

Influence of Feed Grade Amino Acid Inclusion Level in Late Nursery and Grower Diets Fed to Pigs from 21 to 75 lb¹

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Summary

A total of 912 pigs (PIC TR4 × (Fast LW × PIC L02); initially 21.4 lb) were used in a 43-d trial to evaluate the influence of feed grade amino acid in diets containing 30% dried distillers grains with solubles (DDGS) fed to pigs from 21 to 75 lb. Pigs were randomly assigned to pens (19 pigs per pen) and pens were randomly allotted in weight blocks to 1 of 4 dietary treatments with 12 pens per treatment. Dietary treatments contained low, medium, high, or very high additions of feed grade amino acids with L-lysine added at approximately 0.25, 0.40, 0.55, and 0.70% of the diet. This corresponded to 15, 24, 33, and 42% of the standardized ileal digestibility (SID) lysine coming from L-lysine. All other amino acids were added as needed to meet minimum desired ratios relative to lysine (60% Ile; 58% Met and Cys; 65% Thr; 19% Trp; and 72% Val). Predetermined orthogonal contrasts were used to evaluate linear or quadratic effects based on the feed grade lysine to total lysine ratio. Overall (d 0 to 43), there was an increase (quadratic, $P < 0.020$) in average daily gain (ADG) and average daily feed intake (ADFI), with pigs fed increasing feed grade amino acids having increased gain and feed intake up to the high addition of feed grade amino acids and decreasing for pigs fed the very high diet. For overall feed efficiency (F/G), pigs fed the medium feed grade amino acids had improved F/G ($P = 0.002$) compared to pigs fed the high and very high levels of feed grade amino acids, with the pigs fed the low feed grade amino acids intermediate. As feed grade amino acids increased in the diet, blood urea nitrogen decreased (linear, $P = 0.001$) on d 21 and 43. In summary, as the percentage of L-lysine as a proportion of total SID lysine increased in the diet from 15 (Low) to 24% (Medium), ADG and F/G improved; however, as the L-lysine as a proportion of total SID lysine in the diet increased to greater than 24%, F/G worsened.

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Introduction

A meta-regression analysis (Cemin et al., 2019⁵) was developed to predict the influence of branched-chain amino acids (BCAA) on growth performance of pigs. The model predicts the negative impact on growth performance from high levels of leucine in diets and how increasing the inclusion of isoleucine (Ile) and/or valine (Val) can ameliorate the negative impact of high leucine. A study conducted to validate the model in finishing pigs (100-280 lb) found the accuracy of the model to be close to 100% when comparing predicted to actual performance (Kerkaert, 2020⁶). Late nursery and growing pigs ranging in weight from 25 to 100 lb fed diets containing high levels of DDGS are susceptible to imbalances in BCAA. Coupled with other work, this research demonstrated the importance of maintaining higher Val and Ile ratios as increasing levels of synthetic amino acids are added to corn-DDGS-based diets. Maintaining these ratios may allow higher levels of amino acids to replace soybean meal in the diet without reducing pig performance. Therefore, this trial evaluated the use of increasing levels of feed grade amino acids, while maintaining high levels of Ile and Val and other amino acids, on late nursery and growing pig growth performance.

Materials and Methods

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 owned and operated by New Fashion Pork (Jackson, MN). All diets were manufactured at the New Fashion Pork feed mill located in Estherville, IA. Before the beginning of the study, a 3-day composite sample of corn, soybean meal and dried distillers grains with solubles (DDGS) were sent to the Eurofins Nutrition Analysis Center (Des Moines, IA) for amino acid analysis and these values were used in diet formulation.

