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Effects of standardized ileal digestible lysine on growth performance and economic return in duroc-sired finishing pigs

Larissa L. Becker,[†] Emily E. Scholtz,[‡] Joel M. DeRouchey,[†] Mike D. Tokach,[†] Jason C. Woodworth,[†,] Robert D. Goodband,[†] Jon A. De Jong,[‡] Fangzhou Wu,[‡] Kiah M. Berg,[‡] Joe P. Ward,[‡] Casey R. Neill,[‡] and Jordan T. Gebhardt[‖,1,]

[†]Department of Animal Sciences and Industry, College of Agriculture, Kansas State University, KS, USA
[‡]Pipestone Nutrition, Pipestone, MN, USA
[‖]Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506-0201, USA
[1]Corresponding author. jgebhardt@vet.k-state.edu

ABSTRACT

In the United States, emphasis has shifted toward improved pork quality and has resulted in greater use of Duroc-based terminal sires. Duroc sires have differences in ADG, ADFI, G:F, and carcass leanness compared to other sires. Therefore, our objective was to determine the standardized ileal digestible (SID) Lys estimates for Duroc-based sired finishing pigs. In Exp. 1, 2,124 pigs (DNA 600 ×PIC 1050, initially 48.9 kg) were used with 24–27 pigs per pen and 16 pens per treatment. Corn-soybean meal-based diets were fed in three phases (49–59, 59–71, and 71–81 kg). Pens were randomly allotted to 1 of 5 treatments based as a percentage of PIC (2016) SID Lys estimates for gilts (85%, 95%, 103%, 110%, and 120%). Phase 1 diets were formulated to 0.90%, 1.01%, 1.09%, 1.17%, and 1.27%, phase 2 to 0.79%, 0.87%, 0.94%, 1.03%, and 1.10%, and phase 3 to 0.71%, 0.78%, 0.85%, 0.92%, and 0.99% SID Lys. Increasing SID Lys increased (linear, $P < 0.001$) ADG and Lys intake/kg of gain. A marginally significant improvement (quadratic, $P = 0.071$) in G:F was observed as SID Lys increased. Feed cost, feed cost/kg of gain, revenue (linear, $P < 0.01$) and income over feed cost (IOFC) increased (quadratic, $P = 0.045$) with increasing SID Lys. In Exp. 2, 2,099 pigs (DNA 600 ×PIC 1050, initially 90.1 kg) were used with 24–27 pigs per pen and 20 pens per treatment. Corn-soybean meal-based diets were fed in 2 phases (90–106 and 106–136 kg). Pens were randomly allotted to 1 of 4 treatments based as a percentage of PIC (2016) SID Lys estimates for gilts (85%, 93%, 100%, and 110%). Phase 1 diets were formulated to 0.65%, 0.71%, 0.77%, and 0.84% and phase 2 to 0.60%, 0.66%, 0.71%, and 0.78% SID Lys. Overall, increasing SID Lys increased (linear, $P < 0.05$) G:F, Lys intake/kg of gain, live weight and HCW, and increased (quadratic, $P = 0.020$) ADG. Feed cost (linear, $P < 0.01$), revenue, and IOFC increased (quadratic, $P ≤ 0.053$) with increasing SID Lys. In conclusion, the SID Lys estimate for growth and IOFC was 1.19% or 4.63 g SID Lys/Mcal of NE, 1.05% or 4.04 g SID Lys/Mcal of NE, and 0.94% or 3.58 g SID Lys/Mcal of NE for pigs weighing 49–59 kg, 59–71 kg, and 71–81 kg, respectively. The SID Lys estimate for late finishing pigs was 0.74%–0.81% or 2.85–3.10 g SID Lys/Mcal of NE, and 0.69%–0.75% or 2.61–2.84 g SID Lys/Mcal of NE, for 90–106 kg and 106–136 kg pigs, respectively. These data provide SID Lys estimates for current Duroc-sired genetic lines raised in a commercial environment.

Key words: carcass traits, economics, finishing pig, growth, lysine requirement

INTRODUCTION

Lysine is typically the first limiting amino acid in corn and soybean meal-based swine diets (Menegat et al., 2020). In finishing pigs, establishing dietary lysine requirement estimates is crucial for maximizing lean growth and reducing feed cost (Wei and Zimmerman, 2001). There are several factors that impact dietary lysine requirements including: genetics, environmental conditions, sex, and pig body weight (Campbell and Taverner, 1988). Continuous improvements in genetics of modern pigs have resulted in increased growth performance and protein accretion. In 1980, the average market weight was 110 kg (National Pork Board, 2016). By 2019, the average market weight had increased to 128 kg (National Pork Board, 2020). Pigs have also become more feed efficient while being heavier in market weight and together these changes over time may increase amino acid requirement estimates. While genetic suppliers provide amino acid requirement

estimates for the various weight ranges of their specific lines, validating these levels is needed within production systems to achieve optimum performance and economic return (De La Llata et al., 2007; Main et al., 2008; Shelton et al., 2011).

Choosing a terminal sire to use in a swine breeding program is important because it influences traits including growth rate, carcass characteristics, pork quality and alter nutrient requirements. Recently, the US swine industry has placed more emphasis on pork quality resulting in the use of more Duroc-based terminal sires. Duroc's are characterized by their excellent growth rate and intramuscular fat content (Suzuki et al., 2003). Furthermore, Duroc's have a higher feed intake compared to large white pigs (Edwards et al., 1992; Latorre et al., 2003). As a result, nutritional requirements need to be re-evaluated as genetic progress is made over time to maximize performance and pork quality while meeting the pig's nutritional requirements (Aymerich et al., 2020). Therefore,

the objective of these experiments was to determine the optimal standardized ileal digestible lysine requirement for growth performance and economic return of Duroc-based finishing pigs (DNA 600 ×PIC 1050) reared in a commercial environment.

MATERIALS AND METHODS

General

The Pipestone Institutional Animal Care and Use Committee approved the protocols used in these experiments. Both experiments were conducted at a commercial wean-to-finish research facility located in southwest Minnesota (Pipestone Applied Research; Edgerton, MN). The experiments took place during summer and early fall. Each pen contained one nipple waterer and a 1-hole two-sided wet/dry self-feeder or a 4-hole dry self-feeder for ad libitum access to feed and water. Treatments were equally allotted and replicated across different feeder types. Pens were located over a completely slatted concrete floor with a deep pit underneath for manure storage. Diets were manufactured at the Spronk Brothers feed mill in Edgerton, MN. Feed was continuously delivered in bulk throughout the study. A robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) was used to deliver and record daily feed additions to each individual pen.

Experiment 1

A total of 2,124 barrows and gilts (DNA 600 ×PIC 1050, initially 48.9 ± 0.60 kg) were used in a 32-d study. Pens of pigs were blocked by location in the barn (total of eight blocks) and randomly allotted to 1 of 5 dietary treatments with 24–27 pig per pen and 16 replications per treatment. A similar number of barrows and gilts were placed in each pen. Diets were fed over three phases (49–59, 59–71, and 71–81 kg, respectively) and were corn-soybean meal-based and contained 10% (phase 1 and 2) or 5% (phase 3) dried distillers grains with solubles (DDGS) (Tables 1 and 2). Ingredient nutrient values and standardized ileal digestibility (SID) coefficients were derived from NRC (2012). Pens were randomly allotted to 1 of 5 dietary treatments [85%, 95%, 103%, 110%, and 120% of PIC (2016) gilt recommendations]. The 2016 PIC recommendations on a Lys:cal ME basis were 3.22, 2.77, and 2.46 g of SID Lys/Mcal of ME which corresponds to Lys:cal NE basis of 4.14, 3.56, and 3.15 g of SID Lys/Mcal of NE in phase 1 (49–59 kg), phase 2 (59–71 kg), and phase 3 (71–81 kg), respectively. Phase 1 diets were formulated to contain SID Lys levels of 0.90%, 1.01%, 1.09%, 1.17%, and 1.27%, phase 2 levels of 0.79%, 0.87%, 0.94%, 1.03%, and 1.10%, and phase 3 levels of 0.71%, 0.78%, 0.85%, 0.92%, and 0.99%, respectively. During the experiment, pens of pigs were weighed, and feed disappearance was recorded on d 0, 10, 22, and 32 to determine ADG, ADFI, and G:F.

