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Cover Page Footnote

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Effects of Amino Acid Ratios and Lysine Level on Nursery Pig Growth Performance[1]

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Summary

A total of 2,268 pigs (PIC 327 × L42, initially 16.2 lb BW) was used in a 28-d growth study with 54 pigs per feeder (experimental unit) and 6 replications per treatment. Pigs were randomly allotted to pens at weaning and fed a common starter diet for 8 d. Pens were then blocked by BW and allotted to 1 of 7 dietary treatments in a randomized complete block design. Treatments were arranged in two levels of standardized ileal digestible (SID) Lys (low,1.25% and high, 1.35%) and SID amino acid (AA) ratios relative to Lys (industry, 95% of maximum performance, and maximum performance). The seventh dietary treatment was a control diet (1.35% SID Lys). Industry ratios were 55% Met+Cys:Lys, 62% Thr:Lys, 18% Trp:Lys, and 65% Val:Lys. Maximum diet ratios were 60% Met+Cys:Lys, 65% Thr:Lys, 21% Trp:Lys, and 72% Val:Lys. The 95% ratios were formulated to target 95% of maximum performance and were 56% Met+Cys:Lys, 62% Thr:Lys, 19% Trp:Lys, and 67% Val:Lys. Diets were formulated to meet or exceed the Ile requirement with feed-grade Lys, Met, Thr, Trp, and Val added. The control diet contained less feed-grade AA (0.39% L-Lys HCl vs. 0.50 to 0.55% in other diets) and 5% enzymatically-processed soybean meal to achieve a similar conventional soybean meal level to the high SID Lys diets. Experimental diets were formulated using analyzed total AA for corn, soybean meal, and dried distillers grains with solubles and fed for 14 d in meal form. A post-treatment period with a common diet was fed from d 14 to 28. From d 0 to 14, feeding high Lys diets increased (*P* < 0.001) ADG and F/G compared with low Lys diets with no evidence for differences in ADFI. For ADG and F/G, pigs fed maximum AA ratios had improved (*P* < 0.05) performance compared to those fed industry ratios at low Lys, but not at high Lys levels. In conclusion, high AA ratios were more critical in diets formulated below the Lys requirement of the pig.

Introduction

Recent dose-response relationship research regarding amino acids for growing and finishing pigs typically reports the levels at which maximum growth response was observed. Often, these levels may be higher than the current requirement recommenda-

[1] Appreciation is expressed to Ajinomoto Heartland, Inc., Chicago, IL for funding and Holden Farms, Inc. (Northfield, MN) for providing the animals, research facilities, and technical support.
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[3] Ajinomoto Heartland, Inc. (Chicago, IL).

tions or levels fed within the commercial industry for pigs of a particular weight range. Specifically, Gonçalves et al.[4] determined that at least 20.4% SID Trp:Lys maximized performance of pigs weighing approximately 13 to 22 lb. Furthermore, Clark et al.[5] determined that 72% SID Val:Lys maximized G:F for nursery pigs weighing 15 to 25 lb. To our knowledge, there is not a lot of research available regarding pigs fed diets formulated to maximize growth performance using high ratios for multiple AA compared to lower ratios more commonly used in commercial production. Therefore, the objective of this experiment was to determine the effects of three AA ratio levels (industry, 95% of maximum performance, and maximum performance) at or below the Lys requirement for nursery pigs weighing approximately 15 to 25 lb.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The trial was conducted at a commercial research facility that is owned and operated by Holden Farms, Inc., Northfield, MN. Each pen (6 × 11 ft) was equipped with a double-sided 5-hole dry feeder and 1 cup waterer allowing ad libitum access to feed and water. Feed additions were delivered and recorded using a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN).

