Kansas State University
College of Agriculture

SWINE DAY
2026

Effects of Standardized Ileal Digestible Lysine to Crude Protein Ratio on Growth Performance of 163 to 214 lb Pigs

Jessica L. Smallfield, Ron Aldwin S. Navales, Joel M. DeRouchey, Jordan T. Gebhardt[1], Jason C. Woodworth, Katelyn N. Gaffield, Mike D. Tokach, and Robert D. Goodband

Summary

Recent evidence in late nursery and finishing pigs has suggested that nitrogen may become limiting for synthesis of nonessential amino acids in low-protein, amino acid-fortified diets. A previous experiment by Navales et al.[2] using finishing pigs of various stages of growth observed that cubic models provided the best fit for body weight (BW) ranges of 100 to 153 lb, 121 to 172 lb, and 228 to 275 lb to estimate standardized ileal digestible lysine to crude protein (SID Lys:CP) ratios to optimize F/G based on the local minimum. However, for pigs weighing 187 to 238 lb, the requirement was estimated to be below 5.13%, the lowest SID Lys:CP ratio tested based on the linear model. Therefore, a 21-d study was conducted using a total of 693 pigs (241 × 600 DNA; initially 163.3 ± 1.46 lb) to determine the effect of SID Lys:CP on growth performance and blood urea nitrogen (BUN) of 163 to 214 lb pigs using ratios of 77.5 to 107.5% of the NRC (2012) rather than the 85.0 to 115.0% tested by Navales et al.2. Pens of pigs were blocked by BW and randomly assigned to one of five dietary treatments in a randomized complete block design. There were 9 to 10 pigs per pen and 14 replications per treatment. Dietary treatments were corn-soybean meal-based and formulated to contain 0.71% SID Lys. Treatments provided SID Lys:CP ratios of 77.5, 85.0, 92.5, 100.0, and 107.5% of requirement estimates calculated from NRC (2012) resulting in SID Lys:CP ratios of 4.68, 5.13, 5.58, 6.03, and 6.49%, respectively. Intermediate SID Lys:CP levels were achieved by blending diets with the lowest and highest SID Lys:CP ratio. Pen weights, number of pigs per pen, and feed deliveries were recorded to calculate ADG, ADFI, and F/G. Blood samples were collected on d 14 after a 10-h fasting period from one gilt and two barrows per pen and analyzed for serum BUN. Dose-response curves were evaluated using linear, quadratic polynomial, cubic polynomial, and broken-line linear (BLL) models. Overall (d 0 to 21), increasing SID Lys:CP had no effect on ADG or final BW. A cubic response was observed (P = 0.004) for ADFI, where ADFI decreased when increasing SID Lys:CP from a ratio of 4.68

[1] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

[2] Navales, R. A., A. K. Jenkins, T. H. Kim, J. Arroyave, J. M. DeRouchey, K. N. Gaffield, J. T. Gebhardt, R. D. Goodband, M. D. Tokach, and J. C. Woodworth. 2025. Effect of standardized ileal digestible lysine to crude protein ratio on growth performance of 100 to 275 lb pigs. Kansas Agricultural Experiment Station Research Reports.

to 5.13%, then increased up to a SID Lys:CP ratio of 6.03%, followed then by a slight reduction in ADFI at the highest SID Lys:CP treatment of 6.49%. A similar response was observed for F/G (cubic, $P < 0.001$), where F/G improved when SID Lys:CP ratio was increased from 4.68 to 5.13%, followed by a worsening of F/G as the SID Lys:CP ratio increased further to 6.03%, with a slight improvement in F/G at the highest SID Lys:CP ratio of 6.49%. Increasing SID Lys:CP decreased (cubic, $P \leq 0.004$) N intake per day and per kg gain, as well as reduced (linear, $P < 0.001$) blood urea nitrogen. In conclusion, increasing SID Lys:CP worsened F/G and decreased BUN in 163 to 214 lb pigs. Based on the local minimum determined using the cubic model, the estimated SID Lys:CP ratio to optimize F/G for pigs weighing between 163 to 214 lb is 4.98%, which is below the estimate calculated from NRC (2012).