A total of 912 pigs (PIC TR4 × (Fast LW × PIC L02); initially 21.4 lb) were used in a 43-d study. There were 12 pens per treatment and 19 pigs per pen (10 gilts and 9 barrows). Pens were randomly assigned to dietary treatments and blocked based on initial body weight. Dietary treatments (Table 1) were formulated based on increasing levels of feed grade amino acids at the expense of soybean meal. Dietary treatments contained low, medium, high, or very high levels of feed grade amino acids with L-lysine added at approximately 0.25, 0.40, 0.55, and 0.70% of the diet, respectively. This resulted in the percentage of L-lysine as a proportion of the total SID lysine content as: 15, 24, 33, and 42% respectively. All other amino acids were added as needed to meet minimum desired ratios relative to lysine (60% Ile; 58% Met and Cys; 65% Thr; 19% Trp; and 72% Val). Diets were formulated to contain the same net energy content by adjusting the amount of choice white grease. The experimental diets were fed in two phases with the first fed from d 0 to 21 and the second from d 21 to 43.

Pens of pigs were weighed, and feed disappearance was calculated on d 11, 21, 32, and 43 to determine ADG, ADFI, and F/G. Blood was collected from 4 pigs per pen, 2 barrows and 2 gilts of medium size, at the end of phase 3 (d 21) and the end of phase 4

⁵ Cemin, H. S., M. D. Tokach, J. C. Woodworth, S.S. Dritz, J. M. DeRouchey, and R. D. Goodband. 2019. Branched-chain amino acid interactions in growing pig diets. *Transl. Anim. Sci.* 2019.3:1246-1253. doi:10.1093/tas/txz087.

⁶ Kerkaert, H. R., H. S. Cemin, J. C. Woodworth, J. M. DeRouchey, S. S. Dritz, M. D. Tokach, R. D. Goodband, K. D. Haydon, C. W. Hastad, and Z. B. Post. 2020. Improving performance of finishing pigs with added valine, isoleucine, and tryptophan: validating a meta-analysis model. *In process.*

(d 43) to measure blood urea nitrogen (BUN). Blood urea nitrogen was measured using the Arbor Assays (Ann Arbor, MI) 10 plate colorimetric detection kit. Pigs that were bled on d 21 were tagged, and the same pigs were bled on d 43. A titanium dioxide marker was added to each treatment at 0.4% of the diet during the last 7 d of phase 1. The titanium dioxide was sifted through a flour sifter into ground corn and added directly into the mixer. The time for dry mixing was increased by 45 seconds to ensure adequate mixing. Fresh feces were collected from 3 pigs per pen at the end of phase 3 after the marker had been fed in the diet for 7 d. The samples were frozen at -4°F until analysis. Feces were dried and analyzed for dry matter, titanium, and nitrogen. Fecal samples from each pen were dried at 130°F in a forced air oven for 48 h. Fecal dry matter was determined as follows: $(\text{dried sample weight at 48 h} - \text{pan weight}) / (\text{initial wet sample weight} - \text{pan weight}) \times 100$. After feces were dried and ground, feed and fecal samples were sent to the University of Missouri Agricultural Experiment Station Chemical Laboratory (Columbia, MO) for analysis of titanium using spectroscopic methods. Fecal crude protein was measured with the Leco TruMac N (Saint Joseph, MI) by finding the amount of nitrogen in 0.5 g of feces. Crude protein was determined as follows: $\% \text{ N} \times 6.25 = \text{crude protein}$.

Feed samples were collected from the feeder approximately 3 days after starting to feed the treatments and before completion of the trial. Diet samples were kept refrigerated at the Kansas State University Swine Lab until analysis. Complete diet samples were sent to the University of Missouri Agricultural Experiment Station Chemical Laboratory for amino acid and proximate analysis.

Data were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package in R version 3.5.1 (2018-07-2) with pen considered the experimental unit, body weight as a blocking factor, and treatment as a fixed effect. Linear and quadratic effects between treatments were measured based on feed grade lysine as a percentage of total SID lysine. Tukey adjustment was used for multiple comparisons. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Analysis of manufactured diets (Table 2) resulted in amino acid and proximate analysis values consistent with diet formulation, as crude protein in the diet is decreased as the amount of feed grade amino acids is increased in the diet.