Experiment 2

A total of 2,099 barrows and gilts (DNA 600 × PIC 1050, initially 90.1 ± 1.69 kg) were used in a 57-d study. Pens of pigs were blocked by location in the barn and randomly allotted to 1 of 4 dietary treatments with 24–27 pigs per pen and 20 replications per treatment. A similar number of barrows and gilts were placed in each pen. Diets were fed over 2 phases (90–106 and 106–136 kg, respectively). Pigs were randomly allotted to 1 of 4 dietary treatments (85, 93, 100, and 110% of modified PIC [2016] gilt recommendations) (Table 3). Because of the quadratic shape of the 2016 PIC recommendations where the slope of the Lys:calorie ratio curve is positive beyond 114 kg, a modified approach was take where the Lys:cal on a ME basis were estimated to be 2.29 and 2.10 g of SID Lys/Mcal of ME in phase 1 (90–106 kg) and phase 2 (106–136 kg), respectively. This corresponds to a Lys:cal NE basis of 2.94, and 2.69 g of SID Lys/Mcal of NE, respectively. Phase 1 diets were formulated to contain SID Lys levels of 0.65%, 0.71%, 0.77%, and 0.84% and phase 2 levels of 0.60%, 0.66%, 0.71%, and 0.78%, respectively. During the experiment, pens of pigs were weighed, and feed disappearance was recorded on d 0, 16, 29, 44, and 57 to determine ADG, ADFI, and G:F. Pigs were individually ear tagged with RFID ear tags prior to the start of this trial. On d 29 and 44, eight of the heaviest pigs per pen were individually weighed and transported to a commercial packing plant (Wholestone Farms, Fremont, NE) for processing and determination of carcass characteristics. The remaining pigs were marketed on d 57 and transported to the same commercial packing plant for HCW and carcass yield collection. When animals were marketed on d 29 and 44 their weight was counted toward the weight gain for the pen during the d 16–57 growth period (phase 2). The number of days those pigs contributed towards growth were calculated and included within the total pig days for each pen to determine pen ADG, ADFI, and G:F.

Economic Analysis

Total feed cost per pig, feed cost per kg of gain, revenue, and income over feed cost (IOFC) were calculated for high and low ingredient prices, and market pig price. Feed cost per pig placed was determined by multiplying total feed intake by diet cost. Feed cost per kg of gain was calculated by dividing the total feed cost per pig by the total weight gained. Revenue per pig placed was determined by total gain times the dressing percentage (0.75) and then multiplied by carcass price to convert to a live price. Income over feed cost was calculated using revenue per pig placed minus feed cost per pig placed. For high ingredient price scenarios, the following prices were used: corn = $235.71/tonne ($6.00/bushel); soybean meal = $440/tonne; L-Lys HCl = $1.76/kg; DL-Met = $5.51/kg; L-Thr = $2.65/kg; L-Trp = $11.02/kg; and L-Val = $8.82/kg. For low ingredient price scenarios, the following prices were used: corn = $117.86/tonne ($3.00/bushel); soybean meal = $330/tonne; L-Lys HCl = $1.43/kg; DL-Met = $3.75/kg; L-Thr = $1.87/kg; L-Trp = $6.61/kg; and L-Val = $5.51/kg.

Chemical Analysis

In both experiments, diet samples were collected and sent to a commercial laboratory (Ajinomoto Heartland Inc., Eddyville, IA) for complete amino acid analysis (AOAC 994.12; AOAC, 2006) ran in duplicate.

Statistical Analysis

In Exp. 1, data were analyzed as a randomized complete block design with pen as the experimental unit. Treatment was considered a fixed effect and barn location a random effect within the statistical model. In Exp. 2, data were analyzed as a completely randomized design evenly split between two rooms in the research barn. Treatment was considered a

Table 1. Composition of phase 1 and 2 diets in Exp. 1 (as-fed basis)

Item	Phase 1[2]					Phase 2[3]				
	Percentage of PIC SID Lys estimate[4]									
	85	95	103	110	120	85	95	103	110	120
Ingredient, %										
Corn	74.73	69.90	65.96	62.66	57.92	78.54	75.50	72.23	68.68	65.27
Soybean meal, 46.5% CP	11.95	16.35	19.95	22.95	27.25	8.25	11.00	13.95	17.20	20.30
DDGS	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Corn oil	0.78	1.23	1.58	1.88	2.33	0.80	1.08	1.38	1.70	2.03
Monocalcium P, 21% P	0.22	0.19	0.17	0.16	0.13	0.17	0.15	0.14	0.12	0.10
Limestone	0.98	0.95	0.93	0.93	0.90	0.95	0.93	0.93	0.90	0.88
Sodium chloride	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
L-Lys-HCl	0.49	0.49	0.49	0.49	0.49	0.46	0.48	0.48	0.49	0.49
DL-Met	0.05	0.07	0.10	0.11	0.14	0.02	0.04	0.06	0.08	0.10
L-Thr	0.13	0.14	0.14	0.15	0.16	0.12	0.13	0.14	0.15	0.16
L-Trp	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Vitamin and trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Tri-basic copper chloride	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Phytase[5]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total	100	100	100	100	100	100	100	100	100	100
Calculated analysis[6]										
Standardized ileal digestible (SID) amino acids, %										
Lys	0.90	1.01	1.09	1.17	1.27	0.79	0.87	0.94	1.03	1.10
Ile:Lys	55	57	58	58	59	55	55	56	57	58
Leu:Lys	143	138	134	132	128	152	145	141	137	134
Met:Lys	31	32	33	33	34	29	31	32	32	33
Met and Cys:Lys	58	58	58	58	58	58	58	58	58	58
Thr:Lys	63	63	63	63	63	64	64	64	64	64
Trp:Lys	19	19	19	19	19	19	19	19	19	19
Val:Lys	65	65	65	65	65	66	65	65	65	65
Total Lys, %	1.01	1.13	1.23	1.31	1.42	0.89	0.98	1.06	1.15	1.24
ME, kcal/kg	3,285	3,285	3,285	3,285	3,285	3,307	3,307	3,307	3,307	3,307
NE, kcal/kg	2,557	2,560	2,562	2,564	2,566	2,577	2,582	2,582	2,584	2,586
SID Lys:NE, g/Mcal	3.52	3.93	4.27	4.55	4.96	3.06	3.38	3.65	3.97	4.26
CP, %	14.72	16.42	17.82	18.98	20.65	13.26	14.33	15.48	16.73	17.94
Ca, %	0.58	0.58	0.58	0.58	0.58	0.55	0.55	0.55	0.55	0.55
Available P, %	0.29	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28

Table 1. Continued

Item	Phase 1[2]					Phase 2[3]					Phase 3[3]				
	Percentage of PIC SID Lys estimate[4]														
	85	95	103	110	120	85	95	103	110	120	85	95	103	110	120
STTD P, %	0.35	0.36	0.37	0.37	0.38	0.34	0.34	0.34	0.35	0.35	0.34	0.34	0.34	0.35	0.35

[1]Treatment diets were fed to 2,124 pigs (DNA 600 × PIC 1050, initially 48.9 ± 0.60 kg).
[2]Phase 1 treatment diets were fed from 49 to 59 kg.
[3]Phase 2 treatment diets were fed from 59 to 71 kg.
[4]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.
[5]Quantum Blue 5G (AB Vista, Marlborough, UK) provided an estimated release of 0.12% available P.
[6]Ingredient values and SID coefficients were derived from NRC (2012) Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.

