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Effects of Dietary Standardized Ileal Digestible Isoleucine:Lysine Ratio on Nursery Pig Performance

A. B. Clark
Kansas State University, Manhattan, abclark@k-state.edu

M. D. Tokach
Kansas State University, Manhattan, mtokach@k-state.edu

J. M. DeRouchey
Kansas State University, Manhattan, jderouch@k-state.edu

See next page for additional authors

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Effects of Dietary Standardized Ileal Digestible Isoleucine:Lysine Ratio on Nursery Pig Performance

Abstract

A total of 560 nursery pigs were used in 2 experiments to evaluate the effects of increasing dietary standardized ileal digestible (SID) Isoleucine:Lysine (Ile:Lys) ratio on growth performance. In Exp. 1, 280 pigs (PIC 327 × 1050, initially 14.9 lb BW) were fed experimental diets for 12 d with 8 replications and 5 pigs per pen. In Exp. 2, 280 pigs (DNA Genetics Line 600 × Line 241, initially 13.3 lb BW) were fed experimental diets for 18 d with 8 replications and 5 pigs per pen. In both experiments, pens were allotted to 1 of 7 dietary treatments in a randomized complete block design. The 7 dietary treatments were 40, 44, 48, 52, 54, 58, and 63% SID Ile:Lys ratio. After the experimental diet feeding period, a common diet was fed for 14 d. Diets in both phases were fed in meal form.

For Exp. 1, from d 0 to 12 when experimental diets were fed, ADG and ADFI improved (ADG, linear, $P < 0.001$; and ADFI, quadratic, $P < 0.017$) and F/G became poorer (quadratic, $P < 0.041$) as SID Ile:Lys ratio increased. For ADG, the quadratic (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models reported maximum ADG at 64.7, 52.0, and 52.0% SID Ile:Lys ratio, respectively. For ADFI, the BLL breakpoint occurred at 50.6% and the QP predicted maximum ADFI at 56.2% SID Ile:Lys ratio.

In Exp. 2, from d 0 to 18 when experimental diets were fed, ADG and ADFI improved (quadratic, $P < 0.009$) with no significant differences for F/G as SID Ile:Lys ratio increased. For ADG, the BLL and QP had similar fit with breakpoints/maximums occurring at 51.8% SID Ile:Lys ratio and 58.3% SID Ile:Lys ratio, respectively. For ADFI, the QP reported maximum ADFI at 57.2% SID Ile:Lys ratio and the BLQ breakpoint occurred at 52.0% SID Ile:Lys.

In summary, these experiments demonstrate that the SID Ile requirement for 15 to 25 lb nursery pigs is approximately 52% of Lys for ADG and ADFI using broken line models and can be as high as 64% of Lys using quadratic models. A slight quadratic effect was observed in feed efficiency for Exp. 1, however in Exp. 2, there were no appreciable differences detected in F/G. The Ile requirement for 15 to 25 lb pigs was found to be similar to NRC (2012) requirement estimates.

Keywords

isoleucine, growth, nursery pigs, swine

Cover Page Footnote

Appreciation is expressed to Ajinomoto Heartland, Inc. (Chicago, IL) for partial financial support.

Authors

A. B. Clark, M. D. Tokach, J. M. DeRouchey, S. S. Dritz, K. Touchette, R. D. Goodband, and J. C. Woodworth

Effects of Dietary Standardized Ileal Digestible Isoleucine:Lysine Ratio on Nursery Pig Performance[1]

A.B. Clark, M.D. Tokach, J.M. DeRouchey, S.S. Dritz,[2] K.J. Touchette,[3] R.D. Goodband, and J.C. Woodworth

Summary

A total of 560 nursery pigs were used in 2 experiments to evaluate the effects of increasing dietary standardized ileal digestible (SID) Isoleucine:Lysine (Ile:Lys) ratio on growth performance. In Exp. 1, 280 pigs (PIC 327 × 1050, initially 14.9 lb BW) were fed experimental diets for 12 d with 8 replications and 5 pigs per pen. In Exp. 2, 280 pigs (DNA Genetics Line 600 × Line 241, initially 13.3 lb BW) were fed experimental diets for 18 d with 8 replications and 5 pigs per pen. In both experiments, pens were allotted to 1 of 7 dietary treatments in a randomized complete block design. The 7 dietary treatments were 40, 44, 48, 52, 54, 58, and 63% SID Ile:Lys ratio. After the experimental diet feeding period, a common diet was fed for 14 d. Diets in both phases were fed in meal form.

For Exp. 1, from d 0 to 12 when experimental diets were fed, ADG and ADFI improved (ADG, linear, $P < 0.001$; and ADFI, quadratic, $P < 0.017$) and F/G became poorer (quadratic, $P < 0.041$) as SID Ile:Lys ratio increased. For ADG, the quadratic (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models reported maximum ADG at 64.7, 52.0, and 52.0% SID Ile:Lys ratio, respectively. For ADFI, the BLL breakpoint occurred at 50.6% and the QP predicted maximum ADFI at 56.2% SID Ile:Lys ratio.

In Exp. 2, from d 0 to 18 when experimental diets were fed, ADG and ADFI improved (quadratic, $P < 0.009$) with no significant differences for F/G as SID Ile:Lys ratio increased. For ADG, the BLL and QP had similar fit with breakpoints/maximums occurring at 51.8% SID Ile:Lys ratio and 58.3% SID Ile:Lys ratio, respectively. For ADFI, the QP reported maximum ADFI at 57.2% SID Ile:Lys ratio and the BLQ breakpoint occurred at 52.0% SID Ile:Lys.

