	0.88	0.43	0.844	0.982	0.981
Total, %	0.00	0.51	2.17	1.07	1.04	1.329	0.985	0.985

[ab]Means within row with different superscripts differ ($P < 0.05$).
[1]A total of 824 pigs (initial BW = 224.4 ± 1.85 lb) were used in a 36-d growth performance study with 19 to 26 pigs per pen and 7 replicates per treatment.
[2]ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio.
[3]Final marketing event occurred on d 36.
[4]The 4 heaviest pigs were marketed from each pen at each marketing event.
[5]Weighted average final BW for all marketing events (d 17, 23, and 36).

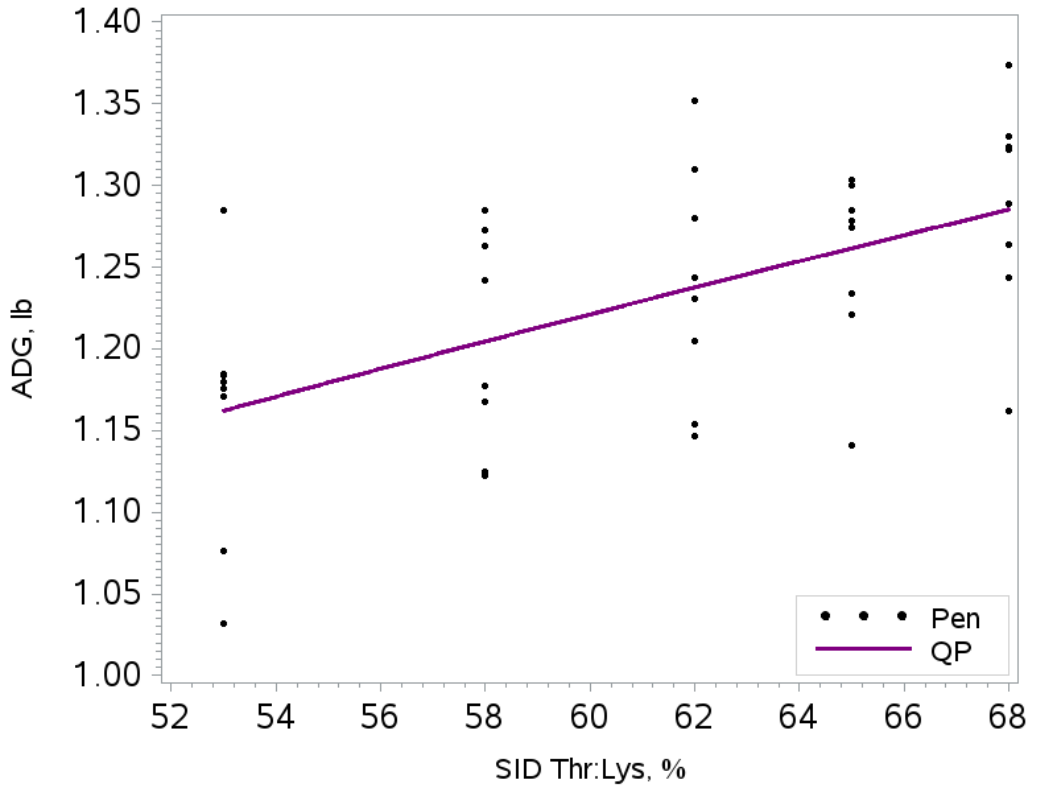

Figure 1. Estimation of SID Thr:Lys requirements to maximize ADG for 26- to 54-lb PIC 337 × 1050 pigs, Exp. 1.
A total of 987 pigs (PIC 337 × 1050; initially 26.0 ± 0.70 lb) were used in a 21-d trial. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit to estimate SID Thr:Lys level required to maximize ADG. The QP model resulted in the best fit, based on Bayesian Information Criterion (BIC), with a lower number being indicative of a better fit. The QP model predicted 95 and 100% of maximum ADG at greater than 68% SID Thr:Lys. The developed QP model equation for ADG was: ADG = -0.00003 × (SID Thr:Lys, %)^2 + 0.01167 × (SID Thr:Lys, %) + 0.6244.

