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Body Composition, Protein Deposition, and Efficiency of Lysine Utilization of Growing Pigs Fed Crystalline or Protein-Bound Lysine

Janeth J. Colina
University of Nebraska-Lincoln

Phillip S. Miller
University of Nebraska-Lincoln, pmiller1@unl.edu

Robert L. Fischer
University of Nebraska-Lincoln

Ruth M. Diedrichsen
University of Nebraska-Lincoln, rdiedrichsen1@unl.edu

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Summary and Implications

Two 4-week experiments were conducted to determine body composition and lysine utilization for protein deposition (PD) in barrows and gilts. Thirty-two growing pigs (16 barrows and 16 gilts; average initial body weight of 40.4 lb) were used in each experiment. Pigs were randomly allotted to one of seven dietary treatments. Four pigs (two barrows and two gilts) were killed at the start and the remaining pigs were killed at the end of the experiments to determine body composition. There were two replications per treatment in each experiment for a total of four replications. Dietary treatments consisted of a basal diet (0.55% lysine) and diets containing 0.65, 0.75, and 0.85% lysine that were achieved by adding lysine to the basal diet from either soybean meal (SBM) or L-lysine•HCl (crystalline). Body protein concentration was greater ($P < 0.01$) in pigs fed the 0.75% crystalline-supplemented diet than in pigs fed SBM at the same concentration. Gilts had greater ($P = 0.05$) body lysine concentration than barrows. Body PD and lysine deposition increased linearly with dietary lysine concentration ($P < 0.01$), but were not different between the two sources of lysine (SBM vs crystalline, respectively) at the same concentration. Barrows and gilts had similar PD and lysine deposition. Body fat concentration decreased ($P < 0.01$) as the dietary lysine concentration increased for both lysine sources; however, fat deposition was not affected by diet. Water deposition increased with dietary lysine concentration ($P = 0.05$). Body ash content was similar in pigs fed crystalline or SBM-lysine. The results suggest that PD of growing pigs fed lysine from SBM is similar to that of pigs fed crystalline lysine. Pigs fed 0.75% or 0.85% total lysine (0.20% or 0.30% from SBM) had greater ($P \leq 0.05$) efficiency of lysine utilization than pigs fed crystalline-supplemented diets at the same concentration. Gilts utilized lysine from SBM more efficiently than barrows ($P < 0.05$) at the dietary lysine concentration of 0.75 and 0.85%. The results indicate no significant differences in PD of pigs fed supplemented diets from L-lysine•HCl and soybean meal. However, it appears that the efficiency of lysine utilization of gilts fed diets supplemented with SBM-bound lysine is greater than that of barrows. Supplementing low-protein diets with crystalline amino acids at adequate concentrations can offer environmental benefits towards reducing nitrogen excretion without affecting protein deposition.

Introduction

Supplementing swine diets with crystalline amino acids and replacing a portion of the dietary protein can reduce diet cost and the amount of nitrogen excreted. Because lysine is present in the least amount relative to its requirement (first-limiting amino acid) in swine diets, it is important to determine how this amino acid is absorbed and utilized for protein deposition.

Estimates of the efficiency of lysine utilization for muscle growth can vary depending on measurements used (e.g., nitrogen balance studies and/or comparative slaughter procedures). Also, the source of amino acid and its concentration in the diet affect its efficiency of utilization. Inefficient utilization of the first limiting amino acid in the diet for protein deposition may be a result of baseline degradation (oxidation) of amino acids. Thus, pigs do not use lysine for protein deposition with 100% efficiency, leading to variation in estimates of the efficiency of lysine utilization above maintenance for growing pigs. Estimates of the efficiency of lysine utilization for protein deposition in growing pigs range from approximately 32 to 44% up to 85 to 95%.

The 2003 Nebraska Swine Report documented a study demonstrating that when pigs were given ad libitum access to feed there were no differences in growth performance and carcass traits between pigs fed diets supplemented with L-lysine•HCl and pigs fed lysine from soybean meal (SBM). However, previous studies have reported the estimates of the efficiency of lysine utilization based on average daily gain and feed efficiency. The aforementioned approaches are not as specific as those based on carcass criteria because the former are sensitive to variations in gut fill. Thus, measuring protein deposition in the whole body represents a potentially more reliable indicator of the difference in the efficiency of lysine utilization between the sources of dietary lysine. Therefore, the objective of this study was to determine body composition and the efficiency of utilization of crystalline lysine as L-lysine•HCl relative to protein-bound lysine in SBM for body protein deposition in growing pigs.