In summary, these experiments demonstrate that the SID Ile requirement for 15 to 25 lb nursery pigs is approximately 52% of Lys for ADG and ADFI using broken line mod-

[1] Appreciation is expressed to Ajinomoto Heartland, Inc. (Chicago, IL) for partial financial support.
[2] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.
[3] Ajinomoto Heartland, Inc. (Chicago, IL).

els and can be as high as 64% of Lys using quadratic models. A slight quadratic effect was observed in feed efficiency for Exp. 1, however in Exp. 2, there were no appreciable differences detected in F/G. The Ile requirement for 15 to 25 lb pigs was found to be similar to NRC (2012)[4] requirement estimates.

Key words: isoleucine, growth, nursery pigs, swine

Introduction

The inclusion of crystalline amino acids in swine diets is an effective strategy to not only meet specific nutritional requirements, but also reduce diet cost and environmental impact. Typically, amino acids are expressed in ratio to lysine (Lys) for diet formulation process. Thus, it is important to evaluate essential amino acids in a Lys deficient scenario to appropriately identify the requirement of the essential amino acid of interest. A previous experiment conducted at Kansas State University demonstrated that the Lys requirement for 15 to 25 lb pigs was 1.45% SID Lys. Previously, we have determined the Thr, Met, Trp, and Val to Lys ratios for pigs from 15 to 25 lb. Therefore, our next step was to determine the appropriate SID Ile:Lys ratio for pigs in this stage of growth.

Mixed model statistical methods have recently been adapted in which multiple models are applied to the data and best fit objectively identified. The NRC (2012) estimates that the Ile requirement for approximately 15 to 25 lb pigs is 51.1% of Lys. Therefore, the objective of this study was to determine the SID Ile:Lys requirement for nursery pigs weighing approximately 15 to 25 lb.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments. Two experiments were conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS, where each pen (Exp. 1: 5 ft × 5 ft; Exp. 2: 4 ft × 5 ft) contained a 4-hole, dry self-feeder and a nipple waterer to provide ad libitum access to feed and water. All diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS.

Diets in both experiments were corn and soybean meal-based with crystalline amino acids increasing to replace soybean meal. Diets contained 10% dried whey and 10% field peas. The field peas were used to lower the Ile:Lys ratio to allow titration of the requirement. The 7 dietary treatments in both experiments were 40, 44, 48, 52, 54, 58, and 63% SID Ile:Lys ratio. Upon manufacturing at the feed mill, the low (40%) and high (63%) treatment diets were blended to create the intermediate diets. Corn, soybean meal, field peas and dried whey were analyzed for AA content prior to diet formulation (Table 1). A new field pea batch and analysis prior to Exp. 2 called for a minor adjustment to Exp. 2 diets by decreasing crystalline amino acids slightly.

Experiment 1

A total of 280 nursery pigs (PIC 327 × 1050; 14.9 lb BW) were used in a 26-d experiment. There were 8 replicate pens per treatment and 5 pigs per pen. Pigs were weaned

[4] NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press, Washington, DC.

at approximately 21 d of age and allotted to the nursery according to BW and gender. A common starter diet was fed for 6 d post-weaning. On d 6, pens were allotted to 1 of 7 dietary treatments by BW and location in a randomized complete block design. Treatment diets were fed for 12 d followed by a common diet for 14 d. Both phases were fed in meal form. Pigs were weighed and feed disappearance was measured on d 0, 7, 12, 19, and 26.

Experiment 2

A total of 280 nursery pigs (DNA Genetics Line 600 × Line 241, initially 13.3 lb BW) were used in a 32-d experiment. There were 8 replicate pens per treatment and 5 pigs per pen. Pigs were weaned at approximately 20 d of age and allotted to the nursery according to BW, gender, and age. One replication was fed a common starter diet for 3 d due to heavier weaning BW and age, and then placed on experimental diets. The remaining 7 replications were fed a common starter diet for 6 d post-weaning before being placed on treatment diets. On d 3 for the first replication and d 6 for the remaining 7 replications, pens were allotted to the dietary treatments by BW in a randomized complete block design. Treatment diets were fed for 18 d followed by a common diet for 14 d. Both phases were fed in meal form. Pigs were weighed and feed disappearance was measured on d 0, 7, 14, 18, 25, and 32.

Samples of treatment diets were collected upon manufacturing at the feed mill. Proximate analysis (Ward Laboratories, Inc., Kearney, NE) was conducted on composite samples. Additionally, experimental diet samples were submitted for amino acid analysis (Ajinomoto Heartland, Chicago, IL).

Data were analyzed as a randomized complete block design using PROC GLIMMIX in SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. A base model was developed and treatments were evaluated as categorical variables with heterogeneity of variance accounted for in the models where appropriate. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$. Feed efficiency was evaluated as G:F and means reported are the reciprocal of G:F values while the *P* values reported were those obtained for the analysis of G:F.

Next, PROC GLIMMIX and PROC NLMIXED were used to predict the SID Ile:Lys ratio dose response curves to optimize ADG and ADFI as a function of the dose of dietary Ile:Lys according to procedures of Gonçalves et al. (2016).[5] As feed efficiency resulted in a minor quadratic effect only in Exp. 1, it was not modeled. Models were evaluated separately for individual experiments. Dose response models evaluated were quadratic (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models. Bayesian Information Criterion (BIC) was used to determine best fit, with a lower number indicating an improved fit. As with the base model, heterogeneous variance was accounted for where appropriate.

