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Effects of increasing crystalline amino acids and the subsequent change in diet net energy on growing pig performance

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EFFECTS OF INCREASING CRYSTALLINE AMINO ACIDS AND THE SUBSEQUENT CHANGE IN DIET NET ENERGY ON GROWING PIG PERFORMANCE[1]

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Summary

Three individual trials were conducted to evaluate the effect of increasing the amount of crystalline amino acids (L-lysine, L-threonine, and DL-methionine) as a replacement for soybean meal in the diet on pig growth performance. A second objective was to determine if increasing net energy (NE) concentration in the diet as a result of increased crystalline amino acids and less soybean meal would affect pig growth. In all three studies, pigs (each approximately 21 lb) were fed a corn-soybean meal diet, or diets with 2, 4, 6, or 8 lb/ton L-lysine HCl and other amino acids to maintain their proper ratio relative to lysine. In Experiments 1 and 3, added fat level was constant at 1%. In Experiment 2, the fat level was reduced slightly as amino acids replaced soybean meal to account for the slight change in ME as synthetic amino acids were added to the diet.

In Experiment 1, increasing L-lysine and other crystalline amino acids had no effect on ADG, but F/G improved (linear, $P<0.05$). In Experiment 2, ADG tended (linear, $P<0.09$) to increase and F/G improved (quadratic, $P<0.04$) with increasing L-lysine. In Experiment 3, ADG and ADFI tended ($P<0.09$) to increase with increasing L-lysine HCl, but F/G was unchanged. In summary, these results indicate that in the young pig, up to 8 lb of L-lysine HCl with other amino acids to maintain a proper ratio relative to lysine are effective replacements for soybean meal in the diet. Furthermore, when replacing soybean meal with crystalline amino acids, feed efficiency improvements are correlated with changes in the diet's net energy concentration. Using ME to calculate the energy value of low-protein amino acid fortified diets will tend to underestimate the diet's actual energy value.

(Key Words: Pigs, Growth, Net Energy, Amino Acids)

Introduction

In 2002, the first production facility dedicated to manufacturing L-threonine was opened in the United States. As a result, L-threonine, like L-lysine HCl and DL methionine, has become more widely available and less expensive for use in swine diets. If economically feasible, the use of L-threonine would allow for greater amounts of L-lysine use than the typical 3 lb/ton inclusion. Use of

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[2]Mid-West Co-op.
[2]Food Animal Health and Management Center.
[3]Ajinomoto Heartland LLC, Chicago, Illinois.

higher levels of synthetic amino acids will have environmental advantages by further decreasing nitrogen concentration in swine waste by 20% or more. Another possible advantage of low-protein crystalline amino acid fortified diets is an increase in the NE content of the diet. Typically in swine diets, ME is used as a measure of energy content of an ingredient. Metabolizable energy is the gross energy of the feed ingredient minus the energy that is lost through digestion (feces), as well as that lost in urine and gas. Net energy takes into account an ingredient's ME, but in addition also takes into account energy lost as heat in the process of digestion. Net energy is frequently used to describe the energy content of ingredients for ruminants.

Soybean meal and corn have a similar energy content on an ME basis. However, soybean meal has a lower energy content based on an NE basis because of its high protein content. Thus, diets formulated with synthetic amino acids should have a higher NE content than those formulated with soybean meal. Using synthetic amino acids will not affect the ME content of the diet. Therefore, pigs fed diets formulated with a similar ME content but increasing amounts of synthetic amino acids should have increased growth rate and improved feed efficiency. The objective of these studies was to verify the efficiency of utilization of crystalline amino acids relative to soybean meal, and a second objective was to evaluate methods of expressing energy (ME versus NE) when using a low crude protein-high crystalline amino acid diet.

Procedures

Three individual 21-d trials were conducted in commercial nurseries with pigs approximately 21 days after weaning. Experiments 1 and 2 were conducted in the same nursery facility in southern Minnesota and Experiment 3 was conducted in a facility in Illinois. In all three studies, pigs (each approximately 21 lb) were fed a corn-soybean meal diet, or diets with 2, 4, 6, or 8 lb/ton of L-lysine HCl and other amino acids to maintain their proper ratio relative to lysine (Tables 1, 2, and 3).

