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Effects of Standardized Ileal Digestible Lysine Level on Growth Performance in 120 to 170 lb DNA Finishing Pigs

Rafe Q. Royall, Robert D. Goodband, Mike D. Tokach, Joel M. DeRouchey, Jordan T. Gebhardt,[1] and Jason C. Woodworth

Summary

The objective of this study was to estimate the SID Lys requirement for growth and feed efficiency of 120- to 170-lb finishing pigs. A total of 700 barrows and gilts (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used in two separate studies, each lasting 21-d. Pens of pigs were blocked by BW and randomly allotted to 1 of 6 dietary treatments with 8 to 10 pigs per pen in a randomized complete block design. A similar number of barrows and gilts were placed in each pen. Dietary treatments were corn-soybean meal-based and formulated to 0.65, 0.72, 0.79, 0.86, 0.93, and 1.00% SID Lys, with 12 replications per treatment. Increasing SID Lys increased (linear, $P < 0.001$) ADG, with pigs fed 1.00% SID Lys having the greatest final BW. In addition, increasing SID Lys decreased (quadratic, $P = 0.004$) ADFI. Feed efficiency improved, while Lys intake/d, and Lys intake/kg of gain increased (quadratic, $P < 0.005$), with increasing SID Lys. At both high and low ingredient and pig prices, feed cost/pig increased (quadratic, $P < 0.05$) as SID Lys increased, while feed cost/lb of gain decreased (quadratic, $P < 0.001$), with pigs fed 0.79% SID Lys having the lowest feed cost/lb of gain. At high and low feed prices, increasing SID Lys increased (linear, $P < 0.002$) IOFC.

A linear model resulted in the best fit for ADG and predicted that the maximum ADG response was beyond 1.00% SID Lys. For F/G, the quadratic polynomial model predicted a requirement of 0.97% SID Lys. At high ingredient and pig prices, the broken-line linear model to maximize IOFC predicted that there was no further significant improvement to IOFC past 0.76% SID Lys. Meanwhile, at low ingredient and pig prices the quadratic polynomial model predicted a requirement of 0.91% SID Lys to maximize IOFC, however, a similar fitting linear model predicted maximum IOFC response at greater than 1.00% SID Lys. In summary, the optimal SID Lys level for 120- to 170-lb finishing pigs depends upon the response criteria, with growth performance optimized at or greater than 0.97% SID Lys and IOFC maximized between 0.76 to 0.91% SID Lys.

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Introduction

In order to optimize growth performance and efficiency it is vitally important to have an accurate estimation of dietary requirements for proper diet formulation. Due to modern advancements in dose-response models, it has become increasingly possible to set precise requirement estimations.[2] This pair of trials is a part of a larger study with the objective of predicting the SID Lys requirement of DNA 600 sired pigs from approximately 50 to 285 lb. The objective of this study was to determine the SID Lys requirement of DNA 600 × 241 pigs from 120- to 170- lb BW to optimize growth performance and economic return.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. The facility was totally enclosed and environmentally regulated, containing 36 pens. Each pen was equipped with a dry, single-sided feeder (Farmweld, Teutopolis, IL) and a 1-cup waterer. Pens were located over a completely slatted concrete floor with a 4-ft pit underneath for manure storage. A robotic feeding system (FeedPro; Feedlogic Corp., Wimar, MN) was used to deliver and record daily feed additions to each individual pen.

Animals and diets

A total of 700 pigs (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used in two separate studies, each lasting 21 d. There were 8 to 10 pigs per pen with similar numbers of barrows and gilts in each pen. Pens were equipped with adjustable gates to allow 7.83 ft^2 per pig to be maintained if a pig died or was removed from a pen during the experiment. Pens of pigs were allotted by BW and randomly assigned to 1 of 6 dietary treatments in a complete randomized block design. The dietary treatments included 6 SID Lys concentrations (0.65, 0.72, 0.79, 0.86, 0.93, and 1.00%), with 12 replications per treatment. Pigs were provided *ad libitum* access to water and to feed in meal form.