[5] Gonçalves, M., N. Bello, S. Dritz, M. Tokach, J. DeRouchey, J. Woodworth, and R. Goodband. 2016. An update on modeling dose–response relationships: Accounting for correlated data structure and heterogeneous error variance in linear and nonlinear mixed models. J. Anim. Sci. 94(5): 1940-1950.

Results and Discussion

Amino acid analysis of ingredients (Table 1) resulted in corn generally being slightly higher in AA concentrations as compared to published values with soybean meal being slightly lower. Field pea analysis for Exp. 1 resulted in values much lower than published levels; however, field pea AA levels for Exp. 2 were extremely close to expected values.

Proximate analysis of experimental diets (Tables 4 and 5) generally matched formulated values. Except for the 48 and 52% SID Ile:Lys ratio treatments (Exp. 1), the 40 and 44% SID Ile:Lys ratio treatments (Exp. 2), and the 54 and 58% SID Ile:Lys ratio treatments (Exp. 2), which had equal analyzed Ile content, amino acid analyses of diets were reasonably consistent with diet formulation with Ile generally increasing across the treatments and other AA remaining relatively constant.

Experiment 1

From d 0 to 12 when experimental diets were fed, ADG and ADFI improved (ADG, linear, $P < 0.001$; ADFI, quadratic, $P < 0.017$) with increasing SID Ile:Lys ratio (Table 6). However, as SID Ile:Lys ratio increased, F/G worsened (quadratic, $P < 0.041$) with the lowest and highest treatments at 40% and 63% SID Ile:Lys ratio having the best feed efficiency creating a quadratic response. During the common phase (d 12 to 28), there were no significant differences in ADG, ADFI or F/G. During the overall period, ADG tended (linear, $P < 0.082$) to improve and ADFI improved (linear, $P < 0.011$) due to increasing SID Ile:Lys ratio in diets from d 0 to 12. Similarly, BW was increased (linear, $P < 0.006$) at the end of Phase 1, but there were no treatment differences detected for final BW.

For ADG (Figures 1), the QP, BLL, and BLQ had competing fits (BIC = 558.3, 556.6, and 557.9, respectively). The QP [0.2161539 + 0.0185359×(SID Ile:Lys ratio) – 0.0001435×(SID Ile:Lys ratio)^2] reported maximum ADG at 64.7% SID Ile:Lys ratio with 99% of maximum performance captured with 57.0% SID Ile:Lys ratio. The BLL and BLQ reported similar breakpoints of 52.0% SID Ile:Lys ratio (95% CI: [51.96, 52.04%] and [51.97, 52.03%], respectively) with no further improvement in ADG found thereafter. For ADFI, (Figure 2), the BLL and QP resulted in competing fits (BIC = 603.8 and 604.4, respectively). The BLL breakpoint occurred at 50.6% SID Ile:Lys ratio (95% CI: [41.99, 59.15%]). The QP [-0.6352513 + 0.0670467×(SID Ile:Lys ratio) – 0.0005963×(SID Ile:Lys ratio)^2] reported maximum ADFI at 56.2% SID Ile:Lys ratio with 99% of maximum intake captured at 51.6% SID Ile:Lys ratio.

Experiment 2

From d 0 to 18 when experimental diets were fed, ADG and ADFI increased (quadratic, $P < 0.009$), but there were no significant differences for F/G as SID Ile:Lys ratio increased (Table 7). During the common period (d 18 to 32), there were no differences for ADG, but ADFI increased (linear, $P < 0.010$) and F/G became poorer (linear, $P < 0.009$) for pigs previously fed diets with increasing SID Ile:Lys ratio. For the overall period, ADG and ADFI increased (quadratic, $P < 0.034$) with increasing SID Ile:Lys ratio with no differences in F/G. Finally, BW was increased (quadratic, $P < 0.032$) at the end of Phase 1 and at the conclusion of the experiment.

For ADG (Figure 3), the BLL and QP were competing best fit models (BIC = 541.8 and 543.3, respectively). The BLL breakpoint occurred at 51.8% SID Ile:Lys ratio (95% CI: [47.65, 55.93%]) with no further improvement thereafter. The QP [-0.6856481 + 0.0450816×(SID Ile:Lys ratio) – 0.0003865×(SID Ile:Lys ratio)^2] reported maximum ADG at 58.3% SID Ile:Lys ratio with 99% of maximum performance captured with 54.3% SID Ile:Lys ratio. For ADFI, (Figure 4), the QP and BLQ resulted in competing fits (BIC = 591.0 and 591.7, respectively). The QP [-1.2973325 + 0.0777712×(SID Ile:Lys ratio) – 0.0006795×(SID Ile:Lys ratio)^2] reported maximum ADFI at 57.2% SID Ile:Lys ratio with 99% of maximum intake captured at 53.5% SID Ile:Lys ratio. The BLQ breakpoint occurred at 52.0% SID Ile:Lys ratio (95% CI: [51.95, 52.05%]).

In conclusion, these experiments demonstrate that the SID Ile requirement for 15 to 25 lb nursery pigs is approximately 52% of Lys for ADG and ADFI using broken line models and can be as high as 64% SID Ile:Lys ratio using quadratic models. A slight quadratic effect was observed in feed efficiency for Exp. 1, however in Exp. 2, there were no appreciable differences detected in F/G. These data validate that the Ile requirement for 15 to 25 lb pigs appears to be similar to NRC (2012) requirement estimates.