A total of 2,268 pigs (PIC 327 × L42, initially 16.2 lb BW) were used in a 28-d growth study trial. There were 27 pigs per feeder with two pens sharing a fenceline feeder. Thus, there were 54 pigs per feeder, which served as the experimental unit, and 6 replications per treatment. Pigs were weaned at approximately 21-d of age and allotted to pens. Pens were blocked by BW and allotted to 1 of 7 dietary treatments arranged in a 2 × 3 + 1 factorial with main effects of standardized ileal digestible (SID) Lys, (low, 1.25% and high, 1.35%), and 3 SID amino acid (AA) ratios relative to Lys (industry, 95% of maximum performance, and maximum performance), as well as a control diet (1.35% SID Lys). Industry ratios were 55% Met+Cys:Lys, 62% Thr:Lys, 18% Trp:Lys, and 65% Val:Lys. Maximum diet ratios were 60% Met+Cys:Lys, 65% Thr:Lys, 21% Trp:Lys, and 72% Val:Lys. The 95% ratios were formulated to target 95% of maximum performance and were 56% Met+Cys:Lys, 62% Thr:Lys, 19% Trp:Lys, and 67% Val:Lys. Diets were formulated to meet or exceed the pig's Ile requirement with added feed-grade Lys, Met, Thr, Trp, and Val. The low SID Lys diets had SID Lys that was below the NRC[6] requirement estimates, and the high SID Lys diets had SID Lys that was at the NRC[6] requirement estimate. The control was formulated to contain less feed-grade AA (0.39% L-Lys HCl vs. 0.50 to 0.55% in other diets) and 5% enzymatically-processed soybean meal (HP 300; Hamlet Protein, Findlay, OH) to achieve a similar conventional soybean meal level to the high SID Lys diets. Experimental diets were formulated using analyzed total AA for corn, soybean meal, and dried distillers grains with solubles and SID coefficients from the NRC (2012). A post-treatment common diet (1.35% SID Lys) was fed from d 14 to 28.

[4] Gonçalves, M., S. Nitikanchana, M. D. Tokach, S. S. Dritz, N. M. Bello, R. D. Goodband, K. Touchette, J. Usry, J. M. DeRouchey, and J. C. Woodworth. 2015. Effects of standardized ileal digestible tryptophan: Lysine ratio on growth performance of nursery pigs. J. Anim. Sci. 93(8): 3909-3918.

[5] Clark, A. B.; Tokach, M. D.; DeRouchey, J. M.; Dritz, S. S.; Touchette, K.; Goodband, R. D.; and Woodworth, J. C. (2016) "Effects of Dietary Standardized Ileal Digestible Valine:Lysine Ratio on 14 to 22 lb Nursery Pigs," Kansas Agricultural Experiment Station Research Reports: Vol. 2: Iss. 8. https://doi.org/10.4148/2378-5977.1288.

[6] NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington DC.

Pens of pigs were weighed and feed disappearance was measured on d 0, 14, and 28 to determine ADG, ADFI, and F/G.

All diets were fed in meal form. Diets were manufactured at a commercial feed mill (Blooming Prairie, MN). Samples of each diet were analyzed for proximate analysis (Ward Laboratory, Kearney, NE) and AA content (Ajinomoto Heartland, Inc., Chicago, IL).

Data were analyzed using the PROC GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) with pen considered the experimental unit. Due to increasing the AA ratios for multiple AA in different increments across treatments, LSMEANS were used to compare treatment results. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Lab analyses matched anticipated values in regards to proximate and AA analysis. Lysine remained relatively constant among similar level treatments, and other AA increased according to formulated targets. This is also indicated in the free AA analysis that additions with feed grade AA were on target.