Introduction

Low-protein, amino acid (AA)-fortified diets offer an opportunity to reduce nitrogen (N) excretion as well as potentially decrease diet cost. However, replacing too much dietary protein with feed-grade AA may affect growth performance, as N from intact protein is needed for the synthesis of nonessential AA[3]. The SID Lys:CP ratio can be used as an indicator to ensure sufficient N is available for synthesis of nonessential AA in low-protein, AA-fortified diets. Using the NRC (2012)[4] estimates for N requirements and an N to CP conversion of 6.25, the calculated SID Lys:CP ratio is approximately 6.02% for 165 to 220 lb pigs. A series of experiments conducted by Navales et al.2 evaluated the SID Lys:CP ratio in 100 to 153 lb, 121 to 172 lb, and 228 to 275 lb pigs and found that based on the local minimum determined using cubic models, the estimated SID Lys:CP ratios to optimize F/G were 5.55, 5.43, and 5.23%, respectively. However, for pigs weighing 187 to 238 lb, the requirement was estimated to be below the lowest level tested, 5.13%, based on the linear model. Therefore, the objective of this study was to determine the effect of SID Lys:CP ratio on growth performance and BUN of 163 to 214 lb pigs using ratios of 77.5 to 107.5% of the NRC (2012) estimates rather than 85.0 to 115.0% previously tested2.

Procedures

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. Each pen provided 7.83 ft2 per pig and was equipped with a dry, two-hole feeder (Farmweld, Teutopolis, IL) and one cup waterer to provide ad libitum access to feed and water. Pens were located over a completely slatted, concrete floor with a 4-ft-deep pit underneath for manure storage. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro, FeedLogic by ComDel Innovation, Wahpeton, ND) able to record feed deliveries for individual pens.

Animals and diets

This experiment was conducted using two groups of pigs (346 in group 1 and 347 in group 2). A total of 693 pigs (241 × 600 DNA; initially 163.3 ± 1.46 lb) were housed in

[3] Peng, X., L. Hu, Y. Liu, C. Yan, Z. F. Fang, Y. Lin, S. Y. Xu, J. Li, C. M. Wu, D. W. Chen, H. Sun, D. Wu, and L. Q. Che. 2016. Effects of low-protein diets supplemented with indispensable amino acids on growth performance, intestinal morphology and immunological parameters in 13 to 35 kg pigs. Animal. 10:1812–1820. doi:10.1017/S1751731116000999.

[4] NRC. 2012. Nutrient requirements of swine. 11th rev. ed. National Academies Press, Washington, D.C. Available from: http://www.nap.edu/catalog/13298

pens of 9 to 10 pigs each, with 14 pens per treatment. All pens were mixed gender and were equipped with adjustable gates to allow space allowance per pig to be maintained if a pig died or was removed during the experiment. Pens of pigs were allotted by body weight (BW) and randomly assigned to one of five dietary treatments in a randomized complete block design.

The dietary treatments were corn-soybean meal-based and formulated to contain 0.71% SID Lys. Treatments consisted of SID Lys:CP ratios of 4.68, 5.13, 5.58, 6.03, and 6.49%, or 77.5, 85.0, 92.5, 100.0, and 107.5% of requirement estimates calculated from NRC (2012). Intermediate SID Lys:CP ratio treatments were created by blending the diets containing the lowest and highest SID Lys:CP ratio (Table 1). The SID Lys level was determined using the prediction models developed by Royall et al.[5] applying the requirement estimate calculated for pig weight at the end of the phase so as not to be above the pig's Lys requirement estimate. This level corresponded to 80% of the requirement at the beginning and up to 100% at the end of the experiment. All other nutrients met or exceeded NRC (2012) requirements.

Before diet formulation, duplicate samples of corn and soybean meal were analyzed for CP and AA profiles (University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO), and the analyzed values were used in diet formulation. Diets were manufactured in meal form at the O.H. Kruse Feed Technology Innovation Center at Kansas State University. Representative diet samples were collected and stored at -4°F, then analyzed in duplicate for CP and AA profiles (University of Missouri Agricultural Experiment Station Chemical Laboratories; Table 2).