Diets in Experiments 1 and 2 were formulated to 1.36% true ileal digestible lysine. In Experiment 3, diets were formulated to 1.29% true ileal digestible lysine. Minimum true digestible amino acid ratios relative to lysine were maintained in all diets with minimum ratios set at 30% for methionine, 60% for methionine and cystine, 65% for threonine, and 16.5% for tryptophan. In Experiments 1 and 3, added fat was maintained constant at 1% of the diet. Corn and soybean meal levels were adjusted as synthetic amino acids were added to the diet. In Experiment 2, the fat level in the diet was reduced from 1% to 0.25% of the diet as increasing synthetic amino acids were added to the diet in an attempt to maintain a constant modified ME level. In modified ME, the energy value for all ingredients except soybean meal is the same as given by NRC (1998). The energy value for soybean meal (3,181 versus 3,380 kcal/kg for NRC) is lower in modified ME in an attempt to account for the lower net energy value of high protein ingredients like soybean meal. Net energy values used in diet calculations were derived from those published by Noblet et al. (2002).

In Experiment 1, 1,440 pigs were used with 60 pens (30 pens of barrows and 30 pens of gilts) and 24 pigs per pen. Two pens (same sex) of pigs consumed feed from a single fence line feeder. Thus, the experimental unit was the combined data from the two pens and provided six observations per treatment. Pens of pigs and feeders were weighed on d 21 (allotment day) and d 28, 35, and 42 after weaning to calculate ADG, ADFI and F/G. In addition, gain/feed ratio (G/F), the inverse of F/G was calculated for modeling the change in efficiency with either the ME or NE content of the diet. In Experiment 2, we repeated the same procedures. Experiment 3 was also conducted in a similar manner, with the exception

that pigs were started on test when they averaged approximately 25 lb. There were 21 pigs per pen with two pens sharing a common feeder. Thus, there were 42 pigs per experimental unit. There were six replications. Pens of pigs were weighed at allotment and 21 days later at completion of the experiment. Feed disappearance also was measured to calculate ADG and feed efficiency.

Data were analyzed using the PROC MIXED procedures of SAS as a randomized complete block design with two pens consuming feed from a single feeder as the experimental unit. Linear and quadratic effects of increasing L-lysine HCl were determined.

Results and Discussion

In Experiment 1, increasing L-lysine HCl did not affect (P>0.10) growth rate (Table 4). However, feed intake tended (linear, P<0.09) to decrease with increasing L-lysine HCl. Feed efficiency improved (linear, P<0.04) as more synthetic L-lysine HCl was added to the diet at the expense of soybean meal. The calculated change in ME content of the diet containing no L-lysine HCl and the diet containing 8-lb/ton lb diet was 0.3%. The corresponding change in calculated NE of the diets was 3.7%. The change in calculated modified ME was 0.8%. The improvement in feed efficiency was approximately 2% indicating that ME and modified ME underestimate the energy value, while NE overestimates the energy value of low crude protein diets containing high levels of synthetic amino acids.

In Experiment 2, ADG tended (linear, P<0.09) to increase and F/G improved (quadratic, P<0.04) with increasing L-lysine (Table 5). When evaluating the energetic efficiency of gain (Mcal of energy required for every kg of gain), energetic efficiency of gain improved (quadratic, P<0.04) as synthetic amino acids were added to the diet when using ME or modified ME values, suggesting these systems underestimate the actual energy value of the diet. When energetic efficiency of gain was compared using the NE system, energetic efficiency of gain improved (linear, P<0.03) suggesting that the NE values overestimated the actual energy value of the diet as synthetic amino acids replaced soybean meal. Feed cost per lb of gain improved slightly (quadratic, P<0.04) as 2 or 4 lb of Lysine HCl with added methionine and threonine replaced soybean meal in the diet. However, feed cost at the higher inclusion rates of amino acids was similar to the feed cost for pigs fed the control diet. Margin over feed cost was not influenced by the level of synthetic amino acids added to the diets.

