1-1-1999

Growth and Carcass Responses of Barrows Fed a Corn-Soybean Meal Diet or Low-Protein Amino Acid-Supplemented Diets at Two Feeding Levels

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Summary and Implications

An experiment, with 39 barrows with high lean gain potential, was conducted to evaluate the growth responses of pigs fed a corn-soybean meal diet (CONTROL) and low-crude protein diets supplemented with crystalline lysine, threonine, tryptophan and methionine either on an ideal protein basis (IDEAL) or to a pattern similar to the control diet (AACON). In both cases the amino acid patterns were on a true ileal digestible basis. The initial and final body weights were 72.0 and 125.8 pounds. The diets were offered on an ad libitum basis or by feeding 80 percent of the ad libitum intake. Pigs were fed for 27 days. Three pigs were killed at the start of the experiment and three from each treatment were killed at the end to determine body chemical composition. Pigs fed the CONTROL diet grew faster and were more efficient than pigs fed the IDEAL and AACON diets. When feed intake was limited to 80 percent of ad libitum, weight gain decreased but efficiency tended to improve. The apparent fecal digestibility of protein was greatest in pigs fed the CONTROL diet and tended to be greater in pigs fed at 80 percent of ad libitum than those given ad libitum access to feed. Plasma urea concentrations were highest in pigs fed the CONTROL diet, regardless of feeding level. On a whole body basis, the protein concentration (g/kg) and the accretion rates of protein (g/d) were greater for pigs fed the CONTROL than for pigs fed the IDEAL and

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AACON diets. In summary, pigs fed the IDEAL and the AACON diets had lower growth performance, had less body protein and lower protein accretion rates than pigs fed the CONTROL diet. It remains unclear how to formulate low-crude protein amino acid-supplemented diets to ensure comparable growth performance and carcass characteristics to pigs fed corn-soybean meal diets.

Introduction

Recommendations for amino acid requirements of growing-finishing pigs in the new edition of the *Nutrient Requirements of Swine* are based on ideal dietary proportions among amino acids needed to support the daily potential for protein accretion in the whole body. Under experimental conditions, diets have been formulated using the ideal protein concept by reducing crude protein (CP) concentration and supplementing the limiting amino acids in crystalline form in ideal ratios, relative to lysine. Using this approach, diets have been formulated to be closer to the ideal protein than standard, high-CP diets.

Using diets formulated on the ideal protein concept, results in regard to growth performance and carcass characteristics and yield have been variable. These conflicting results deserve further clarification if amino acid recommendations are to be based on diets supplemented with crystalline amino acids in ideal ratios. The objective of this study was to evaluate different responses of pigs fed a control corn-soybean meal diet or low-CP diets supplemented with crystalline amino acids. The effect of two feeding levels was also evaluated.

Procedures

For the experiment, 39 crossbred barrows with high lean-gain potential (Danbred, USA, Inc.; Dorchester, Nebr.) with an initial and final body weight of 72.0 and 125.8 pounds were allotted to a randomized complete block experiment with a factorial arrangement of

Table 1. Die composition[a].

Item, percent	CONTROL[b]	IDEAL[b]	AACON[b]
Corn	74.34	84.51	84.37
Soybean meal, 46.5% CP	20.96	10.13	10.14
Tallow	2.00	2.00	2.00
Dicalcium phosphate	1.20	1.40	1.40
Limestone	.40	.40	.40
Salt	.30	.30	.30
Vitamin mix[c]	.70	.70	.70
Trace mineral mix[d]	.10	.10	.10
L-lysine•HC1	——	.33	.33
L-threonine	——	.08	.13
DL-methionine	——	.04	.08
L-tryptophan	——	.01	.05
Chemical composition			
CP, %[e]	15.90	11.70	12.29
Calcium, %[f]	.67	.68	.68
Phosphorus, %[f]	.56	.55	.55
GE, Mcal/lb[e]	1.79	1.77	1.77

[a]As-fed basis.
[b]CONTROL: corn-soybean meal diet; IDEAL: corn-soybean meal-amino acid-supplemented diet in ideal ratios; AACON: corn-soybean meal-amino acid-supplemented diet similar to the control diet.
[c]Supplied per kilogram of diet: retinyl acetate, 4400 IU; cholecalciferol, 550 IU; α-tocopherol acetate, 22 IU; menadione sodium bisulfite, 3.3 mg; riboflavin, 5.5 mg; d-pantothenic acid, 22 µg; niacin, 33 mg; choline chloride, 110 mg; vitamin B_{12} 22 mg; ethoxyquin, 1 mg.
[d]Supplied (mg/kg of diet): Cu (as $CuSO_4$•$5H_2O$), 11; I (as $Ca[IO_3]_2$•H_2O), .22; Fe (as $FeSO_4$•H_2O), 110; Mn (as MnO), 22; Se (as Na_2SeO_3), .3; Zn (as ZnO), 110.
[e]Analyzed composition.
[f]Calculated.