Table 1. Ingredient chemical analysis

Item, %	Corn[1,2]	Soybean meal[1,2]	Dried whey[1,2]	Field peas, Exp. 1[3]	Field peas, Exp. 2[1,3]	Spray dried blood cells[4]
Total Amino acids						
Lys	0.29	2.88	0.79	1.54	1.59	8.88
Ile	0.31	2.09	0.65	0.89	0.91	0.28
Leu	1.10	3.51	1.07	1.52	1.59	12.62
Met	0.18	0.66	0.16	0.19	0.21	1.23
Thr	0.30	1.80	0.68	0.79	0.83	4.29
Trp	0.07	0.65	0.22	0.17	0.21	1.58
Val	0.40	2.12	0.59	0.99	0.99	8.35
His	0.24	1.17	0.18	0.50	0.54	3.17
Phe	0.43	2.35	0.37	1.03	1.07	7.25
Standardized ileal digestible amino acids, % (Calculated)						
Lys	0.21	2.56	0.77	1.40	1.44	8.67
Ile	0.25	1.86	0.62	0.78	0.79	0.25
Leu	0.95	3.09	1.05	1.35	1.41	12.3
Met	0.15	0.59	0.16	0.17	0.19	1.26
Thr	0.23	1.53	0.61	0.69	0.72	4.13
Trp	0.06	0.59	0.21	0.15	0.18	1.48
Val	0.32	1.84	0.56	0.86	0.86	8.14
His	0.20	1.05	0.17	0.46	0.50	6.07
Phe	0.36	2.07	0.34	0.92	0.96	7.08

[1] Analyzed at Ajinomoto Heartland, Inc. (Chicago, IL) for amino acid content.
[2] SID % content calculated using SID coefficients from the NRC (NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington DC).
[3] Exp. 1 peas use total AA content and SID coefficients from Mathai, J. K. 2015. Effects of Fiber on the Optimum Threonine:Lysine Ratio in 25 to 50 kg Growing Gilts. MS Thesis. University of Illinois at Urbana-Champaign, Urbana. Exp. 2 peas use SID coefficients from Mathai thesis.
[4] Spray dried blood cells use total values and coefficients from Almeida, F., Htoo, J., Thomson, J., and Stein, H. (2013). Comparative amino acid digestibility in US blood products fed to weanling pigs. Animal Feed Science and Technology, 181, 80-86.

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

	Formulated SID Ile:Lys ratio, %		
Item	40	63	Common Phase
Ingredient, %			
Corn	57.68	57.59	63.77
Soybean meal (48% CP)	13.25	13.26	32.86
Dried whey	10.00	10.00	--
Field peas	10.00	10.00	--
Spray dried blood cells	1.50	1.50	--
Limestone	1.00	1.00	0.98
Monocalcium phosphate (22% P)	1.80	1.80	1.10
Sodium chloride	0.30	0.30	0.35
L-Lys-HCl	0.63	0.63	0.30
DL-Met	0.33	0.33	0.12
L-Thr	0.32	0.32	0.12
L-Trp	0.10	0.10	--
L-Val	0.24	0.24	--
L-Ile	--	0.29	--
Glutamic acid	1.10	1.00	--
Glycine	1.10	1.00	--
Trace mineral premix	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25
Zinc oxide	0.25	0.25	--
Total	100.00	100.00	100.00

continued

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

	Formulated SID Ile:Lys ratio, %		
Item	40	63	Common Phase
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lys	1.28	1.28	1.22
Ile:Lys	40	63	63
Leu:Lys	107	107	129
Met:Lys	42	42	33
Met and Cys:Lys	59	59	57
Thr:Lys	65	65	63
Trp:Lys	20.3	20.3	18.7
Val:Lys	71	71	69
Total Lys, %	1.38	1.38	1.37
ME, kcal/lb	1,464	1,468	1,484
NE, kcal/lb	1,101	1,105	1,092
SID Lys:ME, g/Mcal	3.96	3.95	3.73
SID Lys:NE, g/Mcal	5.36	5.34	5.16
CP, %	18.2	18.2	21.4
Ca, %	0.82	0.82	0.70
P, %	0.73	0.73	0.64
Available P, %	0.51	0.51	0.41

[1] Treatments 40% and 63% SID Ile:Lys were manufactured and blended at the feed mill to create the intermediate levels of 44, 48, 52, 54, and 58% SID Ile:Lys.

Table 3. Diet composition (Exp. 2, as-fed basis)[1]

	Formulated SID Ile:Lys ratio, %		
Item	40	63	Common Phase
Ingredient, %			
Corn	59.04	58.95	63.77
Soybean meal (48% CP)	11.95	11.96	32.86
Dried whey	10.00	10.00	--
Field peas	10.00	10.00	--
Spray dried blood cells	1.50	1.50	--
Limestone	1.00	1.00	0.98
Monocalcium phosphate (22% P)	1.80	1.80	1.10
Sodium chloride	0.30	0.30	0.35
L-Lys-HCl	0.60	0.60	0.30
DL-Met	0.32	0.32	0.12
L-Thr	0.31	0.31	0.12
L-Trp	0.10	0.10	--
L-Val	0.23	0.23	--
L-Ile	--	0.28	--
Glutamic acid	1.10	1.00	--
Glycine	1.10	1.00	--
Trace mineral premix	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25
Zinc oxide	0.25	0.25	--
Total	100.00	100.00	100.00

continued

Table 3. Diet composition (Exp. 2, as-fed basis)[1]