In Experiment 3, ADG and ADFI tended (P<0.09) to increase with increasing levels of synthetic amino acids, but F/G was unchanged (Table 6). The improvement in ADG again indicates that utilizable energy increased as levels of synthetic amino acids increased in the diet. These data again would suggest that the ME system underestimates the energy value of the diet. An interesting finding in this study was that the number of pigs that were treated (measured as injections per pen) was reduced as higher levels of synthetic amino acids were added and soybean meal level was reduced. Additional studies need to be conducted to verify and confirm this observation.

Results of these trials demonstrate that up to 8 lb/ton of L-lysine HCl and other crystalline amino acids to maintain their proper ratio relative to lysine can effectively replace soybean meal and provide similar if not better pig performance. Furthermore, these studies also demonstrate that the NE content of the diet increases as more crystalline amino acids are added to the diet as reflected by improvements in feed efficiency. Our results would indicate that the NE values for ingredients derived by Noblet et al. (2002) slightly overestimate the actual NE increase while the ME values from NRC (1998) or the Modified ME method underestimate the energy value of diets containing high levels of synthetic amino acids. The

NE values of Noblet et al. (2002) suggest that the energy value of soybean meal is 75% of the energy value of corn. The ME value from NRC (1998) or the modified ME value would suggest the energy value of soybean meal is 99 or 93% of the value of energy in corn. The results of these experiments suggest the energy value of soybean meal is 85 to 88% (average of 86%) of the energy value of corn, midway between the NE and ME values.

Table 1. Diet Composition (Experiment 1, As-fed Basis)

	L-lysine HCl, lb/ton				
Ingredient, %	0	2	4	6	8
Corn	48.99	51.93	54.86	57.80	60.74
Soybean meal, 46.5 CP%	46.41	43.30	40.19	37.08	33.96
Choice white grease	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate, 18.5% P	1.40	1.40	1.40	1.40	1.40
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and trace minerals	0.30	0.30	0.30	0.30	0.30
L-Threonine	0.02	0.07	0.11	0.16	0.20
Antibiotic[a]	0.70	0.70	0.70	0.70	0.70
Lysine HCl	0.00	0.10	0.20	0.30	0.40
DL-Methionine	0.08	0.11	0.14	0.17	0.20
Total	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.53	1.52	1.51	1.51	1.50
True ileal digestibility, %					
Lysine	1.36	1.36	1.36	1.36	1.36
Isoleucine:lysine ratio	74.3	70.5	66.6	62.7	58.9
Leucine:lysine ratio	143.9	138.4	132.9	127.4	122.0
Methionine:lysine ratio	32.1	33.2	34.4	35.5	36.6
Met & Cys:lysine ratio	60.0	60.0	60.0	60.0	60.0
Threonine:lysine ratio	64.9	65.0	65.1	65.2	65.3
Tryptophan:lysine ratio	21.8	20.5	19.3	18.1	16.9
Valine:lysine ratio	80.3	76.5	72.6	68.8	65.0
ME, kcal/lb	1,510	1,511	1,513	1,514	1,515
NE, kcal/lb	1,044	1,054	1,063	1,073	1,083
Modified ME, kcal/lb	1,464	1,467	1,470	1,474	1,477
Protein, %	0.75	0.74	0.73	0.72	0.71
Ca, %	0.72	0.70	0.69	0.68	0.66
P, %	0.35	0.35	0.34	0.34	0.34
Available P, %	0.43	0.43	0.42	0.42	0.42

[a]Provided 140 g/ton of neomycin and 140 g/ton of terramycin.