Table 2. Analyzed total and calculated true ileal digestible amino acid composition (percent) of diets.

	CONTROL[a]		IDEAL[a]		AACON[a]	
Item	Total	True[b]	Total	True	Total	True
Arg	.99	.93	.66	.61	.67	.61
His	.43	.39	.33	.29	.33	.29
Ile	.63	.58	.47	.40	.49	.40
Leu	1.48	1.36	1.26	1.10	1.29	1.10
Lys	.83	.69	.77	.69	.74	.69
Met + Cys	.66	.48	.58	.45	.68	.48
Phe + Tyr	1.32	1.20	.98	.87	1.00	.87
Thr	.60	.52	.49	.48	.54	.52
Trp	.15	.17	.11	.13	.13	.17
Val	.72	.67	.54	.49	.57	.49

Ratios of calculated true ileal digestible amino acids relative to Lysine[c].

	CONTROL	IDEAL	AACON
Arg	135	88	88
His	57	42	42
Ile	84	58	58
Leu	197	159	159
Met + Cys	70	65	70
Pbe + Tyr	174	126	126
Thr	75	70	75
Trp	25	19	25
Val	97	71	71

[a]CONTROL: corn-soybean meal diet; IDEAL: corn-soybean meal-amino acid-supplemented diet in ideal ratios; AACON: corn-soybean meal-amino acid-supplemented diet similar to the control diet.
[b]Calculated true ileal digestible amino acids estimated from true ileal digestible values from corn and soybean meal (NRC, 1998).
[c]On a calculated true ileal digestible basis.

Table 3. Performance of barrows fed a control or low-CF amino acid-supplemented diets at two different feeding levels[a].

Item	Diets / Levels	CONTROL 100	CONTROL 80	IDEAL 100	IDEAL 80	AACON 100	AACON 80	SEM[b]
Initial wt., lb		71.88	71.93	71.88	71.99	72.21	72.21	.987
Final wt, lb[cd]		132.55	124.40	128.55	118.81	130.15	119.95	1.842
ADG, lb[cd]		2.25	1.94	2.09	1.74	2.14	1.76	.053
ADFI, lb[d]		4.74	3.86	4.85	4.01	4.89	4.01	.121
ADG/ADFI[ce]		.47	.50	.43	.43	.44	.44	.008
Apparent nutrient digestibilities								
Dry matter		89.31	89.84	89.70	89.72	89.90	90.83	0.487
Crude protein[ce]		86.54	87.28	82.37	83.48	84.45	85.90	0.678
Energy		88.20	88.89	88.21	88.34	88.58	88.66	0.524

[a]DIETS=CONTROL: corn-soybean meal diet; IDEAL: corn-soybean meal-amino acid-supplemented diet in ideal ratios; AACON: corn-soybean meal-amino acid-supplemented diet similar to the control diet. FEEDING LEVELS 100: pigs had ad libitum access to feed; and 80: pigs were offered 80 percent of feed consumed for pigs with ad libitum access to feed.
[b]SEM = Standard error of the mean.
[c]Diet effect, $P < .05$.
[d]Level effect, $P < .05$.
[e]Level effect, $P < .10$.

six treatments. Three diets were combined with two levels of feed intake. The diets used in the experiment are presented in Table 1. Diets were offered for 27 days. In the IDEAL and AACON diets, the protein concentration was reduced approximately four percentage units from the CONTROL diet. The first four limiting amino acids (lysine, threonine, tryptophan and methionine) were added as crystalline amino acids to meet the lysine concentration of the CONTROL diet and to provide an amino acid pattern (relative to lysine) similar to the ideal pattern developed at the University of Illinois (IDEAL) or to provide an amino acid pattern (relative to lysine) similar to the pattern of the CONTROL diet (AACON). The concentration of lysine and the ratios used for the next three limiting amino acids were based on calculated true ileal digestible values (Table 2). Results of analyzed total amino acid composition of the diets (Table 2) show lysine concentration in the IDEAL and AACON diets was lower than in the CONTROL diet. However, based on calculated values, all three diets contained the same amount of lysine on a true ileal digestible basis.

Two subgroups of six pigs were formed within each dietary treatment and allotted to one of two feeding levels: pigs with ad libitum access to their diet and pigs offered 80 percent of the feed consumed by the pigs that had ad libitum access to the diet on a daily basis.