	Formulated SID Ile:Lys ratio, %		
Item	40	63	Common Phase
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lys	1.24	1.24	1.22
Ile:Lys	40	63	63
Leu:Lys	109	109	129
Met:Lys	42	42	33
Met and Cys:Lys	60	60	57
Thr:Lys	66	66	63
Trp:Lys	21	21	18.7
Val:Lys	71	71	69
Total Lys, %	1.34	1.34	1.37
ME, kcal/lb	1,464	1,468	1,484
NE, kcal/lb	1,104	1,108	1,092
SID Lys:ME, g/Mcal	3.83	3.82	3.73
SID Lys:NE, g/Mcal	5.15	5.14	5.16
CP, %	18.6	18.6	21.4
Ca, %	0.81	0.81	0.70
P, %	0.73	0.73	0.64
Available P, %	0.51	0.51	0.41

[1] Treatments 40% and 63% SID Ile:Lys were manufactured and blended at the feed mill to create the intermediate levels of 44, 48, 52, 54, and 58% SID Ile:Lys.

Table 4. Chemical analysis of diets (Exp. 1, as-fed basis)[1]

	Formulated SID Ile:Lys ratio, %[2]						
Item	40	44	48	52	54	58	63
Proximate analysis, %[3]							
DM	88.11	88.82	89.21	88.94	87.85	88.86	89.23
CP	18.0	18.7	18.6	18.7	18.8	18.8	19.0
Crude fiber	2.2	2.0	2.1	2.2	2.3	2.0	2.1
Ether extract	2.6	2.4	2.4	2.6	2.3	2.3	2.1
Ash	4.64	5.52	4.79	5.07	5.3	5.06	5.29
Amino acid analysis, %[4]							
Lys	1.28	1.34	1.40	1.42	1.39	1.45	1.41
Ile	0.59	0.67	0.74	0.74	0.79	0.86	0.93
Leu	1.46	1.50	1.52	1.52	1.53	1.51	1.56
Met	0.46	0.50	0.50	0.53	0.49	0.56	0.55
Met + Cys	0.75	0.79	0.79	0.74	0.76	0.84	0.83
Thr	0.93	0.92	0.89	0.97	0.87	0.91	0.95
Trp	0.24	0.26	0.27	0.28	0.26	0.28	0.29
Val	0.92	0.98	0.97	1.04	1.01	1.04	1.07
His	0.43	0.45	0.45	0.46	0.45	0.45	0.46
Phe	0.79	0.80	0.81	0.81	0.79	0.79	0.81

[1] Treatment diet samples were collected at the feed mill after manufacturing.
[2] Low (40% SID Ile:Lys) and high (63% SID Ile:Lys) diets were blended at the feed mill to create the intermediate treatments.
[3] Composite samples were submitted to Ward Laboratories (Kearney, NE) for proximate analysis.
[4] Composite samples were submitted to Ajinomoto Heartland Inc. (Chicago, IL) for amino acid analysis.

Table 5. Chemical analysis of diets (Exp. 2, as-fed basis)[1]

	Formulated SID Ile:Lys ratio, %[2]						
Item	40	44	48	52	54	58	63
Proximate analysis, %[3]							
DM	90.29	90.41	90.07	90.37	90.36	90.30	89.97
CP	18.1	18.4	18.6	18.2	18.3	18.7	18.7
Crude fiber	1.9	1.8	2.4	1.7	1.9	1.9	2.3
Ether extract	2.6	2.7	2.4	2.5	2.6	2.7	2.6
Ash	5.25	5.27	5.12	5.24	5.12	5.40	5.18
Amino acid analysis, %[4]							
Lys	1.33	1.34	1.34	1.36	1.36	1.35	1.33
Ile	0.60	0.60	0.65	0.69	0.75	0.75	0.82
Leu	1.47	1.43	1.45	1.47	1.48	1.47	1.48
Met	0.50	0.54	0.51	0.50	0.52	0.50	0.54
Met + Cys	0.75	0.77	0.73	0.75	0.76	0.77	0.82
Thr	0.86	0.84	0.92	0.87	0.90	0.91	0.98
Trp	0.27	0.27	0.27	0.25	0.27	0.26	0.27
Val	0.97	0.96	0.96	0.95	0.99	1.02	0.99
His	0.46	0.43	0.45	0.43	0.45	0.44	0.45
Phe	0.79	0.77	0.78	0.78	0.78	0.78	0.78

[1] Treatment diet samples were collected at the feed mill after manufacturing.
[2] Low (40% SID Ile:Lys) and high (63% SID Ile:Lys) diets were blended at the feed mill to create the intermediate treatments.
[3] Composite samples were submitted to Ward Laboratories (Kearney, NE) for proximate analysis.
[4] Composite samples were submitted to Ajinomoto Heartland Inc. (Chicago, IL) for amino acid analysis.