During the experimental diet phase (d 0 to 14), pigs fed the high Lys diets had improved ($P < 0.001$) ADG and F/G compared to pigs fed the low Lys diets. There was no evidence of differences ($P = 0.692$) in ADFI. Within the low Lys treatments, feeding max AA ratios improved ADG and F/G ($P < 0.05$) compared to industry AA levels, with pigs fed diets with ratios for 95% of maximum performance intermediate. Within the high Lys treatments, feeding industry or 95% max AA levels improved ADG compared to the high AA level, and improved F/G compared to the high AA level. Overall, ADG was improved ($P < 0.05$) for high Lys/industry AA fed pigs and high Lys/95% AA fed pigs, compared to low Lys/industry AA and high Lys/max AA fed pigs, with other treatments being intermediate. Feed intake was improved ($P < 0.05$) for high Lys/95% AA fed pigs compared to control and Low Lys/industry AA fed pigs. Feed efficiency was improved ($P < 0.05$) for high Lys/industry AA pigs compared to low Lys/industry AA, low Lys/95% AA, and high Lys/max AA pigs. During the post-treatment period, there was no evidence of differences ($P > 0.409$) in ADG, ADFI, or F/G between high and low Lys treatments. Feeding high Lys/industry AA improved ($P < 0.05$) F/G compared to low Lys/max AA and high Lys/95% AA fed pigs. During the overall experimental period, ADG was marginally improved ($P = 0.064$) and F/G was improved ($P = 0.002$) for pigs fed the high Lys diets compared to those fed the low Lys diets. Average daily gain was improved ($P < 0.05$) for pigs previously fed the high Lys/industry AA, high Lys/95% AA diets compared to those previously fed the industry AA diets, with other treatments being intermediate. Feed efficiency was also improved ($P < 0.05$) for the high Lys/industry AA treatment compared to all low Lys treatments and high Lys/95% AA treatment. Body weight on d 14 was marginally increased ($P = 0.080$) for pigs fed high Lys with no evidence for differences ($P = 0.156$) on d 28. Similarly to performance data, high Lys/industry and high Lys/95% max AA pigs had heavier BW ($P < 0.05$) compared to low Lys/industry AA pigs, with others being intermediate.

In conclusion, pigs fed high Lys diets had improved growth performance compared to pigs fed the low Lys diets during the treatment period. When pigs were fed below their Lys requirement, formulating to maximum AA ratios relative to Lys for Met, Thr, Trp, and Val was beneficial for growth performance. However, this response was not observed in the high Lys diets. Results from this study suggest that higher AA ratios were more critical in diets formulated below the pig's Lys requirement.

Table 1. Ingredient chemical analysis[1,2]

Item, %	Corn	Soybean meal	Dried distillers grains with solubles
Total AA			
Lys	0.22	2.98	0.95
Ile	0.22	2.06	0.98
Leu	0.76	3.54	3.09
Met	0.13	0.64	0.52
Thr	0.23	1.81	1.01
Trp	0.05	0.64	0.23
Val	0.30	2.02	1.25
His	0.19	1.22	0.74
Phe	0.29	2.35	1.31
Standardized ileal digestible AA, % (Calculated)			
Lys	0.17	2.65	0.56
Ile	0.18	1.84	0.74
Leu	0.66	3.11	2.60
Met	0.11	0.57	0.43
Thr	0.18	1.54	0.72
Trp	0.04	0.58	0.16
Val	0.24	1.76	0.94
His	0.15	1.10	0.58
Phe	0.24	2.07	1.06

[1] Analyzed at Ajinomoto Heartland, Inc. (Chicago, IL) for amino acid content.

[2] SID % content calculated using SID coefficients from the NRC (NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington DC).

Table 2. Diet composition[1]