Table 2. Composition of phase 3 diets in Exp. 1 (as-fed basis) [1,2]

Item	Percentage of PIC SID Lys estimate[3]				
	85	95	103	110	120
Ingredient, %					
Corn	83.98	80.81	77.70	74.50	71.27
Soybean meal, 46.5% CP	7.65	10.55	13.40	16.30	19.25
DDGS	5.00	5.00	5.00	5.00	5.00
Corn oil	1.10	1.40	1.68	1.98	2.28
Monocalcium P, 21% P	0.20	0.19	0.17	0.15	0.14
Limestone	0.88	0.85	0.83	0.83	0.80
Sodium chloride	0.50	0.50	0.50	0.50	0.50
L-Lys-HCl	0.40	0.40	0.40	0.40	0.40
DL-Met	0.00	0.02	0.03	0.05	0.07
L-Thr	0.10	0.10	0.11	0.12	0.12
L-Trp	0.04	0.03	0.03	0.03	0.03
Vitamin and trace mineral premix	0.10	0.10	0.10	0.10	0.10
Tri-basic copper chloride	0.03	0.03	0.03	0.03	0.03
Phytase[4]	0.04	0.04	0.04	0.04	0.04
Total	100	100	100	100	100
Calculated analysis[5]					
Standardized ileal digestible (SID) amino acids					
Lys, %	0.71	0.78	0.85	0.92	0.99
Ile:Lys	56	57	58	58	58
Leu:Lys	154	148	144	140	137
Met:Lys	28	29	30	31	31
Met and Cys:Lys	58	58	58	58	58
Thr:Lys	64	64	64	64	64
Trp:Lys	19	19	19	19	19
Val:Lys	67	67	67	67	67
Total Lys, %	0.80	0.87	0.95	1.03	1.11
ME, kcal/kg	3,344	3,344	3,344	3,344	3,344
NE, kcal/kg	2,612	2,615	2,615	2,617	2,619
SID Lys:NE, g/Mcal	2.72	2.99	3.25	3.52	3.79
CP, %	12.04	13.16	14.26	15.39	16.53
Ca, %	0.52	0.52	0.52	0.52	0.52
Available P, %	0.26	0.26	0.26	0.26	0.26
STTD P, %	0.33	0.33	0.33	0.34	0.34

[1]Treatment diets were fed to 2,124 pigs (DNA 600 × PIC 1050, initially 48.9 ± 0.60 kg).
[2]Phase 3 treatment diets were fed from 71 to 81 kg.
[3]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.
[4]Quantum Blue 5G (AB Vista, Marlborough, UK) provided an estimated release of 0.12% available P.
[5]Ingredient values and SID coefficients were derived from NRC (2012) Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.

fixed effect and room within barn a random effect to account for potential differences in performance between the two rooms within the facility. For both experiments, an initial base model was evaluated using the GLIMMIX procedure of SAS OnDemand for Academics (SAS Institute, Inc., Cary, NC). Linear and quadratic contrasts were evaluated within increasing SID Lys treatments. Contrast coefficients were adjusted to account for unequal spacing in SID Lys

Table 3. Composition of Exp. 2 treatment diets (as-fed basis)[1]

Item	Phase 1[2]				Phase 2[3]			
	Percentage of PIC SID Lys estimate[4]							
	85	93	100	110	85	93	100	110
Ingredient, %								
Corn	90.36	88.16	85.89	82.43	89.99	87.58	85.34	82.11
Soybean meal, 46.5% CP	6.85	8.85	10.90	14.05	7.05	9.25	11.30	14.25
Corn oil	0.65	0.85	1.05	1.38	0.93	1.18	1.38	1.68
Monocalcium P, 21% P	0.21	0.20	0.19	0.18	0.21	0.20	0.19	0.17
Limestone	0.78	0.75	0.75	0.73	0.78	0.75	0.75	0.73
Sodium chloride	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
L-Lys-HCl	0.37	0.39	0.39	0.39	0.30	0.30	0.30	0.30
DL-Met	0.00	0.01	0.03	0.05	0.00	0.00	0.00	0.01
L-Thr	0.10	0.11	0.12	0.13	0.07	0.07	0.08	0.09
L-Trp	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
Vitamin and trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Tri-basic copper chloride	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Phytase[5]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total	100	100	100	100	100	100	100	100
Calculated analysis[6]								
Standardized ileal digestible (SID) amino acids, %								
Lys	0.65	0.71	0.77	0.84	0.60	0.66	0.71	0.78
Ile:Lys	55	55	56	57	60	61	60	62
Leu:Lys	151	145	141	136	164	159	154	149
Met:Lys	27	28	29	30	30	29	29	27
Met and Cys:Lys	59	58	58	58	64	62	60	58
Thr:Lys	65	65	65	65	66	66	66	66
Trp:Lys	19	19	19	19	19	19	19	19
Val:Lys	66	65	65	65	73	72	71	71
Total Lys, %	0.72	0.79	0.85	0.93	0.65	0.73	0.79	0.86
ME, kcal/kg	3,351	3,351	3,351	3,351	3,362	3,362	3,362	3,362
NE, kcal/kg	2,610	2,610	2,612	2,615	2,621	2,626	2,626	2,628
SID Lys:NE, g/Mcal	2.50	2.73	2.94	3.22	2.30	2.50	2.69	2.96
CP, %	10.81	11.59	12.39	13.61	10.84	11.69	12.49	13.64
Ca, %	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Available P, %	0.24	0.24	0.24	0.24	0.25	0.25	0.25	0.25
STTD P, %	0.31	0.31	0.32	0.32	0.31	0.31	0.32	0.32

[1]Treatment diets were fed to 2,099 pigs (DNA 600 × PIC 1050, initially 90.1 ± 1.69 kg).
[2]Phase 1 treatment diets were fed from 90 to 106 kg.
[3]Phase 2 treatment diets were fed from 106 to 136 kg.
[4]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.
[5]Quantum Blue 5G (AB Vista, Marlborough, UK) provided an estimated release of 0.12% available P.
[6]Ingredient values and SID coefficients were derived from NRC (2012) Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.

treatments using the IML procedure. Studentized residuals were used to evaluate model assumptions which were reasonably met.

Dose response curves were evaluated using linear (LM), quadratic polynomial (QP), broken-line linear (BLL), and broken-line quadratic (BLQ) models. For each response variable, the best-fitting model was selected using the Bayesian information criterion (BIC), with a lower number indicative of improved fit (Goncalves et al., 2016). Results from both experiments were considered significant with $P \leq 0.05$ and were considered marginally significant with $P \leq 0.10$.

RESULTS

Chemical Analysis

In Exp. 1, analyzed total Lys concentration in treatment diets for phases 1 and 2 were similar to formulated values and followed the trend of increasing Lys across treatments (Table 4). In Exp. 2, analyzed total amino acids matched closely with formulated values for treatment diets in phase 1 (Table 5). Phase 3 diet samples from Exp. 1, and phase 2 samples from Exp. 2 were inadvertently not collected and, thus, analysis not available.