Table 2. Diet Composition (Experiment 2, As-fed Basis)

	L-lysine HCl, lb/ton				
Ingredient, %	0	2	4	6	8
Corn	48.99	52.12	55.25	58.39	61.52
Soybean meal, 46.5 CP%	46.41	43.29	40.17	37.05	33.93
Choice white grease	1.00	0.81	0.63	0.44	0.25
Dicalcium phosphate, 18.5% P	1.40	1.40	1.40	1.40	1.40
Limestone	0.75	0.75	0.75	0.75	0.75
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and trace minerals	0.30	0.30	0.30	0.30	0.30
L-Threonine	0.02	0.07	0.11	0.16	0.20
Antibiotic[a]	0.70	0.70	0.70	0.70	0.70
Lysine HCl	0.00	0.10	0.20	0.30	0.40
DL-Methionine	0.08	0.11	0.14	0.17	0.20
Total	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.53	1.52	1.51	1.51	1.50
True ileal digestibility, %					
Lysine	1.36	1.36	1.36	1.36	1.36
Isoleucine:lysine ratio	74.3	70.5	66.6	62.8	58.9
Leucine:lysine ratio	143.9	138.5	133.1	127.7	122.3
Methionine:lysine ratio	32.1	33.3	34.4	35.5	36.7
Met & Cys:lysine ratio	60.0	60.0	60.0	60.1	60.1
Threonine:lysine ratio	64.9	65.0	65.2	65.3	65.4
Tryptophan:lysine ratio	21.8	20.5	19.3	18.1	16.9
Valine:lysine ratio	80.3	76.5	72.7	68.9	65.1
ME, kcal/lb	1,510	1,508	1,505	1,502	1,500
NE, kcal/lb	1,044	1,050	1,056	1,062	1,068
Modified ME, kcal/lb	1,464	1,464	1,464	1,464	1,464
Protein, %	0.75	0.74	0.73	0.72	0.71
Ca, %	0.72	0.70	0.69	0.68	0.67
P, %	0.35	0.35	0.34	0.34	0.34
Available P, %	0.43	0.43	0.42	0.42	0.42

[a]Provided 140 g/ton of neomycin and 140 g/ton of terramycin.

Table 3. Diet Composition (Experiment 3, As-fed Basis)

	L-lysine HCl, lb/ton				
Ingredient, %	0	2	4	6	8
Corn	52.22	55.12	58.02	60.92	63.82
Soybean meal, 46.5 CP%	43.55	40.44	37.33	34.22	31.12
Choice white grease	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate, 18.5% P	1.48	1.50	1.52	1.53	1.55
Limestone	1.00	1.02	1.04	1.05	1.07
Salt	0.35	0.35	0.35	0.35	0.35
Vitamins and trace minerals	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.08	0.08	0.08	0.08	0.08
L-Threonine	0.01	0.06	0.10	0.15	0.19
Lysine HCl	0.00	0.10	0.20	0.30	0.40
DL-Methionine	0.06	0.09	0.12	0.15	0.19
Total	100.00	100.00	100.00	100.00	100.00
Total lysine, %	1.45	1.44	1.44	1.43	1.42
True ileal digestibility, %					
Lysine	1.29	1.29	1.29	1.29	1.29
Isoleucine:lysine ratio	74.8	70.7	66.6	62.5	58.4
Leucine:lysine ratio	146.9	141.1	135.3	129.5	123.7
Methionine:lysine ratio	31.7	32.9	34.1	35.3	36.5
Met & Cys:lysine ratio	60.0	60.0	60.1	60.1	60.1
Threonine:lysine ratio	65.0	65.0	65.1	65.1	65.1
Tryptophan:lysine ratio	21.8	20.5	19.2	17.9	16.6
Valine:lysine ratio	81.1	77.1	73.0	69.0	64.9
ME, kcal/lb	1,516	1,517	1,517	1,518	1,519
NE, kcal/lb	1,056	1,066	1,075	1,084	1,094
Modified ME, kcal/lb	1,472	1,475	1,478	1,480	1,483
Protein, %	0.85	0.86	0.86	0.86	0.86
Ca, %	0.72	0.71	0.70	0.69	0.68
P, %	0.36	0.36	0.36	0.36	0.36
Available P, %	0.43	0.43	0.43	0.43	0.43

Table 4. Effect of Replacing Soybean Meal with Synthetic Amino Acids on Pig Performance, Experiment 1[a]