		Low Lys			High Lys		
Ingredient, %	Control	Industry AA	95% AA	Max AA	Industry AA	95% AA	Max AA
Corn	41.85	52.86	52.80	52.67	46.85	46.78	46.65
Soybean meal, 48% CP	26.58	24.76	24.77	24.77	26.61	26.61	26.62
Dried whey	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Corn DDGS, 7.5% Oil	10.00	6.25	6.25	6.25	10.00	10.00	10.00
HP 300[2]	5.00	---	---	---	---	---	---
Antibiotic[3]	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Choice white grease	2.35	1.60	1.60	1.55	2.00	2.00	1.95
Calcium phosphate (monocalcium)	0.85	1.03	1.03	1.03	0.93	0.93	0.93
Limestone	1.18	1.15	1.15	1.15	1.18	1.18	1.18
Sodium chloride	0.53	0.53	0.53	0.53	0.53	0.53	0.53
L-Lys-HCl	0.39	0.50	0.50	0.50	0.55	0.55	0.55
DL-Met	0.22	0.21	0.22	0.27	0.22	0.24	0.29
L-Thr	0.18	0.20	0.20	0.24	0.21	0.22	0.25
L-Trp	0.02	0.03	0.05	0.07	0.04	0.05	0.08
L-Val	0.13	0.14	0.17	0.23	0.15	0.18	0.24
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin and mineral premix[4]	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

continued

Table 2, *continued*. Diet composition[1]

		Low Lys			High Lys		
Ingredient, %	Control	Industry AA	95% AA	Max AA	Industry AA	95% AA	Max AA
SID amino acids, %							
Lys	1.35	1.25	1.25	1.25	1.35	1.35	1.35
Ile:Lys	60	53	53	53	52	52	52
Leu:Lys	122	111	111	111	111	111	111
Met:Lys	37	36	37	41	36	37	41
Met and Cys:Lys	58	55	56	60	55	56	60
Thr:Lys	65	62	62	65	62	62	65
Trp:Lys	19	18	19	21	18	19	21
Val:Lys	70	65	67	72	65	67	72
His:Lys	37	33	33	33	33	33	33
Total Lys, %	1.52	1.39	1.39	1.39	1.50	1.50	1.50
ME, kcal/lb	1,530	1,510	1,511	1,511	1,516	1,516	1,517
NE NRC, kcal/lb	1,135	1,135	1,135	1,135	1,135	1,135	1,135
SID Lys:ME, g/Mcal	4.00	3.75	3.75	3.75	4.04	4.04	4.04
CP, %	22.6	18.8	18.8	19.0	20.4	20.4	20.6
Ca, %	0.75	0.75	0.75	0.75	0.75	0.75	0.75
P, %	0.66	0.65	0.65	0.65	0.65	0.65	0.65

[1] Diet was fed for 14 d from approximately 16 to 27 lbs.

[2] Hamlet Protein, Findlay OH.

[3] CTC 100, Zoetis Services, LLC., Florham Park, NJ.

[4] One pound of premix was formulated to contain 1,816,000 IU vitamin A, 330,000 IU vitamin D, 9,090 IU vitamin E, 667 mg menadione, 5 mg vitamin $B_{12,}$ 7,600 mg niacin, 4,318 mg panthothenic acid, 1,259 mg riboflavin, 50 mg biotin, 545 mg folic acid, 750 mg pyridoxine, 1.7 g Cu from copper sulfate, 100 mg I from Ca iodate, 16 g Fe from ferrous sulfate, 4.0 g Mn from manganese sulfate/manganese oxide, 45.5 mg Se from sodium selenite, 16 g Zn from zinc sulfate, and 227,248 FYT from Ronozyme HiPhos (DSM Nutritional Products, Parsippany, NJ) for an estimated aP release of 0.16%.

Table 3. Analysis of diets (as-fed basis)[1]