Table 4. Chemical analysis of diets in Exp. 1 (as-fed basis)[1,2]

Item	Percentage of PIC SID Lys estimate[3]				
	85	95	103	110	120
Phase 1[4]					
Proximate analysis, %					
DM	87.18	87.46	87.59	87.66	87.92
CP	14.7	16.7	18.5	19.6	21.7
Amino acid analysis, %					
Lys	1.07 (1.01)	1.27 (1.13)	1.39 (1.23)	1.44 (1.31)	1.61 (1.44)
Ile	0.55 (0.58)	0.63 (0.66)	0.72 (0.72)	0.76 (0.78)	0.87 (0.86)
Leu	1.42 (1.48)	1.58 (1.60)	1.69 (1.69)	1.77 (1.77)	1.92 (1.88)
Met	0.27 (0.32)	0.31 (0.36)	0.36 (0.40)	0.38 (0.43)	0.44 (0.48)
Thr	0.64 (0.66)	0.74 (0.74)	0.83 (0.80)	0.88 (0.86)	0.97 (0.94)
Trp	0.18 (0.19)	0.19 (0.21)	0.23 (0.23)	0.24 (0.24)	0.28 (0.27)
Val	0.69 (0.70)	0.79 (0.78)	0.94 (0.84)	0.99 (0.90)	1.11 (0.97)
Phase 2[5]					
Proximate analysis, %					
DM	87.36	87.34	87.15	87.37	87.41
CP	15.0	14.8	15.8	17.1	18.1
Amino acid analysis, %					
Lys	1.11 (0.89)	1.14 (0.98)	1.19 (1.06)	1.22 (1.15)	1.28 (1.24)
Ile	0.56 (0.51)	0.55 (0.56)	0.59 (0.61)	0.63 (0.67)	0.69 (0.73)
Leu	1.46 (1.39)	1.46 (1.46)	1.48 (1.53)	1.56 (1.61)	1.65 (1.69)
Met	0.28 (0.27)	0.28 (0.31)	0.30 (0.34)	0.33 (0.37)	0.35 (0.40)
Thr	0.66 (0.59)	0.68 (0.65)	0.71 (0.71)	0.76 (0.76)	0.80 (0.82)
Trp	0.18 (0.16)	0.18 (0.18)	0.20 (0.20)	0.21 (0.21)	0.23 (0.23)
Val	0.71 (0.63)	0.71 (0.68)	0.79 (0.73)	0.85 (0.79)	0.92 (0.85)

[1]Diet samples were taken from 1 feeder per treatment and submitted to Ajinomoto Heartland Inc. (Eddyville, IA) for amino acid analysis ran in duplicate.
[2]Numbers in parenthesis are the formulated values.
[3]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.
[4]Phase 1 treatment diets were fed from 49 to 59 kg.
[5]Phase 2 treatment diets were fed from 59 to 71 kg.

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

Item	Percentage of PIC SID Lys estimate[3]			
	85	93	100	110
Proximate analysis, %				
DM	86.18	86.71	86.70	86.77
CP	10.0	11.5	12.3	13.2
Total amino acid analysis, %				
Lys	0.67 (0.72)	0.72 (0.79)	0.84 (0.85)	0.94 (0.93)
Ile	0.32 (0.40)	0.40 (0.44)	0.45 (0.47)	0.50 (0.53)
Leu	0.94 (1.12)	1.07 (1.17)	1.17 (1.22)	1.23 (1.30)
Met	0.17 (0.21)	0.20 (0.23)	0.22 (0.25)	0.28 (0.29)
Thr	0.44 (0.47)	0.51 (0.52)	0.56 (0.56)	0.61 (0.62)
Trp	0.12 (0.13)	0.13 (0.14)	0.15 (0.15)	0.17 (0.17)
Val	0.46 (0.50)	0.53 (0.53)	0.58 (0.57)	0.61 (0.63)

[1]Diet samples were taken from 1 feeder per treatment and submitted to Ajinomoto Heartland Inc. (Eddyville, IA) for amino acid analysis ran in duplicate. Phase 1 treatment diets were fed from 90 to 106 kg.
[2]Numbers in parenthesis are the formulated values.
[3]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.

Experiment 1

In Exp. 1 (49–81 kg barrows and gilts), BW increased (linear, $P < 0.01$) on d 10, 22, and 32 (Table 6). Average daily gain increased with increasing SID Lys in phase 1 (linear, $P < 0.001$) and phase 3 (linear, $P < 0.001$; quadratic, $P = 0.022$), resulting in linear ($P < 0.001$) improvement overall. For ADFI, there was a marginally significant increase (linear, $P = 0.067$) in phase 1 with increasing SID Lys. A linear ($P \leq 0.035$) improvement for G:F was observed in phase 1 and 2, with the response being linear ($P < 0.001$) and quadratic ($P = 0.009$) in phase 3, leading to a linear ($P < 0.001$) improvement and quadratic ($P = 0.071$) tendency for improvement in the overall period. Daily SID Lys intake and Lys intake per kilogram of BW increased (linear, $P < 0.001$) with increasing dietary Lys. No differences ($P > 0.10$) were observed in removals or mortality as SID Lys increased across treatments.

For economic analysis, feed cost, feed cost per kg gain, and revenue increased (linear, $P < 0.01$) as SID Lys increased. Income over feed cost increased (quadratic, $P = 0.045$) with increasing SID Lys. Income over feed cost was greatest when pigs were fed 110% of current SID Lys requirement estimates. Similar findings were observed when using high or low ingredient prices for economic analysis.

Table 6. Effects of increasing standardized ileal digestible (SID) lysine on grow-finish pig performance in Exp. 1[1]

	Percentage of PIC SID Lys estimate[2]						Probability, $P <$	
	85	95	103	110	120			
Phase 1 SID Lys, %	0.90	1.01	1.09	1.17	1.27			
Phase 2 SID Lys, %	0.79	0.87	0.94	1.03	1.10			
Item Phase 3 SID Lys, %	0.71	0.78	0.85	0.92	0.99	SEM	Linear	Quadratic
d 0 to 10 (phase 1)								
d 0 BW, kg	48.9	49.0	49.0	48.9	48.8	0.60	0.875	0.672
d 10 BW, kg	57.8	57.7	59.2	59.2	59.1	0.64	0.007	0.510
ADG, kg	0.894	0.864	1.020	1.032	1.034	0.0242	<0.001	0.506
ADFI, kg	2.105	1.933	2.192	2.167	2.142	0.0583	0.067	0.812
G:F	0.427	0.455	0.467	0.478	0.486	0.0128	0.001	0.370
d 10 to 22 (phase 2)								
d 22 BW, kg	69.8	70.0	71.4	71.4	71.9	0.66	0.001	0.733
ADG, kg	1.003	1.029	1.016	1.015	1.063	0.0235	0.104	0.471
ADFI, kg	2.446	2.495	2.482	2.448	2.456	0.0350	0.816	0.286
G:F	0.408	0.413	0.409	0.415	0.434	0.0079	0.035	0.205
d 22 to 32 (phase 3)								
d 32 BW, kg	78.9	80.0	81.3	81.9	82.0	0.72	<0.001	0.213
ADG, kg	0.904	0.984	0.988	1.044	1.010	0.0290	0.001	0.022
ADFI, kg	2.536	2.551	2.513	2.519	2.521	0.0484	0.575	0.905
G:F	0.356	0.386	0.393	0.415	0.401	0.0096	<0.001	0.009
d 0 to 32								
ADG, kg	0.939	0.964	1.008	1.030	1.037	0.0145	<0.001	0.127
ADFI, kg	2.376	2.336	2.400	2.382	2.378	0.0338	0.350	0.806
G:F	0.395	0.412	0.421	0.434	0.437	0.0038	<0.001	0.071
Lys intake g/d	18.9	20.4	22.9	24.6	26.5	0.41	<0.001	0.923
Lys intake g/kg gain	20.1	21.2	22.8	23.9	25.5	0.28	<0.001	0.292
Removals, %	0.47	0.24	0.23	0.71	0.70	0.407	0.416	0.404
Mortality, %	0.47	0.47	0.93	0.47	0.47	0.465	0.995	0.615
Total Removals, %	0.95	0.71	1.17	1.18	1.17	0.524	0.555	0.939
Economics, $/pig placed								
Low ingredient prices[3]								
Feed cost	15.88	16.14	17.26	17.29	18.06	0.251	<0.001	0.887
Feed cost/kg gain[4]	0.531	0.525	0.538	0.530	0.547	0.0047	0.007	0.073
Revenue[5]	29.71	30.56	31.87	32.44	32.79	0.469	<0.001	0.149
IOFC[6]	13.84	14.40	14.61	15.14	14.71	0.298	0.001	0.045
High ingredient prices[7]								
Feed cost	21.85	22.39	23.75	24.19	25.08	0.347	<0.001	0.961
Feed cost/kg gain	0.731	0.728	0.740	0.741	0.759	0.0065	0.001	0.115
Revenue[8]	43.59	44.79	46.75	47.58	48.08	0.689	<0.001	0.149
IOFC	21.73	22.43	23.01	23.38	23.01	0.447	0.001	0.064