Table 6. Effects of increasing SID Ile:Lys ratio on nursery pig growth performance, Exp. 1[1, 2]

	Formulated SID Ile:Lys ratio, %[3]								Probability[4], *P* <	
Item	40	44	48	52	54	58	63	SEM	Linear	Quadratic
Phase 1 (d 0 to 12)										
ADG, lb	0.73	0.76	0.76	0.86	0.76	0.79	0.83	0.025	0.001	0.446
ADFI, lb	1.09	1.16	1.20	1.33	1.15	1.27	1.22	0.037	0.002	0.017
F/G[5]	1.50	1.53	1.60	1.55	1.52	1.61	1.49	0.037	0.900	0.041
Phase 2 (d 12 to 26)										
ADG, lb	1.22	1.22	1.23	1.22	1.26	1.27	1.20	0.032	0.779	0.325
ADFI, lb	1.88	1.84	1.88	1.89	1.91	1.96	1.88	0.043	0.190	0.588
F/G	1.54	1.51	1.53	1.56	1.51	1.55	1.57	0.024	0.159	0.366
Overall (d 0 to 26)										
ADG, lb	0.99	1.01	1.01	1.05	1.03	1.05	1.03	0.024	0.082	0.270
ADFI, lb	1.51	1.52	1.57	1.63	1.56	1.64	1.58	0.034	0.011	0.106
F/G	1.52	1.51	1.55	1.55	1.52	1.57	1.54	0.022	0.317	0.577
BW, lb										
d 0	14.9	14.9	14.9	14.9	14.9	14.9	14.9	0.18	0.995	0.993
d 12	23.6	23.9	23.9	25.1	23.9	24.3	24.8	0.41	0.006	0.536
d 26	40.7	41.1	41.1	42.2	41.6	41.1	41.6	0.73	0.105	0.304

[1] A total of 280 nursery pigs (PIC 327 × 1050, initially 14.9 lb BW) were used in a 26-d growth trial with 5 pigs per pen and 8 pens per treatment. Pigs were weaned at approximately 21 d, fed a common starter diet for 6 d post-weaning, then placed on experimental diets.
[2] Experimental diets were fed from d 0 to 12 and a common Phase 3 diet was fed from d 12 to 26.
[3] Low (40% SID Ile:Lys) and high (63% SID Ile:Lys) complete diets were blended upon manufacturing at the feed mill to create the 44, 48, 52, 54, and 58% SID Ile:Lys dietary treatments.
[4] *P* values reported for F/G were analyzed for G:F means.
[5] Means reported for F/G are the reciprocal of G:F.

Table 7. Effects of increasing SID Ile:Lys ratio on nursery pig growth performance, Exp. 2[1, 2]

	Formulated SID Ile:Lys ratio, %[3]								Probability[4], $P <$	
Item	40	44	48	52	54	58	63	SEM	Linear	Quadratic
Phase 1 (d 0 to 18)										
ADG, lb	0.50	0.54	0.59	0.67	0.58	0.63	0.62	0.024	0.001	0.009
ADFI, lb	0.73	0.82	0.87	1.00	0.87	0.93	0.90	0.036	0.001	0.002
F/G[5]	1.46	1.50	1.48	1.48	1.50	1.47	1.46	0.032	0.935	0.228
Phase 2 (d 18 to 32)										
ADG, lb	1.24	1.30	1.29	1.29	1.27	1.31	1.29	0.035	0.246	0.378
ADFI, lb	1.88	2.00	1.97	2.07	1.99	2.05	2.04	0.057	0.010	0.154
F/G	1.51	1.54	1.54	1.60	1.56	1.57	1.58	0.023	0.009	0.298
Overall (d 0 to 32)										
ADG, lb	0.83	0.88	0.89	0.95	0.88	0.93	0.91	0.025	0.001	0.034
ADFI, lb	1.23	1.33	1.35	1.47	1.36	1.42	1.40	0.041	0.001	0.010
F/G	1.49	1.52	1.51	1.55	1.54	1.53	1.54	0.021	0.107	0.209
BW, lb										
d 0	13.3	13.3	13.3	13.3	13.3	13.3	13.3	0.59	0.824	0.920
d 18	22.3	23.1	23.9	25.4	23.8	24.7	24.5	0.91	0.001	0.010
d 32	39.7	41.3	41.9	43.5	41.7	43.0	42.5	1.30	0.001	0.032

[1] A total of 280 nursery pigs (DNA Genetics Line 600 × Line 241, initially 13.3 lb BW) were used in a 32-d growth trial with 5 pigs per pen and 8 pens per treatment. Pigs were weaned at approximately 20 d of age. One replication was fed a common starter diet for 3 days due to increased weaning BW, and the other seven replications were fed a common starter diet for 6 d post-weaning, then placed on experimental diets.
[2] Experimental diets were fed from d 0 to 18 and a common Phase 3 diet was fed from d 18 to 32.
[3] Low (40% SID Ile:Lys) and high (63% SID Ile:Lys) complete diets were blended upon manufacturing at the feed mill to create the 44, 48, 52, 54, and 58% SID Ile:Lys dietary treatments.
[4] *P* values reported for F/G were analyzed for G:F means.
[5] Means reported for F/G are the reciprocal of G:F.