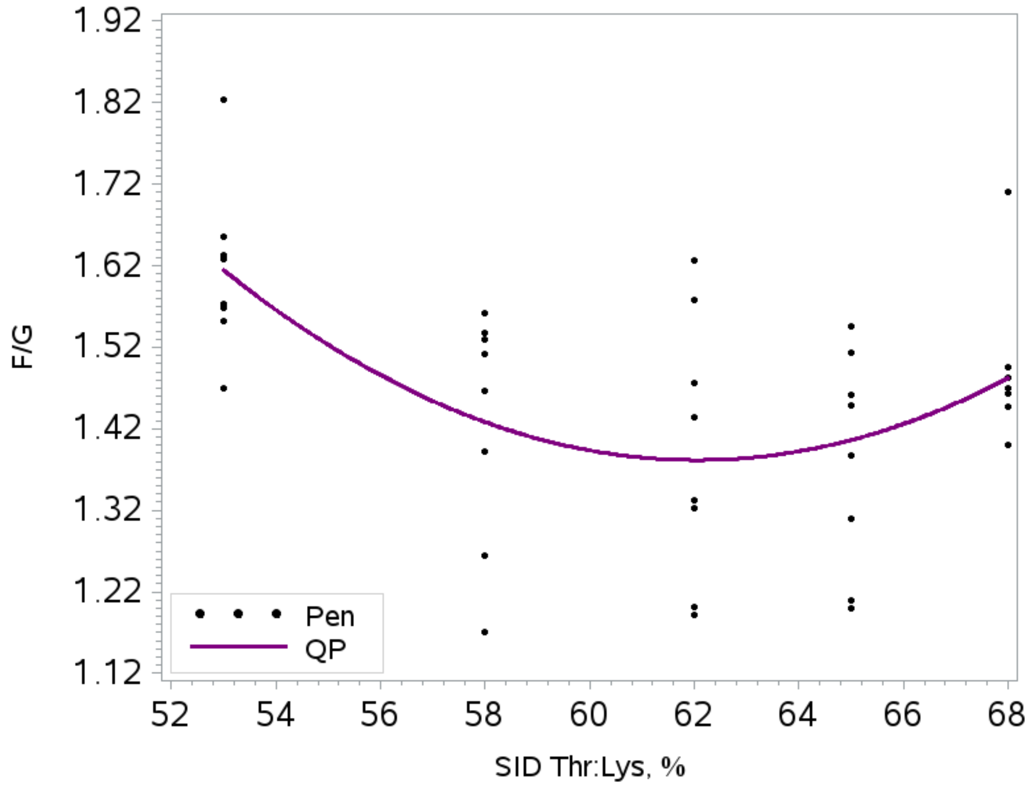

Figure 2. Estimation of SID Thr:Lys requirements to minimize F/G for 26- to 54-lb PIC 337 × 1050 pigs, Exp. 1.
A total of 987 pigs (PIC 337 × 1050; initially 26.0 ± 0.70 lb) were used in a 21-d trial. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit to estimate SID Thr:Lys level required to minimize F/G. The QP model resulted in the best fit, based on Bayesian Information Criterion (BIC), with a lower number being indicative of a better fit. The QP model predicted 95 and 100% of minimum F/G at 57.1 and 62.1% SID Thr:Lys. The developed QP model equation for F/G was: F/G = 0.002845 × (SID Thr:Lys, %)^2 – 0.3531 × (SID Thr:Lys, %) + 12.336.

