Effects of Standardized Ileal Digestible Lysine on 15- to 25-lb Nursery Pigs

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Summary

A total of 300 pigs (DNA 241 × 600; initial pen average BW of 15.4 lb) were used in a 22-d growth trial to determine the standardized ileal digestible (SID) lysine (Lys) requirement of nursery pigs from 15- to 25-lb. Pigs were weaned at approximately 21 d of age and allotted to pens based on BW and gender. There were 10 replicate pens per treatment and 6 pigs per pen. Pigs were fed a common pelleted diet for 10 d post-weaning. Subsequently, pens of pigs were randomly assigned to 1 of 6 experimental diets in a randomized complete block design, with BW as a blocking factor. Dietary treatments consisted of 1.10, 1.20, 1.30, 1.40, 1.50, and 1.60% SID Lys and were achieved by the inclusion of crystalline amino acids at the expense of corn. Experimental diets were fed for 11 d followed by a common diet fed for 11 d. Experimental data were analyzed using generalized linear and non-linear mixed models, fitting the data with heterogeneous residual variances as needed. Competing models included linear (LM), quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ). For the overall treatment period, increasing SID Lys improved (linear, $P < 0.001$) ADG and F/G, with no differences observed in ADFI. Similarly, as dietary SID Lys increased, BW increased linearly on d 11 and 22. Feed cost per pig, feed cost per pound of gain, and total revenue per pig increased (linear, $P < 0.001$) as SID Lys increased, with no observed differences in income over feed cost (IOFC). For ADG, the best-fitting models were the LM and QP models. The maximum mean ADG was estimated at greater than 1.60%, and at 1.54% (95% CI: [1.34, >1.60]%), with 99% of the maximum ADG achieved at 1.43% SID Lys, in the LM and QP models, respectively. Similarly, the best-fitting models for feed efficiency were LM and QP, both estimating the requirement at greater than 1.60% SID Lys. In conclusion, this experiment determined that the mean SID Lys required for nursery pigs from 15- to 25-lb ranged from 1.54% to at least 1.60%. These data provide evidence that different response variables and statistical models can result in different estimates of the requirements. However, formulating nursery diets for 15- to 25-lb pigs to 1.40% would allow for the highest income and approximately 99% of maximum growth to be captured.

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Introduction

Lysine (Lys) is the first limiting amino acid (AA) in practical corn and soybean meal-based diets fed to pigs. Lysine is also essential to establish the requirement of the next-limiting amino acids as they are expressed and formulated as its ratio. Estimation of accurate Lys requirements for each growth phase is critical to optimize growth performance and economic response criteria. The use of standardized ileal digestible (SID) AA approach in diet formulation helps to enhance the ingredient utilization. Although several experiments have been conducted in recent years to determine the Lys requirement from 15 to 25 lb, we are not aware of any research using DNA genetics in this weight range. In addition, statistical modeling capabilities and the selection of the statistical model that best fits the data helps estimate the pig's requirement more precisely. Therefore, the objective of the present study was to determine the SID Lys requirement of DNA nursery pigs weighing approximately 15 to 25 lb.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the K-State Swine Teaching and Research Center in Manhattan, KS.

A total of 300 terminal line nursery pigs (DNA 241 × 600; DNA; initially pen average BW of 15.4 lb) were used in a 22-d growth trial. Pigs were weaned at approximately 21 d of age, and allotted to pens of 6 pigs according to initial BW and gender upon entry in the nursery. At weaning, pigs were fed a common pelleted diet for 10 d. At d 10 after weaning, which was considered d 0 of the trial, the pens of pigs were randomly assigned to 6 different dietary treatments in a randomized complete block design. There were 10 replicate pens per treatment and BW was used as the blocking factor. The experimental diets consisted of different SID Lys concentrations of 1.10, 1.20, 1.30, 1.40, 1.50, and 1.60%. Dietary treatments were fed for 11 d followed by a common diet fed for 11 d, with both phases fed in meal form. Each pen was equipped with a 4-hole, dry self-feeder and a cup waterer to provide ad libitum access to feed and water. Pens of pigs were weighed and feed disappearance was recorded on d 0, 7, 11, and 22 to determine ADG, ADFI, and F/G.