		Low Lys			High Lys		
Ingredient, %	Control	Industry AA	95% AA	Max AA	Industry AA	95% AA	Max AA
Proximate analysis, %[2]							
DM	91.43	90.25	90.89	91.06	91.22	91.35	90.64
CP	22.4	18.1	18.1	18.4	19.4	19.6	18.8
Ca	0.84	0.81	0.75	0.97	0.89	0.92	0.93
P	0.63	0.58	0.57	0.67	0.60	0.58	0.58
AA analysis, %[3]							
Lys	1.45	1.36	1.45	1.34	1.49	1.41	1.40
Ile	0.96	0.82	0.84	0.80	0.85	0.83	0.82
Leu	1.91	1.66	1.68	1.61	1.75	1.69	1.70
Met	0.49	0.44	0.46	0.50	0.47	0.50	0.52
Met + Cys	0.83	0.73	0.76	0.79	0.79	0.81	0.82
Thr	0.96	0.82	0.93	0.95	0.99	0.88	0.95
Trp	0.25	0.24	0.26	0.27	0.27	0.26	0.28
Val	1.17	1.03	1.03	1.09	1.07	1.08	1.13
His	0.55	0.47	0.47	0.45	0.50	0.46	0.48
Phe	1.08	0.91	0.93	0.90	1.00	0.91	0.95
Free Lys	0.31	0.39	0.41	0.39	0.42	0.42	0.44
Free Met	0.20	0.20	0.20	0.25	0.22	0.24	0.26
Free Thr	0.20	0.19	0.24	0.26	0.23	0.18	0.27
Free Trp	0.03	0.03	0.05	0.07	0.04	0.06	0.07
Free Val	0.12	0.14	0.15	0.23	0.14	0.17	0.22

[1] Experimental diets were fed from d 0 to 14 in meal form.

[2] Composite samples were submitted to Ward Laboratories (Kearney, NE) for proximate analysis.

[3] Composite samples were submitted to Ajinomoto Heartland, Inc. (Chicago, IL) for amino acid analysis.

Table 4. Effects of lysine level and amino acid ratios on nursery pig performance[1]

		Low Lys[2]			High Lys[3]				Probability, $P <$
Item	Control	Industry AA	95% AA	Max AA	Industry AA	95% AA	Max AA	SEM	Low vs. high Lys
Treatment period (d 0 to 14)									
ADG, lb	0.81[a,b]	0.76[c]	0.80[b,c]	0.82[a,b]	0.84[a]	0.85[a]	0.80[b]	0.015	0.001
ADFI, lb	0.99[b]	0.99[b]	1.03[a,b]	1.03[a,b]	1.02[a,b]	1.04[a]	1.01[a,b]	0.020	0.692
F/G	1.22[c,d]	1.30[a]	1.29[a,b]	1.26[b,c,d]	1.22[d]	1.23[c,d]	1.26[a,b,c]	0.015	0.001
Post-treatment period (d 14 to 28)[4]									
ADG, lb	0.91	0.90	0.89	0.91	0.90	0.89	0.91	0.014	0.865
ADFI, lb	1.35	1.34	1.33	1.39	1.32	1.35	1.34	0.033	0.500
F/G	1.48[a,b,c]	1.48[b,c]	1.50[a,b,c]	1.53[a,b]	1.48[c]	1.53[a]	1.47[c]	0.025	0.409
Overall (d 0 to 28)									
ADG, lb	0.86[a,b]	0.83[b]	0.84[a,b]	0.86[a,b]	0.86[a]	0.87[a]	0.86[a,b]	0.012	0.064
ADFI, lb	1.17	1.16	1.18	1.21	1.17	1.20	1.17	0.024	0.740
F/G	1.36[b,c]	1.40[a]	1.40[a]	1.40[a]	1.35[c]	1.38[a,b]	1.37[a,b,c]	0.015	0.002
BW, lb									
d 0	16.1	16.2	16.2	16.2	16.2	16.1	16.1	0.27	0.569
d 14	27.5[a,b]	26.9[b]	27.4[a,b]	27.7[a,b]	28.0[a]	28.0[a]	27.3[a,b]	0.43	0.080
d 28	40.2	39.6	39.8	40.4	40.5	40.4	40.3	0.51	0.156

[1] A total of 2,268 nursery pigs (PIC 327 × L42) were used in a two-phase nursery study with 54 pigs per feeder and 6 feeders (replications) per treatment.

[2] Diets were formulated to 1.25% SID Lys.

[3] Diets were formulated to 1.35% SID Lys.

[4] Common diet was fed during the post-treatment period.

[a,b,c,d] Means within a row with different superscripts differ ($P < 0.05$).