[1]A total of 2,124 pigs (DNA 600× PIC 1050, initially 48.9 ± 0.60 kg) were used with 27–24 pigs per pen and 16 replications per treatment in a 32-d study. Phase 1 treatment diets were fed from 49 to 59 kg. Phase 2 diets were fed from 59 to 71 kg. Phase 3 diets were fed from 71 to 81 kg.

[2]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.

[3] Corn = $117.86/tonne ($3.00/bushel); soybean meal = $330/tonne; L-Lys HCl = $1.43/kg; DL-Met = $3.75/kg; L-Thr = $1.87/kg; L-Trp = $6.61/kg; and L-Val = $5.51/kg.

[4]Feed cost/kg gain = total feed cost per pen÷ total gain per pen.

[5]Revenue = (total gain/pig placed × 0.75) × $1.32/kg.

[6]Income over feed cost = revenue – feed cost.

[7]Corn = $235.71/tonne ($6.00/bushel); soybean meal = $440/tonne; L-Lys HCl = $1.76/kg; DL-Met = $5.51/kg; L-Thr = $2.65/kg; L-Trp = $11.02/kg; and L-Val = $8.82/kg.

[8]Revenue = (total gain/pig placed × 0.75) × $1.94/kg.

Figure 1. Estimation of standardized ileal digestible (SID) lysine requirement to maximize ADG, G:F, and income over feed cost (IOFC) for grow-finish pigs weighing 49–81 kg (Exp. 1). A total of 2,124 barrows and gilts (DNA 600 ×PIC 1050, initially 48.9 ± 0.60 kg) were used in a 32-d growth trial with 24–27 pigs per pen and 16 replications per treatment. (A) The broken line linear (BLL) model predicted no further improvement in ADG over 112% of current SID Lys requirement estimates (95% CI: 105.29–118.75%). (B) The BLL model predicted no further improvement in G:F over 112% of current SID Lys requirement estimates (95% CI: 107.08–119.84%). (C) The quadratic polynomial (QP) and BLL models had a comparable fit for IOFC. The QP model equation developed with high ingredient prices was: IOFC = −2.9232 + 0.465 × (SID Lys%) − 0.00207 × (SID Lys%)², with 100% of maximum IOFC estimated at 112.3% SID Lys. For the BLL with high ingredient prices, maximum IOFC was achieved with a minimum of 105.7% of current SID Lys requirement estimates (95% CI: 93.60–117.82%). (D) The QP and BLL models had a comparable fit for IOFC. The QP model equation developed with low ingredient prices was: IOFC = −4.0787 + 0.3388 × (SID Lys%) − 0.00151 × (SID Lys%)², with 100% of maximum IOFC estimated at 112.2% SID Lys. For the BLL with low ingredient prices, maximum IOFC was achieved with a minimum of 109.2% of current SID Lys requirement estimates (95% CI: 93.46–124.92%).

Dose response curves were evaluated for overall growth performance and economic analysis. A broken line linear model was the best fitting model for ADG and G:F. Maximum ADG was achieved with a minimum of 112% of current SID Lys requirement estimates (95% CI: 105.3–118.8%) with no improvement thereafter (Figure 1A). Similarly, maximum feed efficiency was achieved with a minimum of 112% of current SID Lys requirement estimates (95% CI: 107.1–119.8%; Figure 1B). The BLL model indicated that ADG and G:F were optimized at 112% of current SID Lys requirement estimates, corresponding to diets containing 1.19% SID Lys or 4.63 g of SID Lys/Mcal of NE, 1.05% SID Lys or 4.04 g of SID Lys/ Mcal of NE, 0.94% SID Lys or 3.58 g of SID Lys/Mcal of NE in phase 1 (49–59 kg), phase 2 (59–71 kg), and phase 3 (71–81 kg), respectively.

When modeling IOFC, the QP and BLL models had a comparable fit for low and high ingredient prices. The QP model equation developed with high ingredient prices was: IOFC = −2.9232 + 0.465 × (SID Lys%) − 0.00207 × (SID Lys%)², with 100% of maximum IOFC estimated at 112.3% SID Lys (Figure 1C). For the BLL with high ingredient prices, maximum IOFC was achieved with a minimum of 105.7% of current SID Lys requirement estimates (95% CI: 93.6–117.8%; Figure 1C). The QP model equation developed with low ingredient prices was: IOFC = −4.0787 + 0.3388 × (SID Lys%) − 0.00151 × (SID Lys%)², with 100% of maximum IOFC estimated at 112.2% SID Lys (Figure 1D). For the BLL with low ingredient prices, maximum IOFC was achieved with a minimum of 109.2% of current SID Lys requirement estimates (95% CI: 93.5–124.9%; Figure 1D). Similar to growth performance, the QP model indicated that IOFC for low and high ingredient prices was optimized at 112% of current SID Lys requirement estimates.

Experiment 2

In Exp. 2 (90–136 kg barrows and gilts), ADG increased in phase 1 (linear, $P < 0.001$) and phase 2 (quadratic, $P < 0.045$), resulting in a quadratic ($P < 0.020$) response overall (Table 7). For ADFI, there was a marginally significant increase (quadratic, $P \leq 0.092$) in phase 1 and the overall period as SID Lys increased up to 93% of current SID Lys requirement estimates.