The SID Lys levels of the experimental diets were achieved by increasing the inclusion of crystalline AA at the expense of corn, which allowed the amount of soybean meal to stay similar across dietary treatments (Table 1). Treatment diets were corn and soybean meal-based, and contained 10% dried whey. Extreme diets (1.10 and 1.60% SID Lys) were manufactured first and then blended to create the intermediate treatments. All experimental diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center. Diet samples were taken from 6 feeders per dietary treatment every week. After blending, subsamples were analyzed for DM, CP, crude fiber, ash, and ether extract (Ward Laboratories, Inc., Kearney, NE, Table 2). The subsamples were also sent to Ajinomoto Heartland, Inc. (Chicago, IL) for AA analysis (Table 2).

For the economic analysis, total feed cost per pig, cost per lb of gain, revenue, and income over feed cost (IOFC) were calculated. The total feed cost per pig was calculated by multiplying ADFI by diet cost and the number of days it was fed. Cost per lb of gain was calculated by dividing the total feed cost per pig by the total lb gained overall. Revenue per pig was calculated by multiplying the ADG by the total days in the trial times the assumed live price of $46.49 per cwt. To calculate IOFC, total feed cost was subtracted from pig revenue. For all economic evaluations, price of ingredients during fall of 2016 was used; therefore, corn was valued at $3.50/bu ($153/ton), soybean meal at $320/ton, L-lysine HCL at $0.83/lb, DL-methionine at $1.75/lb, L-threonine at $0.96/lb, L-tryptophan at $3.90/lb, and L-valine at $5.00/lb.

The study consisted of a completely randomized design, with pen as the experimental unit and BW as the blocking factor. The response variables were analyzed using generalized linear and non-linear mixed models. Polynomial contrasts were implemented to evaluate the linear and quadratic effects of the dose response to increasing dietary SID Lys on ADG, ADFI, BW, F/G, feed cost/pig, feed cost/lb of gain, total revenue/pig, and IOFC. Statistical models were fitted using the GLIMMIX procedure of SAS (Version 9.3, SAS Institute Inc., Cary, NC). Results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Competing statistical dose response models, including a linear (LM), quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) were built using NLMIXED procedure of SAS according to the procedures of Gonçalves et al.[2] Models were expanded to account for heterogeneous residual variances when needed. Competing dose response models were compared based on the Bayesian information criterion (BIC), where the smaller the value, the better.[3] The 95% confidence interval of the estimated requirement to reach maximum performance or to reach plateau performance was computed. Results reported correspond to inferences yielded by the best fitting models.

Results and Discussion

Diet analysis (Table 2) showed that all the values were reasonably consistent with formulated levels. Amino acid analysis showed a stepwise increase in total Lys levels as treatments increased in formulated SID Lys values.

During the experimental period (d 0 to 11), ADG and F/G improved (linear, $P < 0.001$) as SID Lys increased; however, no evidence for difference was observed for ADFI ($P > 0.10$; Table 3). There was no evidence for significant differences in ADG, ADFI, and F/G during the common period (d 11 to 22; $P > 0.10$). Overall (d 0 to 22), ADG and F/G improved in a linear manner as SID Lys increased ($P < 0.001$), with no evidence for differences in ADFI ($P > 0.10$). As dietary SID Lys increased, BW increased linearly ($P < 0.05$) on d 11 and 22. Similarly, feed cost per pig, feed cost per pound of gain, and total revenue per pig increased (linear, $P < 0.001$) as SID Lys increased, with no observed differences in IOFC.

[2] 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. Journal of Animal Science. 94(5): 1940-1950.

[3] Milliken, G. A., and D. E. Johnson. 2009. Analysis of messy data: designed experiments. Vol. 1, 2nd ed., CRC Press, Boca Raton, FL.

Heterogeneous variance was used for both ADG and feed efficiency models. For ADG (Figure 1), the best fitting models were the LM and QP. The maximum mean ADG was estimated at greater than 1.60%, and at 1.54% (95% CI: [1.34, >1.60]%), with 99% of the maximum ADG achieved at 1.43% SID Lys in the LM and QP models, respectively. The estimated regression equations were ADG, lb = 0.529 + 0.275 × (SID Lys) and ADG, lb = -0.708 + 2.145 × (SID Lys) – 0.696 × $(\text{SID Lys})^2$ for the LM and QP models, respectively. Similarly, the LM and QP models demonstrated better fit to feed efficiency, modeled as G:F (Figure 2). The maximum mean G:F was estimated at greater than 1.60% for both models. The estimated regression equations were G:F, g/kg = 197.86 + 576.14 × (SID Lys) – 140.25 × $(\text{SID Lys})^2$, and G:F, g/kg = 458.78 + 190.56 × (SID Lys) for the QP and LM, respectively.