Measurements and sampling

Pen weight, number of pigs per pen, and feed delivery were recorded weekly to calculate ADG, ADFI, and F/G. On d 14 of the experiment, 10 mL of blood was collected via jugular venipuncture from three pigs per pen (two barrows and one gilt) after a 10-h fasting period. Serum urea nitrogen concentrations were determined using the Urea Nitrogen Colorimetric Detection Kit (Arbor Assays, Ann Arbor, MI).

Statistical analysis

Growth data were analyzed using R Studio (Version 4.3.1, R Core Team, Vienna, Austria) with pen serving as the experimental unit, treatment as fixed effect, group as random effect, and initial BW block as a random effect in a randomized complete block design. Orthogonal linear, quadratic, and cubic contrasts were evaluated to determine the response to increasing SID Lys:CP ratios. Dose-response curves were evaluated using linear, quadratic polynomial, cubic polynomial, and broken-line linear (BLL) models using SAS version 9.4 (SAS Institute, Inc., Cary, NC). The best-fitting models were selected using the Bayesian Information Criterion (BIC) with improved model fit accepted when BIC decreased by at least 2.0. Blood urea nitrogen data were analyzed using R Studio with pen serving as the experimental unit, treatment and sex as fixed effects, and block, pen, and plate as random effects.

[5] Royall, R. Q., R. D. Goodband, M. D. Tokach, J. M. DeRouchey, J. C. Woodworth, and J. T. Gebhardt. 2022. Effects of standardized ileal digestible lysine level on growth performance and economic return for 18 to 128 kg Duroc-sired pigs. Transl. Anim. Sci. 6(4):txac103. doi:10.1093/tas/txac103.

Results and Discussion

Growth performance and BUN

Overall (d 0 to 21), increasing SID Lys:CP had no effect on ADG or final BW (Table 3). A cubic response was observed (cubic, P £ 0.004) for ADFI, where ADFI decreased when increasing SID Lys:CP from a ratio of 4.68 to 5.13%, then increased up to a SID Lys:CP ratio of 6.03%, followed by a slight reduction in ADFI for the highest SID Lys:CP ratio of 6.49%. A similar response was observed for F/G (cubic, P < 0.001), where F/G improved when SID Lys:CP ratio was increased from 4.68 to 5.13%, followed by a worsening of F/G as the SID Lys:CP ratio increased further to 6.03%, with a slight improvement in F/G at the highest SID Lys:CP ratio of 6.49%. Increasing SID Lys:CP decreased (cubic, P £ 0.004) N intake per day and per kg gain, as well as reduced (linear, P < 0.001) blood urea nitrogen. Among the models evaluated, the cubic model yielded the lowest BIC for F/G with the local minimum at an SID Lys:CP ratio of 4.98% (Figure 1).

In conclusion, increasing the SID Lys:CP ratio worsened F/G and decreased BUN in 163 to 214 lb pigs. Based on the local minimum determined using the cubic model, the estimated SID Lys:CP ratio requirement to minimize F/G was 4.98%. The SID Lys:CP ratio is lower than that calculated from the NRC (2012). This suggests higher CP levels than NRC (2012) estimates are required if diets are formulated to be at or below the SID Lys requirement.

Acknowledgments

The authors would like to thank the United Soybean Board for partial financial support.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

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

SID Lys:CP, %:	4.68	5.13	5.58	6.03	6.49
% of NRC, 2012:	77.5	85.0	92.5	100.0	107.5
Ingredient, %					
Corn	77.80	81.59	84.77	87.50	89.86
Soybean meal, 45.1% CP	20.28	16.18	12.72	9.75	7.19
Calcium carbonate	0.79	0.77	0.76	0.75	0.74
Monocalcium P, 21% P	0.28	0.33	0.38	0.42	0.45
Salt	0.55	0.55	0.56	0.56	0.56
L-Lys-HCl	---	0.13	0.24	0.34	0.42
DL-Met	---	0.02	0.04	0.06	0.08
L-Thr	---	0.05	0.10	0.13	0.17
L-Trp	0.01	0.03	0.05	0.06	0.08
L-Val	---	0.03	0.05	0.06	0.08
L-Ile	---	0.03	0.06	0.08	0.11
Trace mineral premix	0.13	0.13	0.13	0.13	0.13
Vitamin premix	0.13	0.13	0.13	0.13	0.13
Phytase[3]	0.04	0.04	0.04	0.04	0.04
Total	100	100	100	100	100
Calculated analysis					
SID Lys, %	0.71	0.71	0.71	0.71	0.71
SID AA:SID Lys					
Ile	78	72	68	64	61
Leu	173	160	148	139	130
Met	33	34	34	35	35
Met and Cys	65	63	61	60	58
Thr	67	66	66	65	65
Trp	21	21	21	21	21
Val	95	88	82	77	72
His	52	46	42	38	34
Arg	121	105	92	80	70
Phe	93	82	74	67	60
Phe and Tyr	149	131	117	104	93
Ala	99	92	86	80	76
Asp	175	151	131	113	98
Glu	349	312	280	253	230
Gly	75	67	60	55	50
Pro	148	135	125	116	108
Ser	81	72	65	59	53
NE, kcal/lb	1,189	1,190	1,191	1,191	1,192
SID Lys:NE, g/Mcal	2.71	2.71	2.71	2.70	2.70