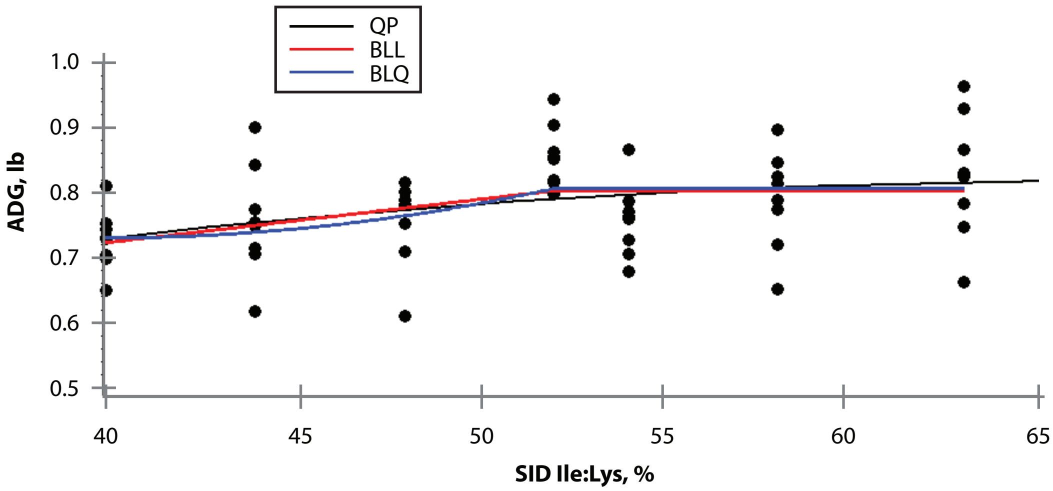

Figure 1. Estimation of the SID Ile:Lys ratio requirement to maximize ADG for nursery pigs, Exp. 1.

ADG **QP** BIC= 558.3
Max 64.7% SID Ile:Lys;
99% of Max 57.0 % SID Ile:Lys
[0.2161539 + 0.0185359×(SID Ile:Lys) – 0.0001435×(SID Ile:Lys)^2]
BLL BIC= 556.6
Breakpoint 52.0% SID Ile:Lys
95% CI:[51.96, 52.04]
BLQ BIC= 557.9
Breakpoint 52.0% SID Ile:Lys
95% CI:[51.97, 52.03]

A total of 280 nursery pigs (PIC 327 × 1050, initially 14.9 lb BW) were used in a 26-d growth trial with 5 pigs per pen and 8 pens per treatment. Pigs were weaned at approximately 21 d, fed a common starter diet for 6 d post-weaning, then placed on experimental diets. Experimental diets were fed from d 0 to 12 and a common Phase 3 diet was fed from d 12 to 26. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit for the experimental period to estimate SID Ile:Lys ratio to maximize ADG. Bayesian Information Criterion (BIC) was used to determine the best fitting model.

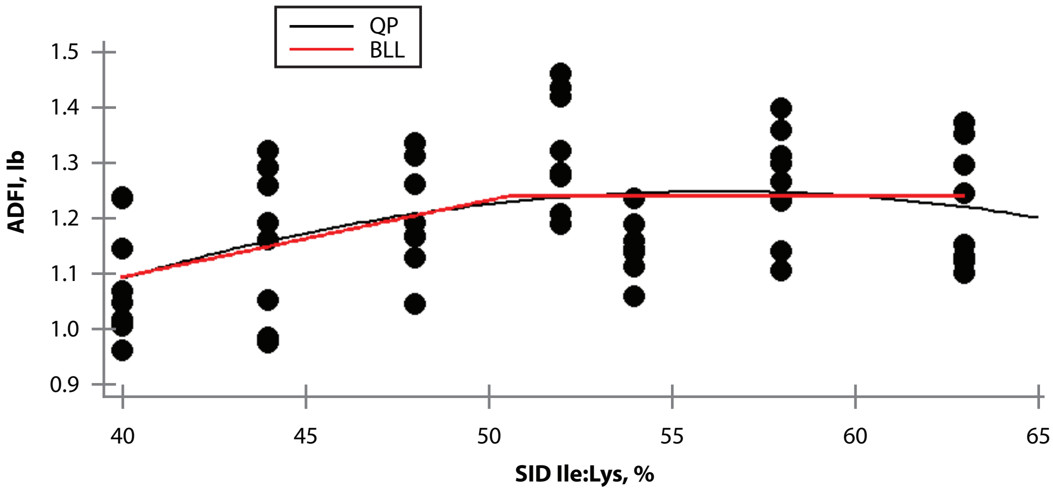

Figure 2. Estimation of the SID Ile:Lys ratio requirement to maximize ADFI for nursery pigs, Exp. 1.

ADFI **QP** BIC= 604.4
Max 56.2% SID Ile:Lys
99% of Max 51.6% SID Ile:Lys
[-0.6352513 + 0.0670467×(SID Ile:Lys) – 0.0005963×(SID Ile:Lys)^2]
BLL BIC= 603.8
Breakpoint 50.6% SID Ile:Lys
95% CI:[41.99, 59.15]

A total of 280 nursery pigs (PIC 327 × 1050, initially 14.9 lb BW) were used in a 26-d growth trial with 5 pigs per pen and 8 pens per treatment. Pigs were weaned at approximately 21 d, fed a common starter diet for 6 d post-weaning, then placed on experimental diets. Experimental diets were fed from d 0 to 12 and a common Phase 3 diet was fed from d 12 to 26. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit for the experimental period to estimate SID Ile:Lys ratio to maximize ADFI. Bayesian Information Criterion (BIC) was used to determine the best fitting model.