In conclusion, the estimated SID Lys required for maximum mean ADG was lower than that required for maximum mean F/G as reported by the QP model. Using the QP model, the maximum mean ADG was at 1.53%, with 99% of maximum growth being achieved at 1.43% SID Lys. No plateau or maximum mean feed efficiency was achieved, with the requirement estimated of at least 1.60%. However, after 1.40% SID Lys, feed efficiency improves with diminishing returns. Although no evidence for differences were observed in IOFC, the highest mean IOFC was achieved at 1.40% SID Lys. Therefore, formulating nursery diets for 15- to 25-lb pigs to 1.40% would allow for the highest income and approximately 99% of maximum growth to be captured.

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

	Standardized ileal digestible Lys		Common
Item	1.10	1.60	phase
Ingredient, %			
Corn	58.78	47.88	62.92
Soybean meal (48% CP)	26.91	27.07	33.68
Dried whey	10.00	10.00	---
HP 300[2]	0.00	10.00	---
Limestone	1.00	1.00	0.95
Monocalcium phosphate (21%P)	1.60	1.50	1.15
Sodium chloride	0.55	0.55	0.35
L-Lys-HCl	0.25	0.55	0.30
DL-Met	0.13	0.33	0.12
L-Thr	0.10	0.26	0.12
L-Trp	0.02	0.06	---
L-Val	0.01	0.15	---
Trace mineral premix	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25
Phytase[3]	---	---	0.02
Zinc oxide	0.25	0.25	---
Total	100.00	100.00	100.00

continued

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

	Standardized ileal digestible Lys		Common phase
	1.10	1.60	
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lys	1.10	1.60	1.24
Ile:Lys	64	57	63
Leu:lys	132	109	129
Met:Lys	36	40	33
Met and Cys:Lys	60	60	57
Thr:Lys	65	65	63
Trp:Lys	20.8	20.3	18.7
Val:Lys	70	70	69
Total Lys, %	1.23	1.77	1.39
ME, kcal/lb	1,473	1,494	1,483
NE, kcal/lb	1,098	1,089	1,070
SID Lys:ME, g/Mcal	3.39	4.86	3.79
CP, %	19.3	24.7	21.7
Ca, %	0.79	0.80	0.70
P, %	0.76	0.79	0.65
Standardized total tract digestible P, %	0.51	0.52	0.48
Available P, %	0.48	0.48	0.43

[1] Treatments 1.10% and 1.60% SID Lys were manufactured and blended at the feed mill to create the intermediate levels of 1.20%, 1.30%, 1.40%, and 1.50% SID Lys.

[2] Hamlet Protein, Findley, OH.

[3] Ronozyme HiPhos GT 2700 FYT/g was added with an expected release value of 0.14% available P.

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

	Standardized ileal digestible Lys, %						Common
Item, %	1.10	1.20	1.30	1.40	1.50	1.60	phase
DM	89.71	90.24	89.27	90.27	90.14	90.3	88.86
CP	19.3	21.2	21.6	22.2	24.0	24.2	21.0
Crude fiber	2.0	2.1	2.1	2.0	2.3	1.9	2.2
Ether extract	2.5	2.5	2.4	2.3	2.2	2.4	2.7
Ash	6.13	5.87	6.30	6.29	6.14	6.05	4.57
Amino acids, %							
Lys	1.12	1.29	1.41	1.43	1.52	1.59	1.38
Thr	0.81	0.89	0.90	1.02	1.06	1.10	0.90
Trp	0.25	0.28	0.28	0.31	0.32	0.33	0.26
Val	0.87	0.97	1.00	1.04	1.08	1.15	1.00
Ile	0.80	0.88	0.90	0.91	0.95	1.00	0.93
Phe	1.11	1.00	1.01	1.03	1.06	1.11	1.08
His	0.45	0.50	0.51	0.52	0.53	0.56	0.54
Leu	1.61	1.75	1.76	1.79	1.81	1.90	1.85
Met	0.38	0.44	0.47	0.51	0.54	0.57	0.42
Cys	0.33	0.36	0.37	0.37	0.37	0.38	0.38
Met + Cys	0.71	0.80	0.83	0.88	0.91	0.96	0.80

[1] A representative sample of each diet was collected from 6 feeders, homogenized, and submitted to Ward Laboratories, Inc., Kearney, NE for analysis of DM, CP, crude fiber, ether extract, and ash. Amino acid analysis was conducted on composite samples by Ajinomoto Heartland, Inc., Chicago, IL.