Feeders from pigs in the ad libitum group were weighed daily to calculate the feed to be offered to pigs allotted to the 80 percent feeding level for the next 24 hours. Restricted-fed pigs were pair fed within each block and diet. Pigs had ad libitum access to water and were fed three times a day throughout the experiment at 9 a.m., 1 p.m. and 5 p.m. Pigs were penned individually in an environmentally controlled room with temperature maintained at 68°F and constant lighting. Pens were fully slated, with a space allocation of 16 ft², a one-hole self-feeder and a nipple waterer. Pig weights and feed intakes were recorded weekly to determine average daily gain (ADG), average daily feed intake (ADFI) and feed efficiency (ADG/ADFI).

Blood samples from each pig were taken at the start of the trial and every week thereafter. Plasma was separated and analyzed for urea, glucose and nonesterified fatty acids (NEFA). The response of each of these metabolites versus week of the study was examined. During the third week of the study, .25 percent of chromic oxide (Cr_2O_3) was added to the diet as an indigestible marker. Fecal samples from each barrow were collected for three consecutive days to calculate the apparent digestibility of dry matter, crude protein and energy.

Three pigs were killed at the start of the experiment and three from each treatment were killed at the end to determine body chemical composition. The whole body was divided in two fractions: the noncarcass, which included the blood, skin, head, feet, leaf fat, mesentery and all organs, including the empty stomach and intestines, and the carcass, which included the meat and bones. Initial weight and body chemical composition of the initial slaughtered pigs were used to estimate the initial body chemical composition of pigs slaughtered at the end of the experiment. Accretion rates of dry matter CP, fat and ash in the noncarcass, carcass and whole body (noncarcass and carcass together) were estimated as the difference between the total weight of chemical components at the end and at the beginning of the experiment divided by the number of days on treatments.

Results and Discussion

Results of growth performance of barrows and apparent nutrient digestibilities of diets are presented in Table 3. Pigs fed the CONTROL diet had greater ($P < .05$) final body weight, ADG and ADG/ADFI than pigs fed the IDEAL and AACON diets. Growth performance of pigs fed the IDEAL and the AACON diet was similar. When feed intake was limited to 80 percent of ad libitum, ADG decreased ($P < .01$) but ADG/ADFI tended to improve ($P < .10$). These findings agree with previous results published in the 1996

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and 1998 Nebraska Swine Reports indicating barrows fed a corn-soybean meal diet had better performance than those fed an ideal protein diet similar to the one used in this report.

The apparent digestibility of protein was greatest in pigs fed the CONTROL diet ($P < .01$), and was greater ($P < .01$) in pigs fed the AACON diet than in pigs fed the IDEAL diet. These results were expected because there is an inverse relationship between protein level and digestibility. Greater crystalline amino acid additions may have caused the greater apparent digestibility in the AACON diet compared with the IDEAL diet. There was a trend ($P < .10$) for greater apparent protein digestibility in pigs fed at 80 percent of ad libitum. This result was also expected. Generally, there is an inverse relationship between feeding level and digestibility.

Plasma concentrations of urea, glucose and NEFA are presented in Figures 1, 2 and 3, respectively. Plasma urea concentrations were lower in pigs fed the IDEAL and AACON diets than in pigs fed the CONTROL diet, regardless of feeding level ($P < .01$). For pigs fed the CONTROL diet, the urea concentrations were lower when feed intake was 80 percent of ad libitum (diet level, $P < .01$). Reductions in plasma urea concentrations have been reported previously in pigs fed low CP diets supplemented with crystalline amino acids as the IDEAL and AACON diets used in this research. Plasma glucose concentrations did not differ among treatments. Plasma NEFA concentrations varied but were greatest ($P < .01$) in pigs fed the AACON diet and in pigs that had ad libitum access to feed.

Results of body and body fraction weights and body fraction chemical composition are presented in Table 4. Final body weight and body fraction weights were similar among diets. Pigs allowed ad libitum access to feed had greater ($P < 05$) final body, noncarcass,