Table 7. Effects of increasing standardized ileal digestible (SID) lysine on grow-finish pig performance in Exp. 2[1]

	Percentage of PIC SID Lys estimate[2]					Probability, P <	
	85	93	100	110			
Phase 1 SID Lys, %	0.65	0.71	0.77	0.84			
Item Phase 2 SID Lys, %	0.60	0.66	0.71	0.78	SEM	Linear	Quadratic
d 0 to 16 (phase 1)							
d 0 BW, kg	89.9	90.0	90.0	90.2	1.69	0.766	0.961
d 16 BW, kg	104.9	105.8	106.1	106.7	1.22	0.107	0.759
ADG, kg	0.926	0.981	1.000	1.027	0.0376	<0.001	0.250
ADFI, kg	2.834	2.936	2.919	2.880	0.0364	0.509	0.057
G:F	0.327	0.334	0.343	0.357	0.0146	<0.001	0.627
d 16 to 57 (phase 2)							
ADG, kg	0.925	0.960	0.988	0.961	0.0162	0.087	0.045
ADFI, kg	3.213	3.268	3.259	3.208	0.0521	0.842	0.224
G:F	0.276	0.280	0.287	0.283	0.0048	0.193	0.376
d 0 to 57							
ADG, kg	0.925	0.967	0.992	0.985	0.0148	0.001	0.020
ADFI, kg	3.074	3.148	3.135	3.089	0.0352	0.883	0.092
G:F	0.301	0.308	0.317	0.319	0.0032	<0.001	0.355
Lysine intake g/d	20.1	22.4	24.0	26.0	0.27	<0.001	0.112
Lysine intake g/kg gain	21.7	23.2	24.3	26.5	0.26	<0.001	0.493
Total removals, %	2.46	3.05	1.72	2.65	0.800	0.845	0.634
Carcass performance							
Marketing event 1 (d 29)[3]							
Live weight, kg	125.4	126.6	127.4	127.1	1.32	0.240	0.437
HCW, kg	92.4	93.2	93.8	94.0	0.93	0.154	0.640
Yield, %	73.64	73.64	73.59	73.95	0.150	0.133	0.230
Marketing event 2 (d 44)[3]							
Live weight, kg	134.6	137.6	137.6	138.3	1.710	0.007	0.168
HCW, kg	99.1	101.2	101.1	102.1	1.12	0.011	0.438
Yield, %	73.66	73.54	73.47	73.80	0.215	0.592	0.197
Marketing event 3 (d 57)[4]							
Live weight, kg	133.5	135.4	137.1	137.0	1.528	0.055	0.400
HCW, kg	99.4	100.9	102.7	102.5	1.10	0.032	0.382
Yield, %	74.44	74.51	74.87	74.80	0.341	0.112	0.617
All marketing events[5]							
Live weight, kg	131.3	133.3	134.2	134.3	1.415	0.024	0.265
HCW, kg	97.1	98.6	99.4	99.8	0.93	0.017	0.407
Yield, %	73.94	73.95	74.04	74.23	0.209	0.082	0.535
Economics, $/pig placed							
Low ingredient prices[6]							
Feed cost	24.53	25.58	26.26	26.71	0.307	< 0.001	0.194
Feed cost/kg gain[7]	0.606	0.602	0.601	0.616	0.007	0.281	0.153
Revenue[8]	40.22	42.30	43.41	43.00	0.705	0.001	0.011
IOFC[9]	15.67	16.71	17.14	16.27	0.510	0.293	0.020
High ingredient prices[10]							
Feed cost	37.31	39.33	40.06	40.65	0.482	< 0.001	0.070
Feed cost/kg gain	0.922	0.925	0.918	0.939	0.0097	0.282	0.358
Revenue[11]	58.98	62.02	63.67	63.04	1.029	0.001	0.011
IOFC	21.64	22.70	23.62	22.43	0.728	0.290	0.053

[1]A total of 2,099 pigs (DNA 600 × PIC 1050, initially 90.1 ± 1.69 kg) were used with 27–24 pigs per pen and 20 replications per treatment. Phase 1 diets were fed from 90 to 106 kg. Phase 2 diets were fed from 106 to 136 kg.
[2]Columns represent the percentage of the 2016 PIC SID Lys recommendations for gilts.
[3]Eight of the heaviest pigs were marketed from each pen.
[4]All pigs remaining in the pen were marketed.
[5]Overall data were calculated using weighted averages for all 3 marketing events.
[6]Corn = $117.86/tonne ($3.00/bushel); soybean meal = $330/tonne; L-Lys HCl = $1.43/kg; DL-Met = $3.75/kg; L-Thr = $1.87/kg; L-Trp = $6.61/kg; L-Val = $5.51/kg.
[7]Feed cost/kg gain = total feed cost per pen÷ total gain per pen.
[8]Revenue = (total gain/pig placed× 0.75) × $1.32/kg.
[9]Income over feed cost = revenue − feed cost.
[10]Corn = $235.71/tonne ($6.00/bushel); soybean meal = $440/tonne; L-Lys HCl = $1.76/kg; DL-Met = $5.51/kg; L-Thr = $2.65/kg; L-Trp = $11.02/kg; L-Val = $8.82/kg.
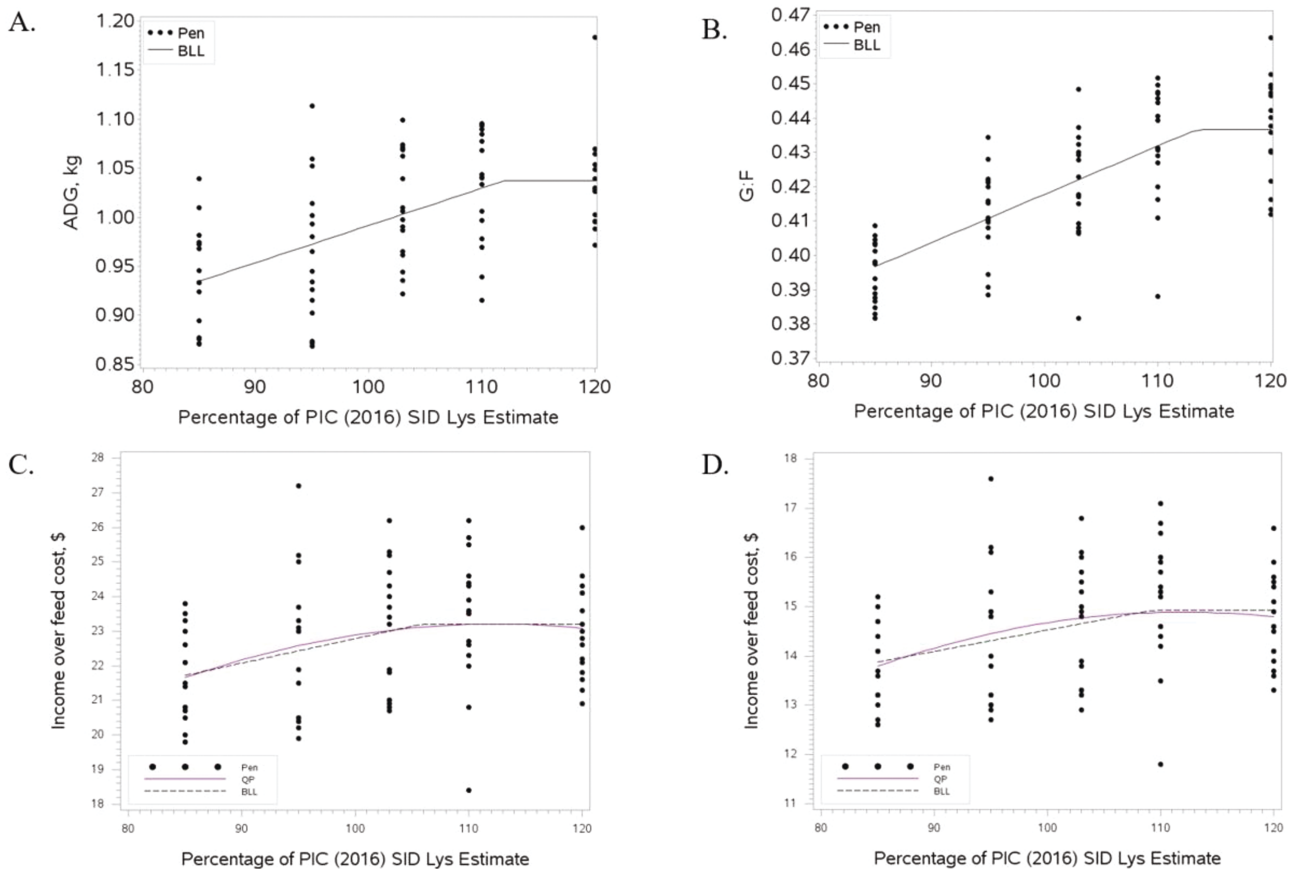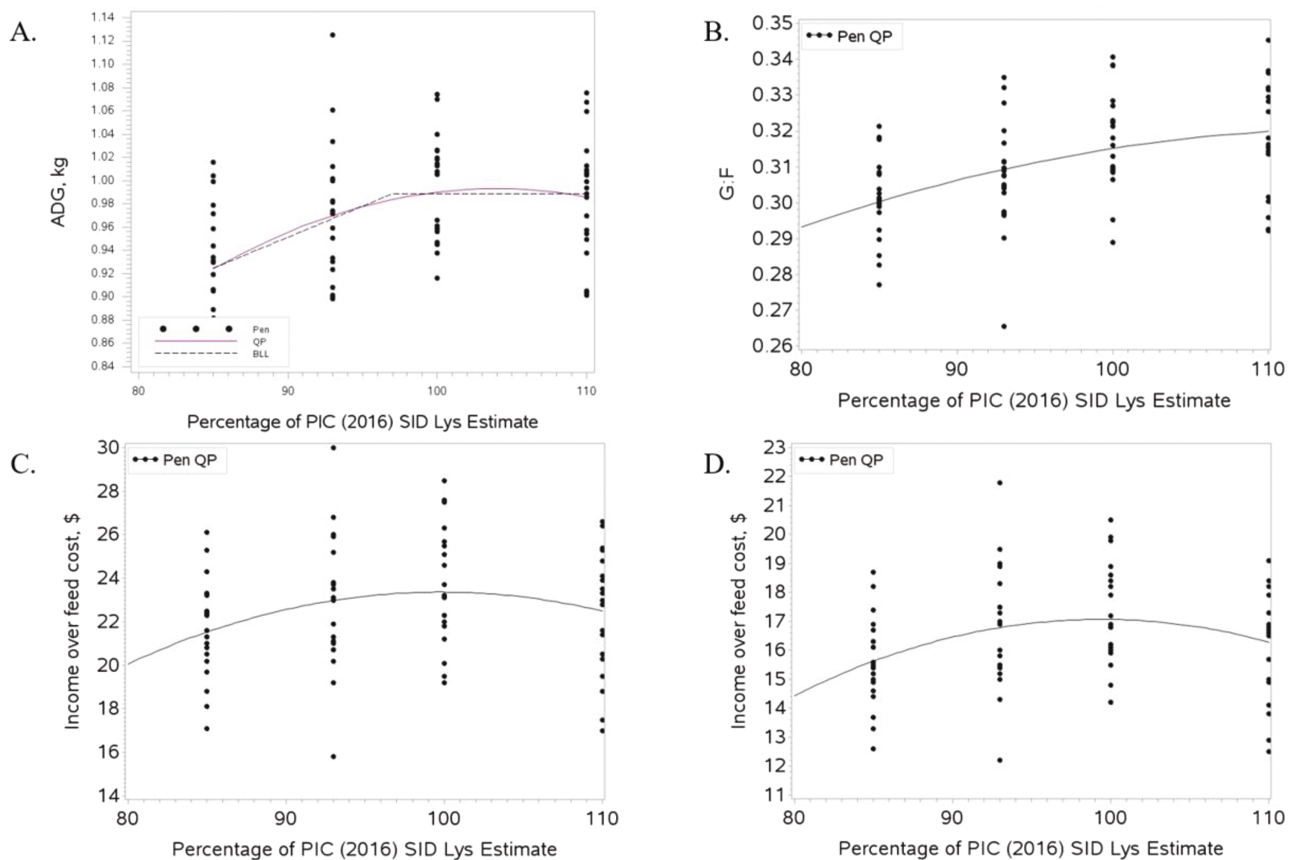[11]Revenue = (total gain/pig placed × 0.75) × $1.94/kg.