Table 3. Effects of increasing standardized ileal digestible lysine on growth performance of nursery pigs[1]

	SID Lys, %							Probability, *P*<	
Item	1.10	1.20	1.30	1.40	1.50	1.60	SEM	Linear	Quadratic
Treatment phase (d 0 to 11)									
ADG, lb	0.80	0.88	0.88	0.99	0.94	0.96	0.029	0.001	0.106
ADFI, lb	1.19	1.30	1.23	1.34	1.26	1.27	0.040	0.253	0.182
F/G	1.51	1.51	1.42	1.37	1.37	1.35	0.032	0.001	0.495
Common phase (d 11 to 22)									
ADG, lb	1.11	1.15	1.13	1.19	1.13	1.16	0.028	0.281	0.336
ADFI, lb	1.84	1.86	1.84	1.91	1.83	1.87	0.037	0.611	0.704
F/G	1.66	1.63	1.63	1.60	1.62	1.62	0.025	0.275	0.331
Overall (d 0 to 22)									
ADG, lb	0.96	1.01	1.00	1.09	1.04	1.06	0.023	0.001	0.124
ADFI, lb	1.52	1.58	1.54	1.62	1.55	1.57	0.034	0.350	0.337
F/G	1.56	1.56	1.50	1.46	1.46	1.45	0.023	0.001	0.317
BW, lb									
d 0	15.4	15.5	15.4	15.4	15.5	15.5	0.26	0.971	0.995
d 11	24.3	25.1	25.1	26.5	25.8	26.1	0.47	0.003	0.209
d 22	36.5	37.7	37.5	39.6	38.3	38.8	0.67	0.010	0.190
Economics									
Feed cost/pig, $	2.08	2.42	2.45	2.82	2.82	3.00	0.083	0.001	0.231
Feed cost/lb gain, $[2]	0.24	0.25	0.26	0.26	0.27	0.28	0.006	0.001	0.746
Total revenue/pig, $[3,4]	4.38	4.76	4.76	5.39	5.09	5.24	0.150	0.001	0.106
IOFC[5]	2.26	2.34	2.31	2.57	2.27	2.24	0.109	0.839	0.145

[1] A total of 300 pigs (241 × 6000, DNA, initially 15.5 lb BW) were used in a 22-d growth trial with 6 pigs per pen and 10 pens per treatment. Pigs were fed a common pelleted diet for 10 d post-weaning. After 11 d of treatment diets, pigs were fed a common phase 3 diet for 11 d.

[2] Feed cost/lb gain = total feed cost divided by total gain per pig. Cost per ton used considering processing costs.

[3] One pound of live gain was considered to be worth $0.4649.

[4] Total revenue/pig = total gain/pig × $0.4649.

[5] Income over feed cost = total revenue/pig – feed cost/pig.