To formulate the experimental diets, a corn-soybean meal diet with 0.65% SID Lys was formulated containing 0.19% L-Lys HCl and other feed-grade AAs as necessary to maintain appropriate ratios relative to Lys. Then a 1.00% SID Lys corn-soybean meal diet was formulated containing 0.28% L-Lys HCl and other feed-grade AAs as necessary to maintain appropriate ratios relative to Lys. Amino acid ratios relative to Lys were maintained well above requirement estimates to ensure that Lys was the first-limiting AA. The 0.65 and 1.00% SID Lys diets were blended via a robotic feeding system to create the 0.72, 0.79, 0.86 and 0.93% SID Lys diets (Table 1). Pigs were weighed and feed disappearance was recorded on d 0, 7, 14 and 21 of each trial to determine ADG, ADFI, and F/G.

Economic analysis

For the economic analysis, feed cost/pig, feed cost/lb gain, revenue per pig, and income over feed cost (IOFC) were calculated for high- and low-priced diets. Diet costs were determined using the following ingredient costs for the high-priced diets:

[2] Gonçalves, M., N. Bello, S. Dritz, M. Tokach, J. DeRouchey, J. Woodworth, R. Goodband 2015. An update on modeling dose-response relationships: accounting for correlated data structures and heterogeneous variance in linear and non-linear mixed models. J. Anim. Sci. 94: 1940-1950.

corn = \$6.00/bushel (\$214/ton); soybean meal = \$400/ton; L-Lys HCl = \$0.80/lb; DL-methionine = \$2.50/lb; L-threonine = \$1.20/lb; L-tryptophan = \$5.00/lb; and L-valine = \$4.00/lb. Diet costs were determined using the following ingredient costs for the low-priced diets: corn = \$3.00/bushel (\$107.14/ton); soybean meal = \$300/ton; L-Lys HCl = \$0.65/lb; DL-methionine = \$1.70/lb; L-threonine = \$0.85/lb; L-tryptophan = \$3.00/lb; and L-valine = \$2.50/lb. Feed cost/pig was determined by total feed intake × diet cost (\$/lb). Feed cost/lb of gain was calculated using feed cost/pig divided by total gain. Revenue per pig was determined for both a high price and a low price by total gain × \$0.66/lb live gain or total gain × \$0.45/lb live gain, respectively. Income over feed cost (IOFC) was calculated using revenue/pig – feed cost/pig.

Statistical analysis

Data were analyzed as a randomized complete block design for one one-way ANOVA using the lmer function from the lme4 package in R Studio (Version 3.5.2, R Core Team. Vienna, Austria) with pen serving as the experimental unit, initial BW as blocking factor, and treatment as fixed effect. Dose response curves were evaluated using linear (LM), quadratic polynomial (QP), and broken-line linear (BLL) models. For each response variable, the best-fitting model was selected using the Bayesian Information Criterion (BIC). A decrease in BIC greater than 2.0 among models for a particular response criterion was considered an improved fit. Results were considered significant with $P \leq 0.05$ and were considered marginally significant with $P \leq 0.10$.

Results and Discussion

When analyzing overall growth performance, increasing the SID Lys increased (linear, $P < 0.001$) ADG, resulting in pigs fed 1.00% SID Lys having the highest BW at each weighing event. In addition, ADFI decreased (quadratic, $P = 0.004$) with increasing SID Lys, resulting in pigs fed 0.93% SID Lys having the lowest numeric feed intake. Feed efficiency improved (quadratic, $P < 0.001$), Lys intake/d increased (quadratic, $P = 0.003$), and Lys intake/kg of gain increased (quadratic, $P = 0.002$) as SID Lys increased. Feed cost/pig increased (quadratic, $P < 0.05$) as SID Lys increased at both high and low prices. Moreover, at both high and low prices, feed cost/lb of gain had a quadratic response ($P < 0.001$), with pigs fed diets containing 0.79% SID Lys having the lowest cost of gain. Total revenue/pig increased (linear, $P < 0.001$) with increasing SID Lys at both high and low costs. Income over feed cost, at both high and low ingredient and pig prices, increased (linear, $P < 0.001$) with increasing SID Lys.