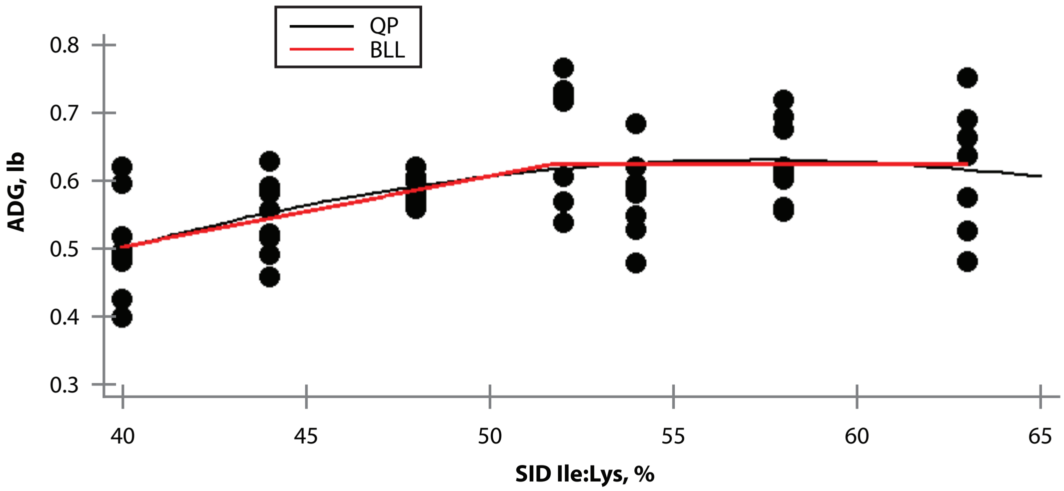

Figure 3. Estimation of the SID Ile:Lys ratio requirement to maximize ADG for nursery pigs, Exp. 2.

ADG **QP** BIC= 543.3
Max 58.3% SID Ile:Lys
99% of Max 54.3% SID Ile:Lys
[-0.6856481 + 0.0450816×(SID Ile:Lys) – 0.0003865×(SID Ile:Lys)^2]
BLL BIC= 541.8
Breakpoint 51.8% SID Ile:Lys
95% CI:[47.65, 55.93]

A total of 280 nursery pigs (DNA Genetics Line 600 × Line 241, initially 13.3 lb BW) were used in a 32-d growth trial with 5 pigs per pen and 8 pens per treatment. Pigs were weaned at approximately 20 d of age. One replication was fed a common starter diet for 3 days due to increased weaning BW, and the other seven replications were fed a common starter diet for 6 d post-weaning, then placed on experimental diets. Experimental diets were fed from d 0 to 18 and a common Phase 3 diet was fed from d 18 to 32. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit for the experimental period to estimate SID Ile:Lys ratio to maximize ADG. Bayesian Information Criterion (BIC) was used to determine the best fitting model.

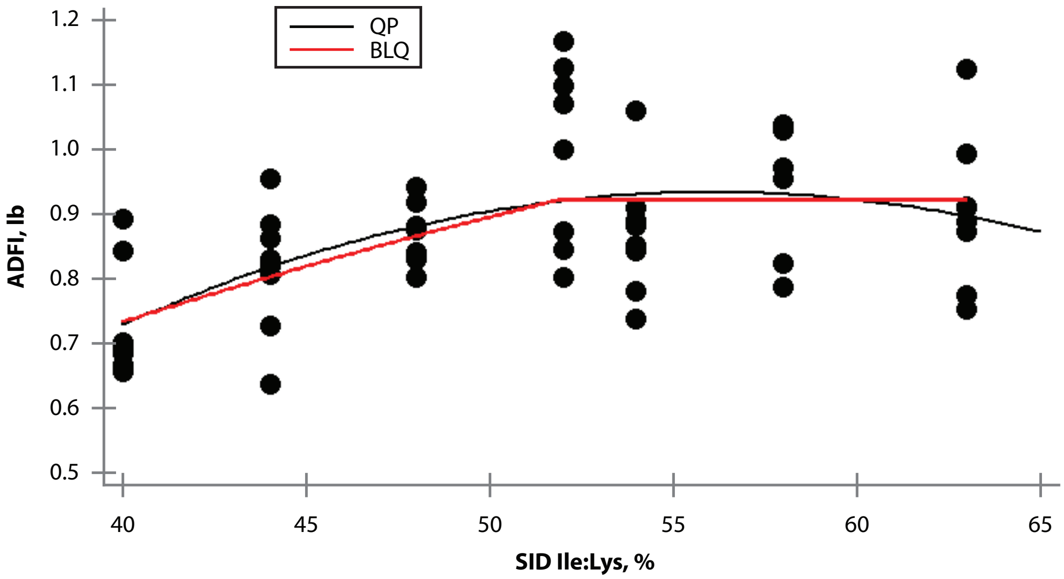

Figure 4. Estimation of the SID Ile:Lys ratio requirement to maximize ADFI for nursery pigs, Exp. 2.

ADFI **QP** BIC= 591.0
Max 57.2% SID Ile:Lys
99% of Max 53.5% SID Ile:Lys
[-1.2973325 + 0.0777712×(SID Ile:Lys) – 0.0006795×(SID Ile:Lys)^2]
BLQ BIC= 591.7
Breakpoint 52.0% SID Ile:Lys
95% CI:[51.95, 52.05]

A total of 280 nursery pigs (DNA Genetics Line 600 × Line 241, initially 13.3 lb BW) were used in a 32-d growth trial with 5 pigs per pen and 8 pens per treatment. Pigs were weaned at approximately 20 d of age. One replication was fed a common starter diet for 3 days due to increased weaning BW, and the other seven replications were fed a common starter diet for 6 d post-weaning, then placed on experimental diets. Experimental diets were fed from d 0 to 18 and a common Phase 3 diet was fed from d 18 to 32. Quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models were fit for the experimental period to estimate SID Ile:Lys ratio to maximize ADFI. Bayesian Information Criterion (BIC) was used to determine the best fitting model.