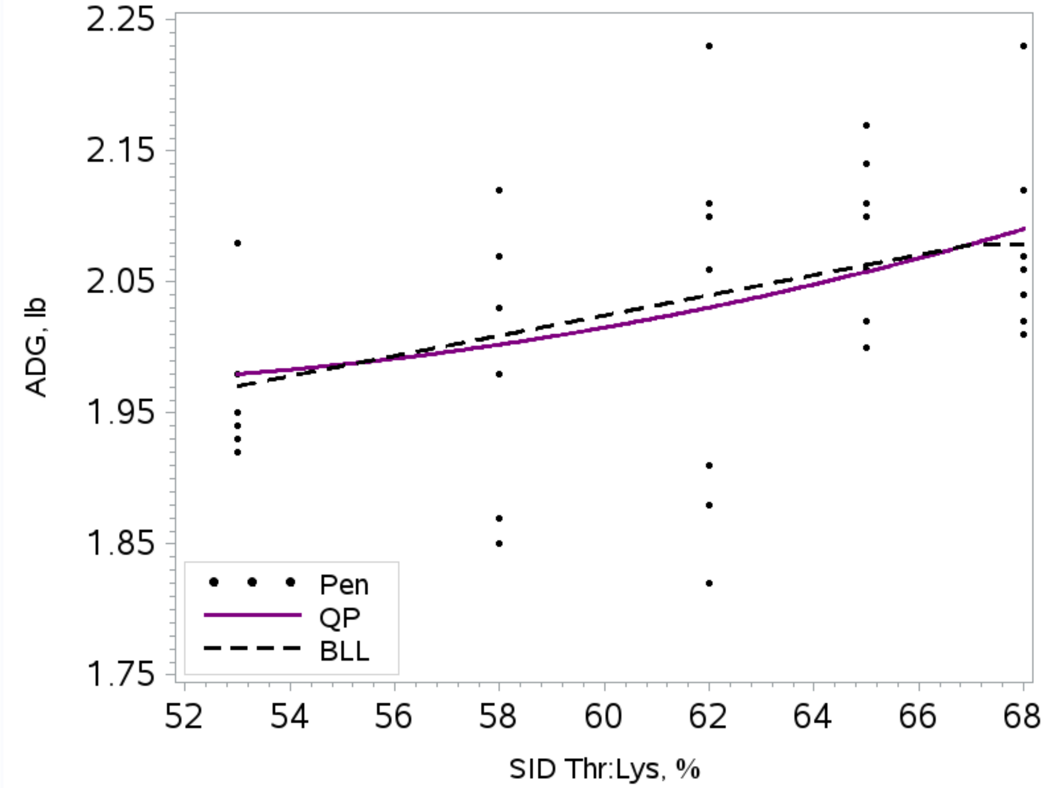

Figure 3. Estimation of SID Thr:Lys requirements to maximize ADG for 95- to 155-lb PIC 337 × 1050 pigs, Exp. 2.
A total of 875 pigs (PIC 337 × 1050; initially 95.5 ± 1.17 lb) were used in a 28-d trial. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit to estimate SID Thr:Lys level to maximize ADG. The QP and BLL models resulted in the best fit, based on Bayesian Information Criterion (BIC), with a lower number being indicative of a better fit (BIC = -60.0 vs. -58.5, QP vs. BLL). The QP model predicted 95 and 100% of maximum ADG at 66.2 and greater than 68% SID Thr:Lys, respectively. The developed QP model equation for ADG was: ADG = 0.000288 × (SID Thr:Lys, %)^2 – 0.0275 × (SID Thr:Lys, %) + 2.6277. The BLL model predicted no further improvement beyond 67% SID Thr:Lys.

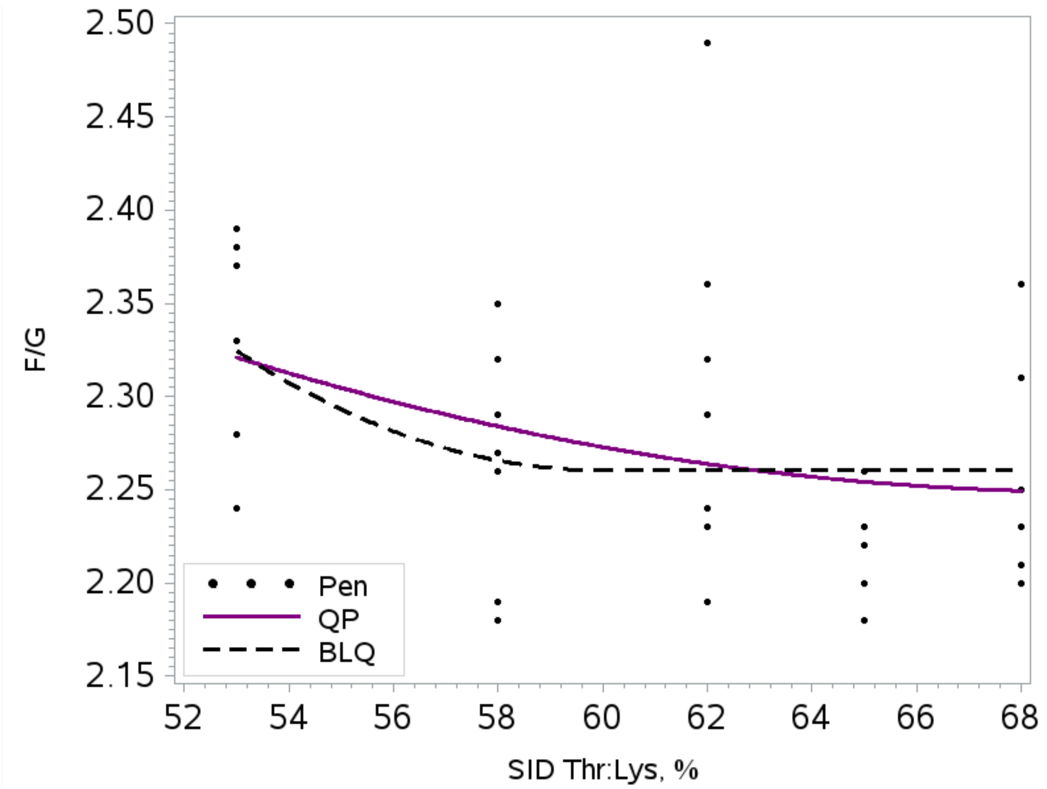

Figure 4. Estimation of SID Thr:Lys requirements to minimize F/G for 95- to 155-lb PIC 337 × 1050 pigs, Exp. 2.
A total of 875 pigs (PIC 337 × 1050; initially 95.5 ± 1.17 lb) were used in a 28-d trial. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit to estimate SID Thr:Lys level to minimize F/G. The QP and BLQ models resulted in the best fit, based on Bayesian Information Criterion (BIC), with a lower number being indicative of a better fit (BIC = -81.3 vs. -79.5, QP vs. BLQ). The QP model predicted 95 and 100% of minimum F/G at levels greater than 68% SID Thr:Lys. The developed QP model equation for F/G was: $F/G = 0.000263 \times (\text{SID Thr:Lys, \%})^2 - 0.03654 \times (\text{SID Thr:Lys, \%}) + 3.5203$. The BLQ model suggested no further improvement in F/G beyond 61% SID Thr:Lys.