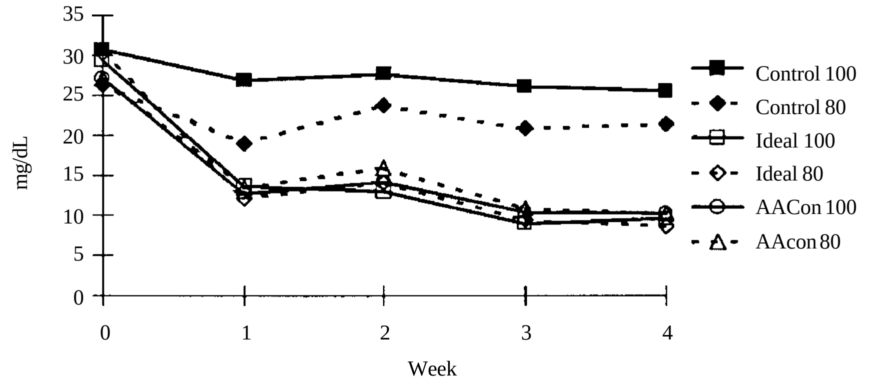

Figure 1. Plasma urea concentrations of barrows fed a corn-soybean meal diet (Control) or low-protein amino acid-supplemented diets either on an ideal ratio basis (Ideal) or to a ratio similar to the Control diet (AACon) at two feeding levels (Diet x Level, P<.01, SEM=.459; Diet x Time, P<.01, SEM=.592).

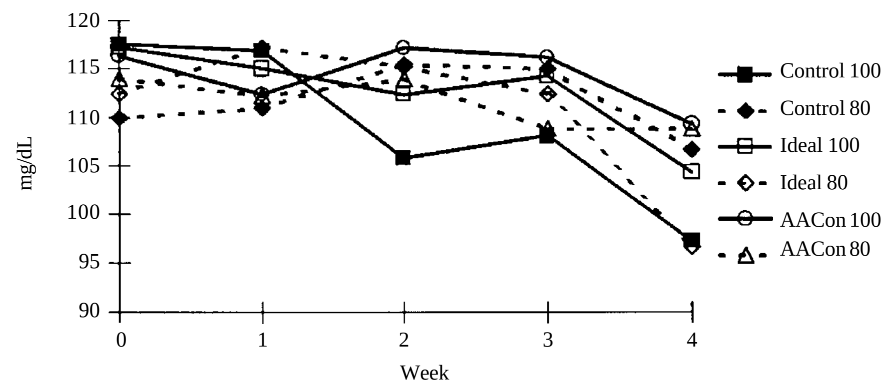

Figure 2. Plasma glucose concentrations of barrows fed a corn-soybean meal diet (Control) or low-protein amino acid-supplemented diets either on an ideal ratio basis (Ideal) or to a ratio similar to the Control diet (AACon) at two feeding levels (Time, P<.01, SEM = 1.404).

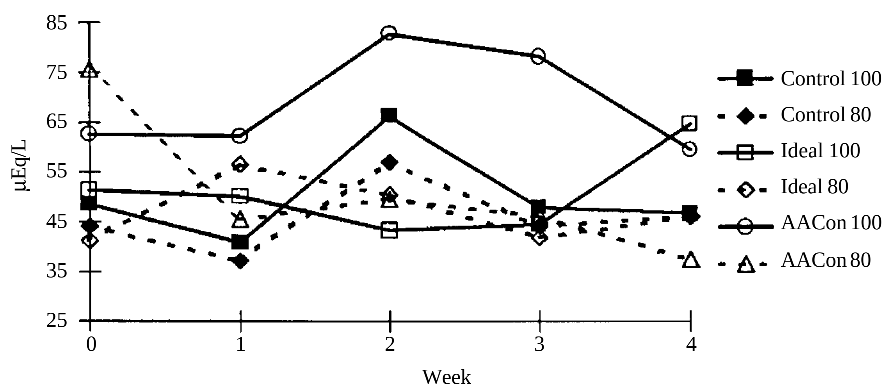

Figure 3. Plasma NEFA concentrations of barrows fed a corn-soybean meal diet (Control) or low-protein amino acid-supplemented diets either on an ideal ratio basis (Ideal) or to a ratio similar to the Control diet (AACon) at two feeding levels (Diet, P<.05, SEM=3.238; Level, P<.05, SEM=2.644).

Table 4. Body and body fraction weights and chemical composition of barrows fed a control or low-CP amino acid-supplemented diets at two different feeding levels[a].

Item[b]	Diet Level	CONTROL 100	CONTROL 80	IDEAL 100	IDEAL 80	AACON 100	AACON 80	SEM[c]
Final body wt, lb[d]		125.35	115.68	122.69	113.67	123.02	114.03	2.09
Body fractions, lb								
Noncarcass[d]		38.22	35.93	38.66	34.98	38.62	35.58	.88
Carcass[d]		80.85	72.02	76.84	71.51	77.35	71.00	2.16
Whole body[d]		119.07	107.95	115.50	105.85	115.97	106.60	2.47
Body fractions chemical composition, g/kg								
Noncarcass								
Water[e]		600	629	581	576	600	600	11.70
Protein		154	147	148	152	150	144	3.26
Fat		220	191	231	230	216	219	14.15
Ash		24	22	22	24	22	22	1.97
Carcass								
Water		624	619	627	619	624	629	16.04
Protein[e]		184	183	172	179	174	179	3.14
Fat		168	181	170	181	185	166	20.00
Ash		29	30	30	28	29	27	1.42
Wholebody								
Water		616	623	611	605	617	620	11.69
Protein[e]		174	171	164	170	166	167	2.71
Fat		185	184	191	197	194	184	15.11
Ash		27	28	27	26	27	26	1.07