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Procedures

Animals and Facilities

This study consisted of two experiments, each with 32 growing pigs (16 barrows and 16 gilts; average initial body weight of 40.4 lb) individually penned. Pigs were randomly allotted to one of seven dietary treatments. Four pigs (two barrows and two gilts) were killed at the start and the remaining pigs were killed at the end of the experiments to determine body composition. There were two replications per treatment in each experiment for a total of four replications.

Dietary Treatments

Diets were limiting only in lysine. For the 28-day experiment, pigs were allowed ad libitum access to one of the seven experimental diets and water. The seven diets used (Table 1) consisted of a basal diet (0.55% lysine) and diets containing 0.65, 0.75, and 0.85% total lysine that were achieved by adding lysine to the basal diet from either soybean meal (SBM) or L-lysine•HCl (crystalline). Tryptophan, methionine and threonine were added to the diets to meet the requirements for these amino acids in the basal diet and to the other diets to provide an amino acid pattern relative to lysine similar to the pattern in the basal diet.

Slaughter Procedures

The four pigs at the start and 28 pigs at the end of the experiment were killed by injecting an overdose of sodium pentobarbital. Gut contents (any remaining digesta) were removed and the whole body (including the gastrointestinal tract) weighed (empty body weight; EBW), and frozen at 0°F until further processing. The frozen empty body was ground using a commercial grinder with a 12.5-mm die. The ground body was thoroughly mixed to ensure homogeneity and a sample of approximately 9.0 lb was saved. Subsequently, each sample was ground three times using a smaller grinder with successively smaller dies (6.5-to 2-mm). Samples were mixed thoroughly by hand between each pass through the grinder. During the last mincing, frequent grab samples of approximately 100 g were taken at random, mixed thoroughly to obtain a total sample of approximately 500 g that was placed in a plastic bag and frozen at 0°F until laboratory analysis were conducted. Samples were analyzed in duplicate for dry matter (DM), ash, crude protein (CP), fat, and lysine.

Statistical Analyses and Calculations

Initial empty body weight (EBW) and chemical body composition of pigs slaughtered initially were used to estimate the initial EBW and body chemical composition of pigs slaughtered at the end of the experiment. Deposition rates of water, CP, lysine, fat and ash in the whole body were estimated as the difference between the total weight of chemical components at the end and at the start of the experiment divided by the number of experimental days. The treatment design was 2 × 3 × 2 factorial + 2 (basal diet): 2 lysine sources (SBM and L-Lysine•HCl) × 3 lysine concentrations (0.65, 0.75, and 0.85%) × 2 sexes (barrows and gilts) + 2 (basal diets: 0.55% lysine barrows, 0.55% lysine gilts). Pig was considered the experimental unit. Data for concentration of body chemical components and deposition rates were analyzed as a complete randomized block design. The block for both analyses was considered as the combination between experiment and room (two experiments and two rooms). Linear contrasts were used to compare the seven dietary treatments. The contrasts were: basal diet vs the other diets and comparisons between lysine supplemented from crystalline lysine vs soybean meal at the lysine concentrations of 0.65%, 0.75%, and 0.85%, respectively. Linear and quadratic effects of dietary lysine concentration were tested. The

Table 1. Composition of diets, as-fed basis.

Diets:	BASAL	CRYSTALLINE			SOYBEAN MEAL		
Lysine, %:	0.55	0.65	0.75	0.85	0.65	0.75	0.85
Ingredient, %							
Corn	52.44	52.44	52.44	52.44	52.44	52.44	52.44
Cornstarch	13.00	12.61	12.23	11.85	9.64	6.33	2.97
Soybean meal, 46.5% CP	7.50	7.50	7.50	7.50	10.80	14.10	17.40
Sunflower meal	21.20	21.50	21.50	21.50	21.50	21.50	21.50
Tallow	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Dicalcium phosphate	2.20	2.20	2.20	2.20	2.10	1.95	1.85
Limestone	0.47	0.47	0.47	0.47	0.50	0.55	0.57
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Vitamin premix[a]	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Trace mineral premix[b]	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-Lysine•HCl	—	0.13	0.26	0.39	—	—	—
L-tryptophan	0.05	0.08	0.12	0.14	0.06	0.07	0.08
L-threonine	0.10	0.23	0.33	0.46	0.17	0.21	0.28
DL-methionine	0.07	0.19	0.29	0.39	0.14	0.20	0.25
Nutrient Composition[c]							
Crude protein, %	14.80	14.90	15.00	15.40	16.30	17.80	19.30
Lysine, %	0.55	0.65	0.75	0.85	0.65	0.75	0.85
Calcium, %	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Phosphorus, %	0.60	0.60	0.60	0.60	0.60	0.60	0.60
ME[d], Mcal/lb	1.38	1.37	1.36	1.35	1.37	1.36	1.35