CP, %	15.18	13.85	12.73	11.77	10.94
Ca, %	0.49	0.48	0.47	0.47	0.46
STTD P, %	0.31	0.31	0.31	0.31	0.31
Ca:P	1.21	1.21	1.21	1.21	1.21

[1] Diets were formulated based on the requirements of 165 to 220 lb pigs.

[2] The standardized ileal digestible Lys level was determined using the prediction models developed by Royall et al. (2022), applying the requirement estimated at the end of the phase. This level corresponded to at least 80% of the requirement at the beginning and up to 100% at the end of the phase. Intermediate SID Lys:CP treatments were created by blending the diets containing the lowest and highest SID Lys:CP ratios.

[3] Ronozyme HiPhorius 2400 (Novonesis, Kongens Lyngby, Denmark) provided an estimated release of 0.12% STTD P with 408 FYT/lb.

Table 2. Analyzed composition of diets (as-fed basis)[1]

SID Lys:CP, %:	4.68	5.13	5.58	6.03	6.49
% of NRC, 2012:	77.5	85.0	92.5	100.0	107.5
Nutrient, %					
CP	15.21	13.39	12.22	11.50	10.95
Moisture	13.01	13.13	13.14	13.28	13.25
Crude fat	2.41	2.34	2.58	2.30	2.64
Crude fiber	2.37	1.51	1.76	1.71	1.76
Ash	3.44	3.35	3.09	3.16	2.74
Essential AAs					
Arg	0.92	0.77	0.72	0.64	0.59
His	0.41	0.36	0.35	0.31	0.30
Ile	0.65	0.60	0.57	0.55	0.51
Leu	1.41	1.29	1.23	1.16	1.10
Lys	0.79	0.79	0.79	0.77	0.75
Met	0.26	0.26	0.27	0.29	0.28
Phe	0.76	0.67	0.62	0.57	0.53
Thr	0.57	0.56	0.55	0.53	0.53
Trp	0.17	0.17	0.16	0.16	0.16
Val	0.74	0.68	0.65	0.62	0.57
Nonessential AAs					
Ala	0.84	0.77	0.74	0.70	0.68
Asp	1.42	1.19	1.10	0.96	0.87
Cys	0.28	0.25	0.25	0.24	0.22
Glu	2.81	2.46	2.32	2.12	1.97
Gly	0.63	0.53	0.51	0.46	0.44
Pro	0.95	0.88	0.84	0.81	0.77
Ser	0.65	0.56	0.54	0.49	0.47
Tyr	0.50	0.44	0.41	0.37	0.36

[1] Samples were analyzed for proximate analysis and complete AA profile (University of Missouri Agricultural Experiment Station Chemical Laboratory).

Table 3. Effect of standardized ileal digestible lysine to crude protein (SID Lys:CP) ratio on growth performance and blood urea nitrogen (BUN) of 163 to 214 lb pigs[1]