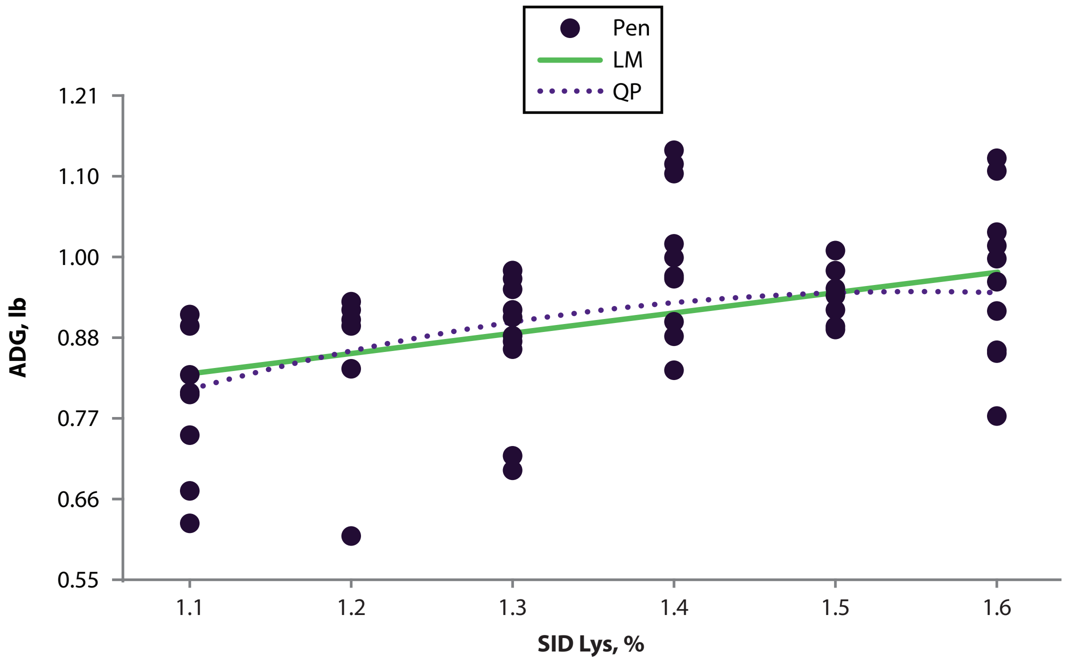

Figure 1. Fitted linear model (LM) and quadratic polynomial (QP) regression models on ADG as a function of increasing standardized ileal digestible (SID) Lys in 15- to 25-lb pigs. The maximum mean ADG was estimated at greater than 1.60%, and at 1.54% (95% CI: [1.34, >1.60]%), with 99% of the maximum ADG achieved at 1.43% SID Lys in the LM and QP models, respectively. The estimated regression equations were ADG, lb = 0.529 + 0.275 × (SID Lys) and ADG, lb = -0.708 + 2.145 × (SID Lys) – 0.696 × $(\text{SID Lys})^2$ for the LM and QP models, respectively.

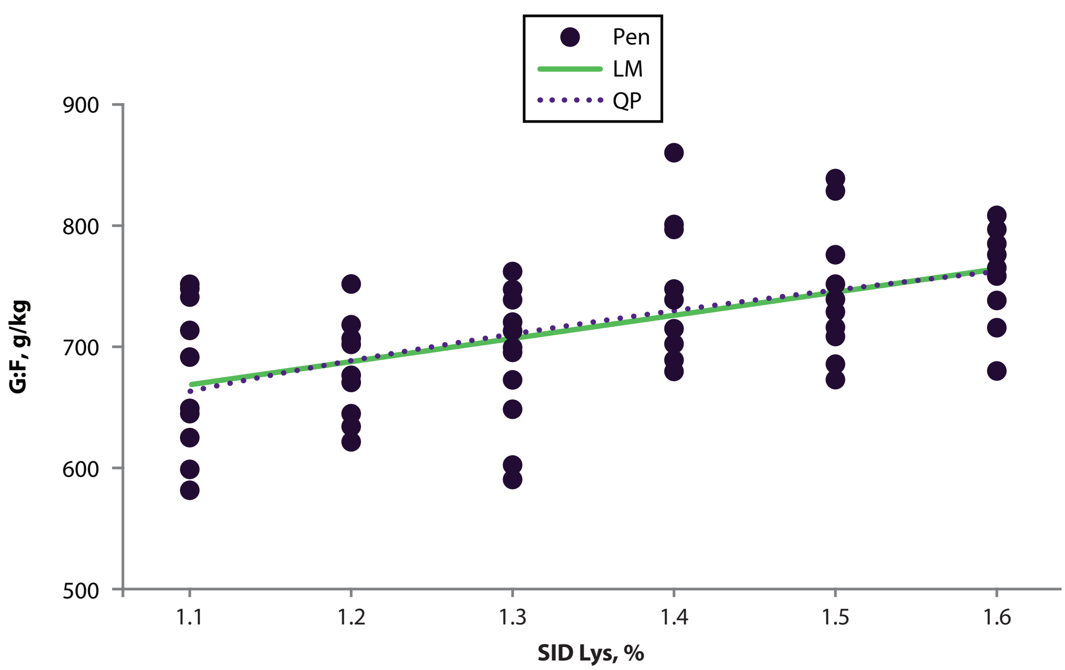

Figure 2. Fitted linear model (LM) and quadratic polynomial (QP) regression models on G:F as a function of increasing standardized ileal digestible (SID) Lys in 15- to 25-lb pigs. The maximum mean G:F was estimated at greater than 1.6% for both models. The estimated regression equations were G:F, g/kg = 197.86 + 576.14 × (SID Lys) – 140.25 × $(\text{SID Lys})^2$, and G:F, g/kg = 458.78 + 190.56 × (SID Lys) for the QP and LM, respectively.