[a]DIETS=CONTROL: corn-soybean meal diet; IDEAL: corn-soybean meal-amino acid-supplemented diet in ideal ratios; AACON: corn-soybean meal-amino acid-supplemented diet similar to the control diet. FEEDING LEVELS=100: pigs had ad libitum access to feed; and 80: pigs were offered 80 percent of feed consumed for pigs with ad libitum access to feed.
[b]Noncarcass: included the head, skin, feet, blood, all organs, and internal fat; carcass: included the meat and bones; whole body: sum of noncarcass and carcass.
[c]SEM=Standard error of the mean.
[d]Level effect, $P < .05$.
[e]Diet effect, $P < .05$.

Table 5. Tissue accretion rates on body fractions of barrows fed a control or low-CP amino acid-supplemented diets at two different feeding levels[a].

Item[b]	Diet Level	CONTROL 100	CONTROL 80	IDEAL 100	IDEAL 80	AACON 100	AACON 80	SEM[c]
Noncarcass, g/d								
Water[de]		142	137	134	89	149	116	9.40
Protein[e]		43	32	40	31	41	29	2.31
Fat		87	61	95	78	83	76	10.92
Ash		7	5	6	5	6	5	1.27
Carcass, g/d								
Water[e]		405	302	365	298	365	305	22.87
Protein[ef]		119	91	92	86	96	83	7.30
Fat		136	131	129	129	151	109	29.03
Ash[g]		20	18	19	14	18	14	1.16
Wholebody, g/d								
Water[e]		546	440	499	387	514	421	29.39
Protein[ef]		162	123	132	117	137	113	8.58
Fat		223	192	224	207	235	184	31.54
Ash[e]		27	22	25	19	24	18	1.39

[a]DIETS=CONTROL: corn-soybean meal diet; IDEAL: corn-soybean meal-amino acid-supplemented diet in ideal ratios; AACON: corn-soybean meal-amino acid-supplemented diet similar to the control diet. FEEDING LEVELS=100: pigs had ad libitum access to feed; and 80: pigs were offered 80 percent of feed consumed for pigs with ad libitum access to feed.
[b]Noncarcass: included the head, skin, feet, blood, all organs, and internal fat; carcass: included the meat and bones; whole body: sum of noncarcass and carcass.
[c]SEM=Standard error of the mean.
[d]Diet effect, $P < .10$.
[e]Level effect, $P < .05$.
[f]Diet effect, $P < .05$.
[g]Level effect, $P < .10$.

carcass and whole body weights. Water concentration in the noncarcass was greater ($P < .05$) in pigs fed the CONTROL than in pigs fed the IDEAL and AACON diets and tended to be greater ($P < .10$) in pigs fed the AACON than in pigs fed the IDEAL diet. Protein concentration in the carcass and whole body was greatest ($P < .05$) in pigs fed the CONTROL diet.

Results of tissue accretion rates on body fractions are presented in Table 5. Water accretion rate in the noncarcass tended to be greatest in pigs fed the CONTROL diet and tended to be lowest in pigs fed the IDEAL diet ($P < .10$). Protein accretion rate in the carcass and whole body was greatest ($P < .05$) in pigs fed the CONTROL diet. These results, together with the reduction in protein concentration, are in agreement with other reports in which a reduction in lean percentage or muscle yield was observed in pigs fed low-CP amino acid supplemented diets. Pigs that had ad libitum access to the diet had greater ($P < .05$) water and protein accretion rates in the noncarcass, carcass and whole body. Fat accretion rate in the noncarcass tended to be greater ($P < .10$), ash accretion rate in the carcass tended to be greater ($P < .10$) and in the whole body was greater ($P < .05$) in pigs allowed ad libitum access to feed than in pigs fed at 80 percent of ad libitum.

Conclusion

Reductions in growth performance, plasma urea concentrations, body protein concentration and body protein accretion rate were observed in pigs fed the IDEAL and the AACON diets compared to pigs fed the CONTROL diet. This suggests the formulated amino acid patterns in the IDEAL and AACON diets were not "ideal" for the pigs used in this research.

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