The best fitting model for predicting ADG requirement was the LM model, which estimated that maximum ADG would be achieved by feeding greater than 1.00% SID Lys. For minimization of F/G, the resulting QP model had the best fit, with this model predicting the lowest F/G response to be at 0.97% SID Lys. The QP model equation was: $F/G = 3.1539 \times (\text{SID Lys, \%})^2 - 6.0974 \times (\text{SID Lys, \%}) + 5.1945$, with 0.95% of the lowest F/G estimated at 0.78% SID Lys. Economic impacts of increasing SID Lys were calculated using IOFC at high and low ingredient and pig prices to optimize profitability. At high prices the best fitting model to predict maximum IOFC was the BLL model, which predicted no further increase in IOFC past 0.76% SID Lys. Meanwhile, at low prices, the QP and LM models resulted in a similar fit (BIC = 192.8 vs. 192.3, QP vs. LM, respectively); with the QP model predicting maximum IOFC at 0.91% SID Lys. The QP model equation was: $\text{IOFC} = -14.5694 \times (\text{SID Lys, \%})^2 + 26.6594 \times (\text{SID Lys, \%}) - 0.0571$, with 95% of the greatest IOFC at 0.71% SID Lys (Figures 1 to 4).

In summary, for maximum growth, feed efficiency, and economic return, it is recommended that the optimal SID Lys level for 120- to 170-lb finishing pigs depends upon the response criteria, with growth performance optimized at or greater than 0.97% SID Lys and IOFC maximized between 0.76 to 0.91% SID Lys. However, these calculations are largely a result of set ingredient and market pig prices. As a result, maximum growth performance should always be compared with potential economic returns to determine the optimal dietary SID Lys level. In addition, further statistical and economic analysis will be conducted in combination with subsequent trials to create a model to predict the SID Lys requirements of DNA 600 sired pigs throughout the grow-finish phase.

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

Item	SID Lys, % 0.65	0.72	0.79	0.86	0.93	1.00
Ingredient, %						
Corn	83.12	80.98	78.63	76.49	74.35	71.87
Soybean meal (46.5% CP)	13.15	15.36	17.74	19.95	22.15	24.69
Corn oil	1.40	1.30	1.25	1.15	1.05	1.00
Limestone	0.80	0.79	0.79	0.78	0.78	0.78
Monocalcium P (21% P)	0.58	0.55	0.53	0.50	0.48	0.43
Sodium chloride	0.50	0.50	0.50	0.50	0.50	0.50
L-Lys-HCl	0.19	0.21	0.23	0.25	0.27	0.28
DL-Met	0.02	0.03	0.05	0.07	0.08	0.10
L-Thr	0.04	0.06	0.08	0.09	0.11	0.11
L-Trp	0.01	0.01	0.01	0.01	0.01	0.01
L-Val	0.01	0.02	0.02	0.03	0.04	0.05
Vitamin premix with phytase[2]	0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100	100
Calculated analysis[3]						
SID AA, %						
Lys, %	0.65	0.72	0.79	0.86	0.93	1.00
Ile:Lys	68	66	66	65	64	64
Leu:Lys	171	162	155	148	143	139
Met:Lys	33	34	34	35	35	35
Met and Cys:Lys	65	63	63	62	61	61
Thr:Lys	66	66	66	66	66	65
Trp:Lys	19	19	19	19	19	19
Val:Lys	80	78	77	76	75	75
His:Lys	49	47	46	44	43	43
ME, kcal/lb	1,533	1,531	1,529	1,527	1,525	1,524
NE, kcal/lb	1,224	1,225	1,225	1,225	1,225	1,226
SID Lys:NE, g/Mcal	2.41	2.67	2.93	3.18	3.44	3.70
CP, %	13.4	14.3	15.2	16.2	17.1	18.1
Ca, %	0.51	0.51	0.51	0.51	0.51	0.51
STTD P, %	0.32	0.32	0.32	0.32	0.32	0.32

[1]Treatment diets were fed to 700 pigs (600 × 241, DNA; initially 117.2 ± 1.89 lb). Treatment diets were fed from d 0 to 21.
[2] HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided 227 FTU/lb, for an estimated release of 0.09% STTD P.
[3] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

Table 2. Effects of increasing lysine on growth performance in DNA finishing pigs from 120-170 lb[1]