From d 0 to 21, there was no evidence of difference in ADG between treatments, but as additions of feed grade amino acids increased, ADFI increased (linear, $P = 0.001$), which resulted in worsening (linear, $P = 0.001$) F/G (Table 3). Feces were collected on d 21 and measured for dry matter and crude protein. There was no evidence for difference between treatments on fecal crude protein, but there was an increase (linear, $P = 0.007$) in fecal dry matter as feed grade amino acids were increased in the diet.

From d 21 to 43, ADG increased (quadratic, $P = 0.045$) as feed grade amino acids increased from low to medium and then decreased thereafter. For ADFI, there was a quadratic ($P = 0.036$) increase as feed grade amino acids increased up to the high amino acid addition, then decreased at the very high level. Pigs fed the medium levels of feed

grade amino acid had improved F/G ($P = 0.003$) compared to pigs fed high levels, with the low and very high levels of feed grade amino acid diets intermediate.

Overall, when feed grade amino acids increased from low to medium, ADG increased (quadratic, $P = 0.020$) and then decreased when pigs were fed high and very high AA diets. Average daily feed intake increased (quadratic, $P = 0.016$) up to high inclusion levels of feed grade amino acids and plateaued thereafter. Overall, pigs fed medium levels of feed grade amino acids had improved ($P = 0.002$) F/G compared to pigs fed high and very high levels, with pigs fed low levels of feed grade amino acids intermediate.

As expected, on d 21 and 43 there was a decrease (linear, $P = 0.001$) in BUN as feed grade amino acids increased. The reason for the decrease in BUN is as feed grade amino acids are increased, the amount of soybean meal is decreased. This results in a decrease in dietary crude protein and decreases circulation of excess amino acids in the blood. There was also a tendency for an interaction ($P = 0.051$) for treatment \times day, with BUN being lower with less difference between treatments on day 43 than on d 21.

In summary, this study shows that as the percentage of L-lysine as a proportion of total SID lysine in the diet increases from 15 (Low) to 24% (Medium) by increasing the amount of feed grade amino acids, ADG and F/G improved. As L-lysine as a proportion of total SID lysine in the diet further increases to greater than 24%, F/G worsened.

Table 1. Diet composition, as-fed basis

Ingredient, %	Phase 1 ¹				Phase 2 ²			
	Feed grade amino acids							
	Low	Medium	High	Very high	Low	Medium	High	Very high
Corn	35.85	40.15	44.35	48.60	42.05	46.20	50.15	54.20
Soybean meal	30.80	26.25	21.75	17.20	24.90	20.55	16.30	11.95
Corn DDGS, 7.5% oil	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Choice white grease	1.05	0.90	0.70	0.50	1.00	0.90	0.70	0.50
Limestone	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Monocalcium P	0.20	0.28	0.33	0.39	0.07	0.16	0.22	0.29
Sodium chloride	0.60	0.60	0.60	0.60	0.50	0.50	0.50	0.50
L-Lysine-HCl	0.25	0.40	0.55	0.70	0.24	0.39	0.53	0.67
DL-Methionine	0.11	0.15	0.20	0.24	0.08	0.11	0.15	0.19
L-Threonine	0.07	0.13	0.20	0.26	0.05	0.11	0.17	0.23
L-Tryptophan	---	0.03	0.05	0.08	---	0.03	0.05	0.08
L-Valine	---	0.03	0.10	0.18	---	---	0.08	0.15
L-Isoleucine	---	---	0.09	0.18	---	---	0.08	0.16
Phytase ³	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
GF VTM 5000	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100	100	100	100