	L-lysine HCl, lb/ton							Probabilty, P<	
Item	0	2	4	6	8	SED	Model	Linear	Quadratic
ADG, lb	1.29	1.28	1.27	1.27	1.27	0.029	0.93	0.63	0.64
ADF, lb	1.91	1.90	1.85	1.88	1.85	0.035	0.32	0.09	0.57
F/G	1.49	1.48	1.46	1.48	1.45	0.015	0.19	0.05	0.99
Gain:Feed	0.673	0.675	0.684	0.678	0.688	0.007	0.17	0.04	0.98
Day 21 wt, lb	50.6	50.5	50.2	50.3	50.4	0.6	0.96	0.72	0.59
Feed cost, $/lb of gain[b]	$ 0.107	$ 0.108	$ 0.107	$ 0.109	$ 0.107	$ 0.001	0.65	0.79	0.99

[a]Each value is the mean of six experimental units with 48 pigs per experimental unit (24 pigs per pen with 2 pens sharing a common feeder as the experimental unit).
[b]Diet costs were calculated using: $2.24/bu corn, $170/ton soybean meal, $0.90/lb Lysine HCl, $1.35/lb threonine, and $1.20/lb methionine. The five treatment diets were each formulated to contain similar lysine, threonine, and methionine content. Thus, the diets with more synthetic lysine contained less soybean meal. Note that as more synthetic amino acids are used, diet cost increases by about $0.80 per ton.

Table 5. Effect of Replacing Soybean Meal with Synthetic Amino Acids on Pig Performance, Experiment 2[a]

	L-lysine HCl, lb/ton						P-value		
Item	0	2	4	6	8	SEM	Treatment	Linear	Quad
ADG, lb	1.11	1.14	1.12	1.13	1.16	0.017	0.28	0.09	0.66
ADF, lb	1.62	1.62	1.60	1.64	1.68	0.023	0.14	0.06	0.09
F/G	1.46	1.42	1.43	1.45	1.44	0.013	0.10	0.83	0.04
Energetic efficiency, Mcal/kg gain									
ME	4.85	4.70	4.72	4.78	4.76	0.04	0.08	0.36	0.04
Modified ME	4.72	4.59	4.62	4.68	4.67	0.04	0.10	0.84	0.04
Noblet NE	3.35	3.28	3.31	3.38	3.39	0.03	0.03	0.04	0.04
Weight, lb									
Day 0	21.3	21.7	21.6	21.3	21.5	0.5	0.69	0.81	0.52
Day 21	44.7	45.6	45.1	45.2	45.9	0.7	0.47	0.22	0.96
Feed cost, $/lb of gain	$0.107	$0.104	$0.105	$0.107	$0.107	$0.001	0.09	0.53	0.04
Margin over feed, $/pig	$ 6.85	$ 7.08	$ 6.94	$ 7.00	$ 7.16	$ 0.12	0.43	0.18	0.91

[a]Each value is the mean of six experimental units with 48 pigs per experimental unit (24 pigs per pen with 2 pens sharing a common feeder as the experimental unit).

Table 6. Effect of Replacing Soybean Meal with Synthetic Amino Acids on Pig Performance, Experiment 3[a]

	L-lysine HCl, lb/ton					P-values			
	0	2	4	6	8	Treatment	Linear	Quad	S.E.
ADG, lb	1.15	1.15	1.20	1.22	1.18	.19	.09	---	.024
ADFI, lb	1.72	1.76	1.82	1.83	1.79	.16	.06	---	.035
F/G	1.49	1.53	1.52	1.51	1.51	.80	---	---	.021
Initial wt, lb	26.9	26.8	26.7	26.9	26.9	.99	---	---	.511
Day 21 wt, lb	51.5	51.7	51.9	52.6	52.0	.86	---	---	.765
Margin over feed, $/pig	8.89	8.97	9.03	9.25	9.03				
Injections per pen[b]	6.3	7.5	4.5	2.3	4.2	.06	.03	---	1.22

[a]Each value is the mean of six experimental units with 42 pigs per experimental unit (21 pigs per pen with 2 pens sharing a common feeder as the experimental unit).
[b]Total number of injection treatments administered per pen for the trial (@ 42 pigs per pen)