[a]Supplied per kilogram of diet: retinyl acetate, 5,500 IU; cholecalciferol, 550 IU; alpha-tocopheryl acetate, 30 IU; menadione, 4.4 mg; riboflavin, 11 mg; d-pantothenic acid, 22.05 mg; niacin, 30 mg; cyanocobalamin (vitamin B_{12}), 33.0 µg.

[b]Supplied per kilogram of diet: Cu (as $CuSO_4 \bullet 5H_2O$), 10.5 mg; I (as $Ca(IO_3) \bullet H_2O$), 0.26 mg; Zn (as ZnO), 125 mg; Fe (as $FeSO_4 \bullet H_2O$), 125 mg; Mn (as MnO), 30 mg; Se (as Na_2SeO_3), 0.3 mg.

[c]Calculated composition.

[d]ME = Metabolizable energy.

Table 2. Empty body weight (EBW), total lysine intake, whole body chemical composition and body deposition rates of pigs fed a basal or lysine supplemented diets.

Item	Diets[a] BASAL	CRYSTALLINE			SOYBEAN MEAL				P-Value	
Lysine, %	0.55	0.65	0.75	0.85	0.65	0.75	0.85	SEM[b]	Diet[c]	Basal vs others
Initial EBW, lb	38.13	38.85	38.60	37.22	37.22	39.10	37.25	1.25	0.86	0.95
Final EBW, lb	65.00	69.50	73.13	73.00	64.22	73.02	72.00	2.64	0.07	< 0.05
Total lysine intake, g/d	7.20	8.20	10.13	11.40	7.82	9.90	10.10	0.30	< 0.01	< 0.01
Body composition, %										
Protein[e]	15.10	15.22	15.28	16.10	15.51	16.04	15.72	0.18	< 0.01	< 0.01
Lysine	4.57	4.72	4.71	4.88	4.70	4.85	4.80	0.06	< 0.05	< 0.01
Fat[f]	15.88	15.71	14.24	12.93	15.08	14.70	12.71	0.49	< 0.01	< 0.01
Water[d]	65.00	65.00	66.27	66.24	65.00	62.45	64.34	1.12	0.27	0.90
Ash	2.54	2.30	2.27	2.25	2.47	2.39	2.30	0.08	0.06	< 0.05
Body deposition, g/d										
Protein[f]	63.16	73.19	84.24	96.71	67.68	90.87	89.82	4.51	< 0.01	< 0.01
Lysine	3.40	4.50	5.03	6.40	4.12	5.90	6.30	0.35	< 0.01	< 0.01
Fat	117.50	125.22	117.08	102.97	108.20	121.47	98.88	8.94	0.32	0.60
Water[f]	234.54	272.66	331.60	345.30	236.70	278.80	311.56	18.44	< 0.01	< 0.01
Ash	13.21	11.98	13.09	13.10	12.19	14.33	12.57	1.14	0.83	0.80

[a]BASAL: lysine concentration provided by corn, soybean meal, and sunflower meal; CRYSTALLINE: BASAL diet supplemented with additional 0.10, 0.20 or 0.30% lysine from of L-lysine•HCl (78% lysine); SOYBEAN MEAL: BASAL diet supplemented with additional 0.10, 0.20 or 0.30% lysine from soybean meal.
[b]Standard error of the mean.
[c]Significance of main effect.
[d]Significance of contrasts: CRYSTALLINE vs SOYBEAN MEAL at 0.75% Lys, (P < 0.05).
[e]Significance of contrasts: CRYSTALLINE vs SOYBEAN MEAL, at 0.75% Lys (P < 0.01).
[f]Linear effect of lysine concentration (P < 0.01).

efficiency of lysine utilization for protein deposition (PD) was calculated for individual pigs considering the lysine deposition (g/d) in the whole body divided by total lysine intake above maintenance. It was assumed that the maintenance lysine requirement was 36 mg/kg $BW^{0.75}$ (NRC, 1998).