continued

Table 1. Diet composition, as-fed basis

Ingredient, %	Phase 1 ¹				Phase 2 ²			
	Feed grade amino acids							
	Low	Medium	High	Very high	Low	Medium	High	Very high
Calculated analysis								
L-lysine as a proportion of total SID lysine, %	15	24	33	42	16	26	36	46
Standardized ileal digestible (SID) amino acids %								
Lysine	1.31	1.31	1.31	1.31	1.15	1.15	1.15	1.15
Isoleucine:Lysine	66	60	60	60	67	60	60	60
Leucine:Lysine	151	142	133	124	159	149	140	130
Methionine:Lysine	34	36	38	39	34	35	36	38
Methionine and cysteine:Lysine	58	58	58	58	58	58	58	58
Threonine:Lysine	65	65	65	65	65	65	65	65
Tryptophan:Lysine	19.1	19.1	19.1	19.1	19	19.1	19.2	19.2
Valine:Lysine	76	72	72	72	78	72	72	72
Histidine:Lysine	43	40	37	34	45	41	38	34
Total lysine, %	1.56	1.55	1.54	1.53	1.39	1.38	1.36	1.35
Net energy, kcal/lb	1,154	1,154	1,154	1,154	1,159	1,159	1,159	1,159
SID lysine:NE, g/mcal	5.15	5.15	5.15	5.15	4.50	4.50	4.50	4.50
Crude protein, %	26.4	24.9	23.4	22.0	24.1	22.6	21.2	19.8
Calcium, %	0.57	0.57	0.56	0.56	0.52	0.53	0.52	0.52
STTD P with phytase, %	0.43	0.43	0.43	0.43	0.39	0.39	0.39	0.39
Analyzed Ca:STTD P	1.33	1.33	1.30	1.30	1.33	1.33	1.33	1.33

¹Phase 1 was fed from d 0 to 21.²Phase 2 was fed from d 21 to 43.³Quantum Blue 10G (ABVista, Marlborough, Wiltshire) provided an estimated release of 0.13% available P.

Table 2. Analyzed experimental diets, as fed basis¹

Item, % ⁴	Phase 1 ²				Phase 2 ³			
	Feed grade amino acid levels							
	Low	Medium	High	Very high	Low	Medium	High	Very high
Analyzed total lysine	1.44 (1.56)	1.53 (1.55)	1.51 (1.54)	1.48 (1.53)	1.38 (1.39)	1.43 (1.38)	1.35 (1.36)	1.41 (1.35)
Isoleucine:Lysine	77 (65)	70 (60)	65 (60)	67 (60)	74 (66)	66 (60)	62 (60)	66 (60)
Leucine:Lysine	153 (146)	142 (139)	132 (132)	128 (124)	156 (153)	143 (145)	130 (137)	129 (129)
Methionine:Lysine	37 (32)	38 (33)	38 (35)	37 (37)	35 (32)	33 (33)	31 (34)	36 (36)
Methionine and Cysteine:Lysine	65 (57)	65 (57)	62 (57)	61 (57)	64 (57)	59 (57)	56 (57)	60 (57)
Threonine:Lysine	69 (67)	65 (67)	64 (67)	66 (67)	67 (68)	66 (68)	63 (67)	64 (67)
Tryptophan:Lysine	18 (19)	16 (19)	20 (19)	19 (19)	17 (19)	17 (19)	19 (19)	16 (19)
Valine:Lysine	88 (77)	82 (74)	78 (73)	80 (74)	86 (79)	77 (73)	73 (74)	77 (73)
Histidine:Lysine	46 (43)	42 (40)	38 (37)	36 (35)	46 (44)	41 (41)	38 (38)	35 (35)
Crude protein	24.54	23.25	20.56	20.86	23.30	20.82	19.17	19.69
Moisture	11.63	11.84	11.77	11.71	11.69	11.78	12.40	11.80
Crude fat	4.62	4.40	4.41	4.10	4.38	4.39	4.37	4.21
Crude fiber	3.76	3.66	3.56	3.40	3.90	3.78	3.24	3.54
Ash	5.71	5.44	4.96	5.11	4.82	5.18	4.10	4.29

¹All samples were sent to the University of Missouri Agricultural Experiment Station Chemical Laboratory (Columbia, MO) for complete amino acid profile and proximate analysis.