	SID Lys, %							*P* =	
Item	**0.65**	**0.72**	**0.79**	**0.86**	**0.93**	**1.00**	**SEM**	**Linear**	**Quadratic**
BW, lb									
d 0	117.1	117.3	117.3	117.2	117.1	117.3	1.89	0.926	0.857
d 21	160.7	161.9	163.4	163.7	164.6	166.6	2.28	< 0.001	0.804
d 0 to 21									
ADG, lb	2.08	2.12	2.20	2.22	2.27	2.34	0.038	< 0.001	0.910
ADFI, lb	5.34	5.14	5.13	5.12	5.11	5.25	0.106	0.295	0.004
F/G	2.57	2.43	2.33	2.31	2.25	2.25	0.027	< 0.001	< 0.001
SID Lys g/d	15.79	16.78	18.37	19.97	21.56	23.94	0.396	< 0.001	0.003
SID Lys g/kg gain	16.76	17.47	18.43	19.83	20.96	22.58	0.220	< 0.001	0.002
Economic, $									
High ingredient prices[2]									
Feed cost/pig	15.04	15.23	15.07	15.53	15.57	16.45	0.344	< 0.001	0.023
Feed cost/lb gain[3]	0.345	0.332	0.327	0.330	0.327	0.335	0.0038	0.012	< 0.001
Total revenue/pig[4]	28.79	30.20	30.43	31.10	31.42	32.48	0.566	< 0.001	0.745
IOFC[5]	13.76	14.97	15.36	15.57	15.85	16.03	0.326	< 0.001	0.063
Low ingredient prices[6]									
Feed cost/pig	8.64	8.78	8.83	9.23	9.34	10.05	0.203	< 0.001	0.006
Feed cost/lb gain	0.198	0.192	0.191	0.196	0.196	0.204	0.0023	0.002	< 0.001
Total revenue/pig	19.63	20.59	20.75	21.20	21.42	22.15	0.386	< 0.001	0.745
IOFC	10.99	11.81	11.92	11.97	12.08	12.10	0.238	0.002	0.063

[1]A total of 700 pigs (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used with 8 to 10 pigs per pen and 12 replications per treatment and were fed trial diets for a 21-d period in two groups.

[2] For high-priced diets, corn was valued at $6.00/bu ($214/ton), soybean meal at $400/ton, L-Lys at $0.80/lb, DL-Met at $2.50/lb, L-Thr at $1.20/lb, L-Trp at $5.00/lb, and L-Val at $4.00/lb.

[3] Feed cost/lb gain = (feed cost/pig) / total gain.

[4] Total revenue/pig = total gain/pig × gain value ($0.66/lb at high prices; $0.45/lb at low prices).

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

[6] For low priced diets, corn was valued at $3.00/bu ($107.14/ton), soybean meal at $300/ton, L-Lys at $0.65/lb, DL-Met at $1.70/lb, L-Thr at $0.85/lb, L-Trp at $3.00/lb, and L-Val at $2.50/lb.

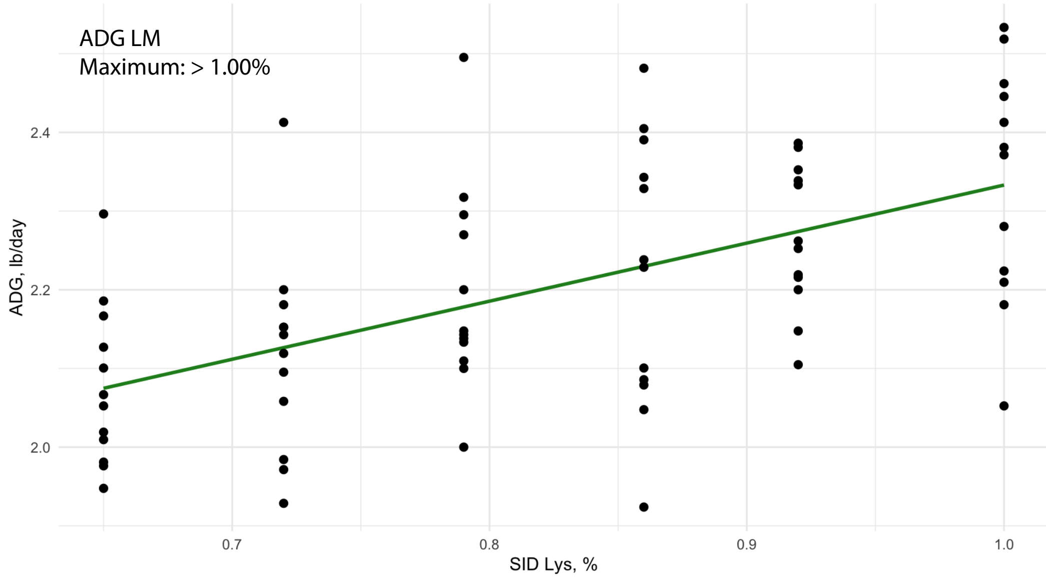

Figure 1. Estimation of SID Lys requirement to maximize ADG for 120- to 170-lb DNA finishing pigs.
A total of 700 pigs (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used in two separate studies, each lasting 21-d. Linear (LM), quadratic polynomial (QP), and broken-line linear (BLL) models were fit to estimate SID Lys level to maximize ADG. The LM models resulted in the best fit based on Bayseian Information Criterion (BIC).