Figure 2. Estimation of standardized ileal digestible (SID) Lysine requirement to maximize ADG, G:F, and income over feed cost (IOFC) for grow-finish pigs weighing 90–136 kg (Exp. 2). A total of 2,099 pigs (DNA 600 × PIC 1050, initially 90.1 ± 1.69 kg) were used in a 57-d trial with 27–24 pigs per pen and 20 replications per treatment. (A) The quadratic polynomial (QP) and broken line linear (BLL) models had a comparable fit (BIC = −245.8 and −245.7, QP and BLL, respectively) with the SID Lys requirement to achieve maximal ADG predicted at 105.6% with QP and 97.0% for the BLL model. The QP model equation was: ADG = −1.0914 + 0.04011 × (SID Lys%) − 0.00019 × (SID Lys %)^2. For BLL, there was no further improvement in ADG beyond the breakpoint of 97.0% SID Lys (95% CI: 50.32, 143.75%). (B) The QP was the best fitting model with the SID Lys requirement to achieve maximal feed efficiency predicted at 120.7% SID Lys. The QP model equation was: G:F = 0.03976 + 0.004827 × (SID Lys%) − 0.00002 × (SID Lys %)^2. (C) The QP model was the best fit with the SID Lys requirement to achieve maximal IOFC with high ingredient prices predicted at 99% of the current SID Lys requirement estimates for high ingredient prices. The QP model equation was: IOFC = −59.9429 + 1.6699 × (SID Lys%) − 0.00837 × (SID Lys %)^2. (D) The QP model was the best fit (BIC = 326.98) with the SID Lys requirement to achieve maximal IOFC with low ingredient prices predicted at 99% of the current SID Lys requirement estimates. The QP model equation was: IOFC = -51.4696 + 1.3792 × (SID Lys%) − 0.00694 × (SID Lys %)^2.

An improvement (linear, $P < 0.001$) in G:F was observed for phase 1 and the overall period with increasing SID Lys in the diet. Additionally, live weight in marketing event 2 and overall (all marketing events combined) increased (linear, $P ≤ 0.02$) as SID Lys increased. For live weight in marketing event 3, there was a marginally significant increase (linear, $P = 0.055$) as SID Lys increased. An increase (linear, $P ≤ 0.03$) in HCW was observed for marketing event 2, 3, and overall (all marketing events combined) as SID Lys increased. For overall yield (all marketing events combined), there was a marginally significant increase (linear, $P = 0.082$) as SID Lys increased. Similar to Exp. 1, daily SID Lys intake and Lys intake per kilogram of BW increased (linear, $P < 0.001$) with increasing dietary Lys. No differences ($P > 0.10$) were observed in removals as SID Lys increased across treatments.

For economic analysis, feed cost increased (linear, $P < 0.01$) when dietary SID Lys increased. Revenue and income over feed cost increased (quadratic, $P ≤ 0.02$) when SID Lys increased in the diet with the greatest observed in pigs consuming 100% of current SID Lys requirement estimates, corresponding to pigs fed treatment diets of 0.77% SID Lys or

2.94 g of SID Lys/Mcal of NE in phase 1 (90–106 kg) and 0.71% SID Lys or 2.69 g of SID Lys/Mcal of NE in phase 2 (106–136 kg). Similar findings were observed when using high or low ingredient prices for economic analysis.