SID Lys:CP, %:	4.68	5.13	5.58	6.03	6.49				
% of NRC, 2012:	77.5	85.0	92.5	100.0	107.5			*P* =	
CP, %:	15.18	13.85	12.73	11.77	10.94	SEM	Linear	Quadratic	Cubic
BW, lb									
Initial	163.3	163.3	163.3	163.3	163.3	1.46	0.850	0.959	0.963
Final	214.8	214.9	214.9	214.1	213.7	1.94	0.159	0.478	0.872
Overall (d 0 to 21)									
ADG, lb	2.45	2.46	2.46	2.43	2.40	0.043	0.211	0.461	0.986
ADFI, lb	6.32	6.24	6.49	6.60	6.36	0.132	0.048	0.080	0.004
F/G	2.57	2.54	2.64	2.72	2.65	0.026	< 0.001	0.319	< 0.001
N intake, g/d	69.6	62.7	59.9	56.3	50.5	1.23	< 0.001	0.555	0.004
N intake, g/kg gain	62.5	56.3	53.7	51.2	46.4	0.54	< 0.001	0.059	< 0.001
BUN, mg/dL[2]	10.32	9.04	7.05	6.29	4.67	0.285	< 0.001	0.498	0.857

[1] A total of 693 pigs were used with 9 to 10 pigs per pen and 14 pens per treatment.

[2] Blood samples were taken on d 14 from three pigs per pen (two barrows and one gilt) to measure serum urea N.

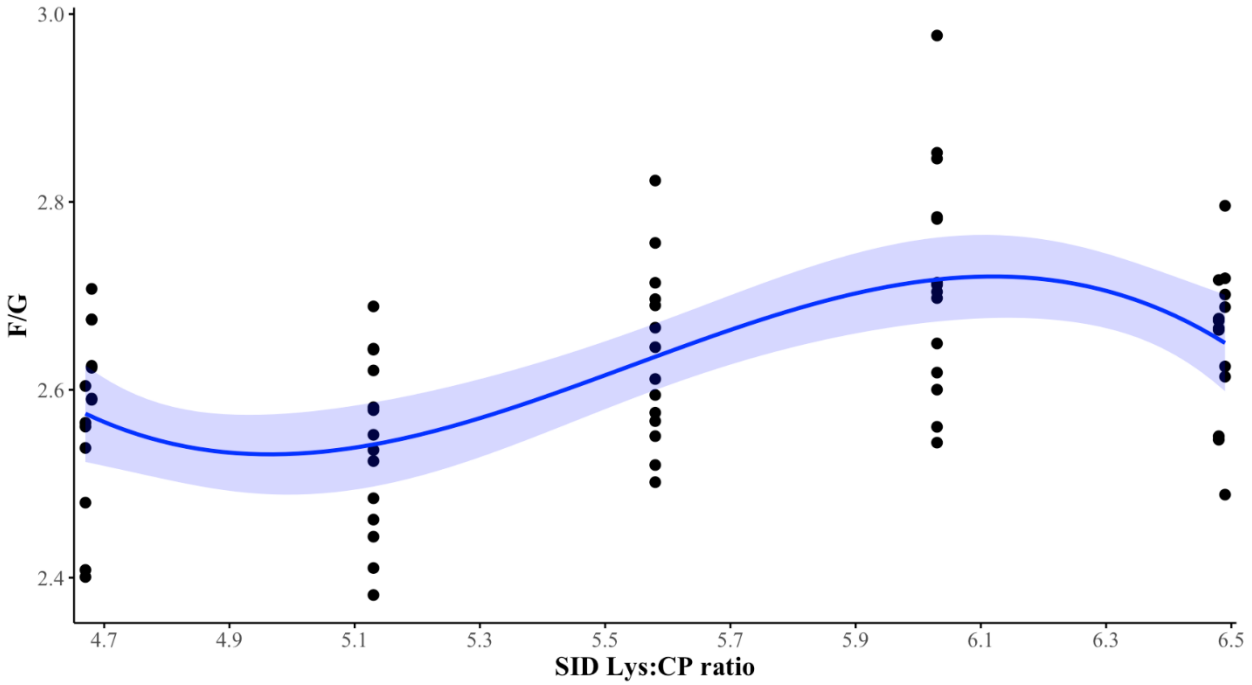


Figure 1. Estimation of SID Lys:CP ratio requirements to minimize F/G for 163 to 214 lb pigs using a cubic model (· Pen ¾ linear predictor). Linear, quadratic, cubic, and broken line linear models were fit to estimate SID Lys:CP ratio required to minimize F/G. The cubic model resulted in the lowest BIC, with the local minimum at 4.98% SID Lys:CP ratio.