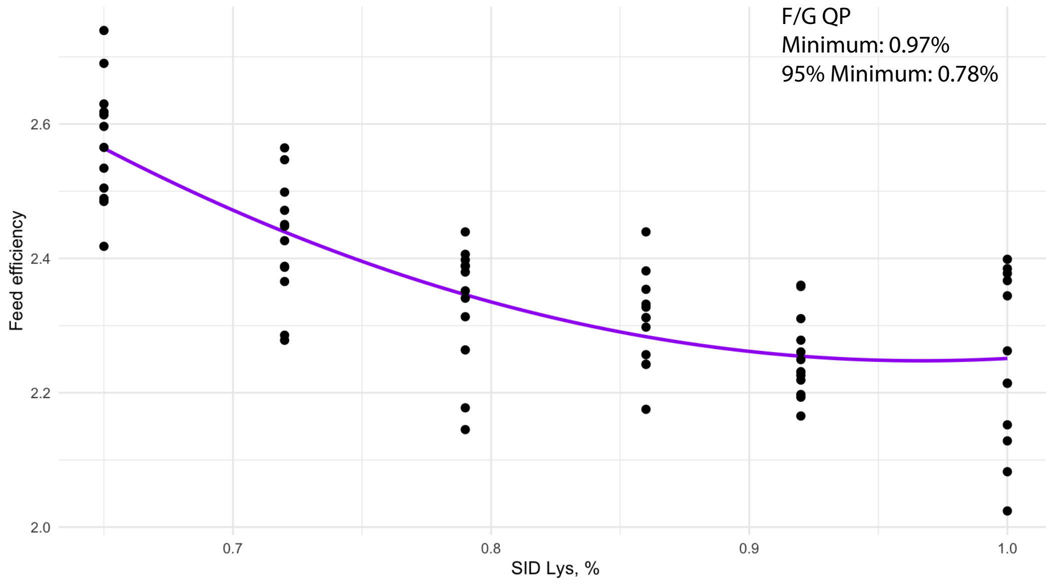

Figure 2. Estimation of SID Lys requirement to optimize F/G for 120- to 170-lb DNA finishing pigs.
A total of 700 pigs (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used in two separate studies, each lasting 21-d. Linear (LM), quadratic polynomial (QP), and broken-line linear (BLL) models were fit to estimate SID Lys level to optimize F/G. The QP resulted in the best fit, based on Bayseian Information Criterion (BIC), with a lower number being indicative of an improved fit. The QP model predicted 95 and 100% of optimal feed efficiency at 0.78 and 0.97% SID Lys, respectively. The QP model equation was: F/G = 3.1539 × (SID Lys, %)^2 – 6.0974 × (SID Lys, %) + 5.1945.