Results

Whole Body Chemical Composition

Means and standard errors of EBW and chemical composition of pigs slaughtered at the end of the experiments are shown in Table 2. Body protein concentration was affected by dietary lysine concentration (P < 0.01). Pigs fed the basal diet had the lowest (P < 0.01) protein concentration in comparison with pigs fed the other diets. Protein concentration was greater (P < 0.01) in pigs fed the 0.75% crystalline-supplemented diet compared to pigs fed SBM at the same concentration (15.28 vs 16.04 %). However, pigs fed crystalline or SBM-supplemented diets had similar protein concentrations when compared at 0.65 and 0.85% total dietary lysine. Pigs fed crystalline or SBM-supplemented diets had similar body lysine concentration. Body fat concentration decreased (P < 0.01) as the dietary lysine concentration increased similarly for both lysine sources as lysine concentration increased. Pigs fed the basal diets had the greatest fat concentration (P < 0.01). Dietary lysine did not affect (P > 0.10) body water concentration. However, water concentration was greater (P < 0.05) in pigs fed the crystalline-supplemented diets than pigs fed the SBM-supplemented diets (0.75% total lysine). There was a trend for ash concentration to be affected by dietary lysine concentration (P = 0.06). Pigs fed the basal diet had greater ash concentrations (P < 0.05). Whole body chemical components (protein, fat, ash, and water) were similar between barrows and gilts (Table 3). However, gilts had greater (P = 0.05) body lysine concentration than barrows. Total lysine intake increased with increasing dietary lysine concentration (P < 0.01).

Whole Body Deposition Rates

Tissue deposition rates of pigs slaughtered at the end of the experiments are presented in Table 2. Body PD and lysine deposition increased linearly as dietary lysine concentration increased (P < 0.01), but were not significantly different between the two sources of lysine when compared at the same concentration. Pigs fed the basal diet had the lowest PD (63.16 g/d; P < 0.01). Although barrows fed crystalline or SBM-supplemented diets had numerically greater PD than gilts, these differences were not significant. Thus, barrows and gilts had similar PD and lysine deposition regardless of lysine source (Table 4). Fat deposition was not affected by diet, sex, or lysine source. Water deposition increased linearly with dietary lysine concentration (P < 0.01) and was lowest (P < 0.01) in pigs fed the basal diet. Ash deposition was similar among dietary lysine concentrations and between sources of lysine. Water and ash deposition were similar between barrows and gilts (Table 4).

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Table 3. Whole body chemical composition of barrows and gilts fed a basal or lysine supplemented diets.

Item	Diets[a]	BASAL	CRYSTALLINE			SOYBEAN MEAL			SEM[b]	P-Value	
	Lysine, %	0.55	0.65	0.75	0.85	0.65	0.75	0.85		Sex[c]	Diet x Sex[d]
Body composition, %											
Water									0.16	0.18	0.35
Barrows		65.90	65.00	65.70	66.41	64.63	59.70	62.80			
Gilts		64.14	64.77	66.85	66.07	65.22	65.21	65.83			
Protein									0.26	0.66	0.58
Barrows		15.05	15.10	15.25	16.20	15.76	15.88	15.95			
Gilts		15.12	15.35	15.33	16.00	15.25	16.20	15.50			
Lysine									0.09	0.05	0.26
Barrows		4.61	4.75	4.50	4.80	4.65	4.80	4.78			
Gilts		4.53	4.70	4.88	5.00	4.74	4.92	4.82			
Fat									0.70	0.71	0.25
Barrows		15.23	15.63	14.80	12.70	15.70	15.44	12.25			
Gilts		16.55	15.60	13.70	13.20	14.45	13.93	13.20			
Ash									0.11	0.59	0.81
Barrows		2.45	2.30	2.35	2.26	2.40	2.35	2.30			
Gilts		2.63	2.31	2.20	2.24	2.54	2.42	2.23			

[a]BASAL: lysine concentration provided by corn, soybean meal, and sunflower meal; CRYSTALLINE: BASAL diet supplemented with additional 0.10, 0.20 or 0.30% lysine from of L-lysine•HCl (78% lysine); SOYBEAN MEAL: BASAL diet supplemented with additional 0.10, 0.20 or 0.30% lysine from soybean meal.
[b]Standard error of the mean.
[c]Significance of main effect.
[d]Significance of interaction.

Table 4. Whole-body deposition rates of barrows and gilts fed a basal or lysine supplemented diets.