Dose response curves were evaluated for overall growth performance and economic analysis. For ADG, the QP and BLL models had a comparable fit with the SID Lys requirement to achieve maximal performance predicted at 105.6% with QP and 97.0% for the BLL model (Figure 2A). The QP model equation for ADG was: ADG = −1.0914 + 0.04011 × (SID Lys%) − 0.00019 × (SID Lys%)^2. For BLL, there was no further improvement in ADG beyond the breakpoint of 97.0% SID Lys (95% CI: 50.3, 143.8%). For G:F, QP was the best fitting model with the SID Lys requirement to achieve maximal performance predicted at 120.7% SID Lys (Figure 2B). The QP model equation for feed efficiency was: G:F = 0.03976 + 0.004827 × (SID Lys%) − 0.00002 × (SID Lys%)^2. Depending on the model used, growth performance was optimized between 97.0% and 120.7% of current SID Lys requirement estimates, corresponding to diets containing 0.74%–0.92% SID Lys or 2.85–3.53 g of SID Lys/Mcal of

NE, and 0.69%–0.86% SID Lys or 2.61–3.25 g of SID Lys/Mcal of NE in phase 1 (90–106 kg) and phase 2 (106–136 kg), respectively.

When modeling IOFC for low and high ingredient prices, the QP model was the best fit with the SID Lys requirement to achieve maximal IOFC predicted at 99% of the current SID Lys requirement estimates for both high and low ingredient prices, corresponding to diets containing 0.76% SID Lys or 2.85 g of SID Lys/Mcal of NE, and 0.70% SID Lys or 2.66 g of SID Lys/Mcal of NE in phase 1 (90–106 kg) and phase 2 (106–136 kg), respectively. The QP model equation with high ingredient prices was: IOFC = −59.9429 + 1.6699 × (SID Lys%) − 0.00837 × (SID Lys %)^2 (Figure 2C). The QP model equation with low ingredient prices was: IOFC = −51.4696 + 1.3792 × (SID Lys%) − 0.00694 × (SID Lys %)^2 (Figure 2D).

DISCUSSION

The adoption of new technologies to optimize health status, environmental conditions, management plans, and genomic selection has allowed for significant improvements in pig growth performance and carcass composition over the last 40 years. In 1980, the average market weight was 110 kg (National Pork Board, 2016). By 2019, the average market weight had increased to 128 kg (National Pork Board, 2020). Pigs have also become more feed efficient while being heavier in market weight. In 1990, pigs grew at 0.58 kg/day with 3.2 kg of feed per kg of gain from weaning to market (PigChamp, 1990). In comparison, by 2019, wean-to-finish pigs grew at 0.80 kg/day with 2.6 kg of feed per kg of gain (National Pork Board, 2020). The trends in genetic improvement were also observed in our study as pigs grew at an average of 1.0 kg/day in Exp. 1 (49–81 kg pigs) and 0.97 kg/day in Exp. 2 (90–136 kg pigs) in a commercial setting. As a result of these genetic advancements, nutrient requirements, specifically Lys, have increased from 0.66% (NRC, 1998) to 0.85% (NRC, 2012) in 50–75 kg pigs. Furthermore, the 2016 PIC gilt recommendation for this same weight range for SID Lys is 0.93% (assuming 3,307 kcal ME/kg).

It has been well documented that factors that change feed intake, such as genetic potential for lean growth (Campbell and Taverner, 1988; Mohn et al., 2000), will influence the dietary SID Lys concentration required to optimize performance. Statistical method of interpreting growth responses (Goncalves et al., 2016) and economics (De La Llata et al., 2001) also play a role in the dietary SID Lys requirement. The level of feed consumption and associated growth rate may be an important source of variation in estimated SID Lys requirements among experiments. Research conducted with 112–136 kg pigs in a university setting, reported an average feed intake of 3.1 kg (Soto et al., 2019). Conversely, research conducted in a commercial environment reported an average feed intake of 2.6 kg for 102–120 kg pigs (Main et al., 2008). In agreement, we observed feed intake comparable to other research conducted in a commercial environment in the present study (Main et al., 2008; Shelton et al., 2011; Menegat et al., 2020). The level of feed intake and growing environment of the pig have a key impact on SID Lys requirements and further highlight the importance of determining production system-specific nutrient requirements.

Variation in Lys requirements could be attributed to differences in genetic capacities for amino acid utilization by the pig in terms of Lys efficiency and protein deposition. Thong and Liebert (2004) modeled the lysine requirement of growing barrows and indicated the required daily intake of lysine increases as the rate of protein deposition increases as would be expected, but the efficiency of lysine utilization for different feed ingredients also can affect the calculated lysine requirement. When Lys requirements are expressed as a function of SID Lys required per kg of daily BW gain, our estimated requirement was approximately 24.3 g SID Lys/kg gain for 49–81 kg pigs and range from approximately 24.2–25.7 g SID Lys/kg gain for 90–136 kg pigs. In comparison to Soto et al. (2019) with pigs weighing over 100 kg, our requirement of SID Lys g/kg gain is greater (24.2–25.7 vs. 17.0–19.8). Furthermore, Main et al. (2008) and Shelton et al. (2011) also observed lower SID Lys g/kg gain requirements of 21.9 and 19.6, respectively. Thus, a greater requirement of SID Lys intake per kg of BW gain was observed in the current experiment compared to previous research, but further research is needed to characterize this further.

Diets are formulated on a lysine-to-calorie ratio, and other amino acids are balanced accordingly as a ratio relative to Lys (Wang and Fuller, 1989). Responses to SID Lys or Lys:calorie ratio should be expected to differ among production environments and genetic lines (Main et al., 2008). This change in diet formulation strategy has been helpful for swine producers through improved growth rate, feed efficiency, and carcass leanness. Thus, the concept of adjusting SID Lys concentration in a ratio relative to dietary energy content has been demonstrated by previous researchers (Allee and Hines, 1972; Chiba et al. 1991; Marcal et al., 2019). Previous research by Soto et al. (2019) reported a Lys:calorie ratio of 2.14–2.53 g of SID Lys/Mcal of NE was needed to achieve optimal performance in 100–120 kg pigs. We determined the requirement to be a Lys:calorie ratio of 2.85–3.10 g of SID Lys/Mcal of NE, and 2.61–2.84 g of SID Lys/Mcal of NE in 90–106 and 106–136 kg pigs, respectively, to achieve optimal economics and growth performance. An accurate requirement estimate for Lys in the finishing growth period becomes crucial for maximizing lean growth and optimizing feed cost leading to a cost-effective nutritional program.

When developing and evaluating nutritional programs, it is crucial to factor in economics along with growth performance (Li et al., 2012). Swine producers can use a variety of economic criteria including income over feed cost which accounts for the revenue and expenses generated. Research has documented that nutrient requirements needed to maximize biological performance may align with optimal IOFC estimates (De La Llata et al., 2001; Main et al., 2008). Similarly, when we evaluated the data in terms of IOFC for both experiments, we observed the dietary SID Lys resulting in optimized growth performance was associated with the optimal IOFC estimate, even though feed cost was increased. It is documented that feed cost per unit of gain may be more sensitive to changes in feed ingredient prices than IOFC (De La Llata et al., 2001; Main et al., 2008).

In conclusion, the SID Lys requirement to optimize growth performance and IOFC was 1.19% or 4.63 g of SID Lys/Mcal of NE, 1.05% or 4.04 g of SID Lys/Mcal of NE, and 0.94% or 3.58 g of SID Lys/Mcal of NE for pigs weighing 49–59 kg, 59–71 kg, and 71–81 kg, respectively. The SID Lys requirement for late finishing pigs was 0.74%–0.81% or 2.85–3.10 g of SID Lys/Mcal of NE, and 0.69%–0.75% or 2.61–2.84 g of SID Lys/Mcal of NE, for 90–106 kg and

106–136 kg pigs, respectively. While these requirements are dependent on the statistical model utilized, our data provides SID Lys requirements for current Duroc-sired pigs grown in a commercial environment. The increased Lys estimate requirements highlight advances in management, health status, and genetic improvements over time.

Acknowledgments

Conflict of Interest Statement

None declared.

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