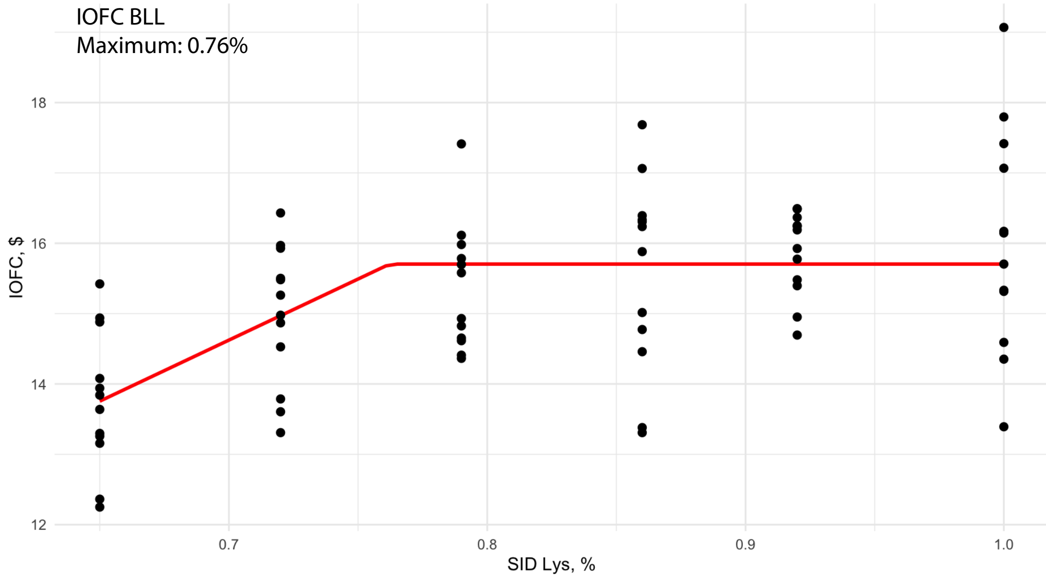

Figure 3. Estimation of SID Lys requirement to maximize IOFC at high ingredient and pig prices for 120- to 170-lb DNA finishing pigs.
A total of 700 pigs (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used in two separate studies, each lasting 21-d. Linear (LM), quadratic polynomial (QP), and broken-line linear (BLL) models were fit to estimate SID Lys level to maximize IOFC using high ingredient and pig prices. The BLL model resulted in the best fit, based on Bayseian Information Criterion (BIC), with a lower number being indicative of an improved fit. The BLL model predicted no further improvement past 0.76% SID Lys.

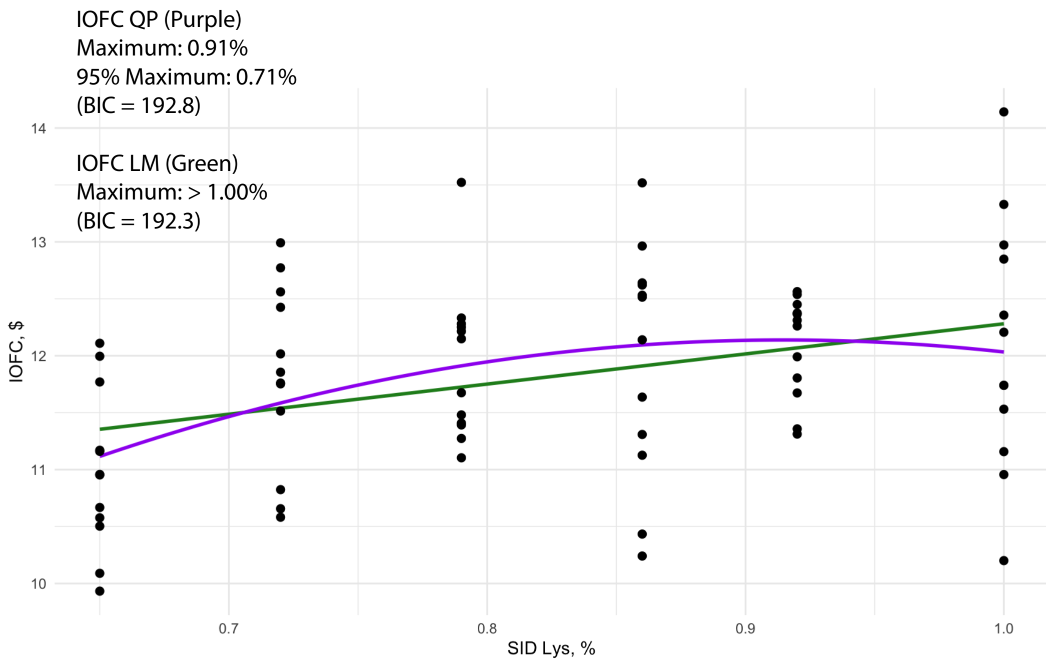

Figure 4. Estimation of SID Lys requirement to maximize IOFC at low ingredient and pig prices for 120- to 170-lb DNA finishing pigs.

A total of 700 pigs (600 × 241, DNA; initial BW of 117.2 ± 1.89 lb) were used in two separate studies, each lasting 21-d. Linear (LM), quadratic polynomial (QP), and broken-line linear (BLL) models were fit to estimate SID Lys level to maximize IOFC using low ingredient and pig prices. The QP and LM models resulted in the best fit, based on Bayseian Information Criterion (BIC), with a lower number being indicative of an improved fit. The QP model predicted 95 and 100% of maximum IOFC at 0.71 and 0.91% SID Lys, respectively. The QP model equation was: IOFC = $-14.5694 \times (\text{SID Lys, \%})^2 + 26.6594 \times (\text{SID Lys, \%}) - 0.0571$.