²Phase 1 was fed from d 0 to 21.

³Phase 2 was fed from d 21 to 43.

⁴Numbers in parenthesis are the formulated values.

Table 3. Effect of feed grade amino acid levels on growth performance of late nursery and grower pigs¹

Item ³	Feed grade amino acids				SEM	Probability, $P =$ ²		
	Low	Medium	High	Very high		Treatment	Linear	Quadratic
BW, lb								
d 0	21.4	21.4	21.4	21.4	0.32	0.976	0.904	0.791
d 21	42.5	42.7	43.7	43.2	0.61	0.229	0.140	0.423
d 43	73.2	75.7	74.9	74.1	1.11	0.112	0.534	0.032
d 0 to 21								
ADG, lb	1.00	1.01	1.06	1.02	0.020	0.213	0.185	0.329
ADFI, lb	1.42 ^b	1.47 ^{ab}	1.55 ^a	1.54 ^a	0.029	0.001	0.001	0.213
F/G	1.42 ^b	1.46 ^{ab}	1.47 ^{ab}	1.51 ^a	0.018	0.011	0.001	0.884
d 21 to 43								
ADG, lb	1.36 ^b	1.49 ^a	1.41 ^{ab}	1.42 ^{ab}	0.035	0.028	0.528	0.045
ADFI, lb	2.57 ^b	2.68 ^{ab}	2.72 ^a	2.66 ^{ab}	0.056	0.053	0.059	0.036
F/G	1.89 ^{ab}	1.80 ^b	1.94 ^a	1.88 ^{ab}	0.024	0.003	0.210	0.546
Overall								
ADG, lb	1.18 ^b	1.25 ^a	1.24 ^{ab}	1.22 ^{ab}	0.021	0.043	0.204	0.020
ADFI, lb	1.99 ^b	2.08 ^{ab}	2.15 ^a	2.11 ^a	0.038	0.002	0.001	0.016
F/G	1.69 ^{ab}	1.66 ^b	1.74 ^a	1.73 ^a	0.014	0.002	0.005	0.752
Feces ⁴								
Dry matter, %	22.47 ^b	23.15 ^{ab}	22.94 ^{ab}	24.21 ^a	0.401	0.024	0.007	0.449
Crude protein, %	28.26	27.84	27.52	27.39	0.469	0.571	0.172	0.763
BUN ^{5,6}								
d 21	14.48 ^a	11.99 ^b	10.81 ^b	8.83 ^c	0.554	0.001	0.001	0.668
d 43	11.67 ^a	11.27 ^a	9.92 ^b	7.23 ^c	0.270	0.001	0.001	0.001
CP digestibility, % ⁷	71.3	73.7	72.2	73.0	0.837	0.219	0.311	0.371

^{a,b}Means within a row with different superscripts differ ($P < 0.05$).

¹A total of 912 pigs (initially 21.4 lb) were used in a 43-d study at New Fashion Pork wean to finish research facility, Jackson, MN. Diets were manufactured at New Fashion Pork feed mill, Estherville, IA.

²Linear and quadratic was measured based on % intact lysine vs. % feed grade lysine.

³BW = body weight; ADG = average daily gain; ADFI = average daily feed intake; F/G = feed efficiency.

⁴On d 21 of the study, feces were collected (400 g) from each pen and analyzed for dry matter and crude protein.

⁵On d 21 and 43, 4 pigs per pen (2 barrows and 2 gilts of equal weight) were bled to determine blood urea nitrogen (BUN) concentrations. Pigs were tagged on d 21 and re-bled on d 43.

⁶There was a main effect ($P = 0.001$) for treatment and day. There was a tendency for an interaction for treatment \times day ($P = 0.051$).

⁷Feed and fecal samples were sent to the University of Missouri Agricultural Experiment Station Chemical Laboratory (Columbia, MO) for analysis of titanium. Crude protein was measured using a digestibility equation 13-1 (National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13298>).