Item	Diets[a]	BASAL	CRYSTALLINE			SOYBEAN MEAL			SEM[b]	P-Value	
	Lysine, %	0.55	0.65	0.75	0.85	0.65	0.75	0.85		Sex[c]	Diet x Sex[d]
Deposition rates, g/d											
Water									26.10	0.15	0.31
Barrows		194.10	280.37	314.10	337.40	259.50	263.74	290.82			
Gilts		275.01	264.96	349.10	353.14	213.81	293.84	332.30			
Protein									6.38	0.53	0.12
Barrows		52.81	75.27	82.61	97.77	77.17	94.37	93.18			
Gilts		73.51	71.11	85.88	95.64	58.19	87.36	86.46			
Lysine									0.49	0.17	0.57
Barrows		2.90	4.80	4.60	6.14	4.22	5.70	5.93			
Gilts		3.90	4.10	5.50	6.70	4.01	6.10	6.66			
Fat									12.64	0.25	0.21
Barrows		101.73	132.24	126.50	103.50	122.20	136.70	98.30			
Gilts		133.23	118.20	107.70	102.44	94.25	106.30	101.50			
Ash									1.62	0.26	0.43
Barrows		10.15	11.74	13.50	12.80	12.25	14.23	12.31			
Gilts		16.30	12.22	12.70	13.41	12.12	14.42	12.83			

[a]BASAL: lysine concentration provided by corn, soybean meal, and sunflower meal; CRYSTALLINE: BASAL diet supplemented with additional 0.10, 0.20 or 0.30% lysine from of L-lysine•HCl (78% lysine); SOYBEAN MEAL: BASAL diet supplemented with additional 0.10, 0.20 or 0.30% lysine from soybean meal.
[b]Standard error of the mean.
[c]Significance of main effect.
[d]Significance of interaction.

Efficiency of Lysine Utilization

Pigs fed 0.10% crystalline or SBM-supplemented diets (0.65% total lysine) utilized dietary lysine similarly (Figure 1). On the contrary, pigs fed 0.75% or 0.85% total lysine (0.20% or 0.30% added lysine from SBM) had greater ($P \leq 0.05$) efficiency of lysine utilization than pigs fed crystalline-supplemented diets at the same concentrations. Gilts utilized lysine from SBM more efficiently than barrows ($P < 0.05$) at the dietary lysine concentrations of 0.75 and 0.85%.

Discussion

Body concentrations of protein, ash and water of pigs slaughtered at the end of the experiments were similar between pigs fed crystalline or SBM-supplemented diets. This indicates that pigs fed either source of dietary lysine will have similar body composition. As expected, whole body protein concentration was lowest in pigs fed the basal diet because it was the diet most limiting in dietary lysine concentration. Although differences in water and protein concentrations were observed between pigs fed crystalline and SBM-bound lysine at 0.75% total lysine (0.20% added lysine), these differences were not consistent. Fat and ash concentra-

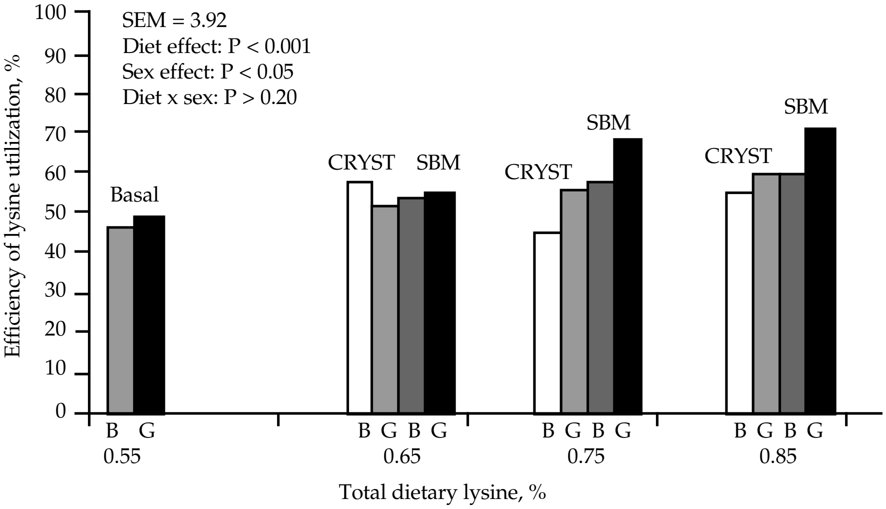

Figure 1. Efficiency of lysine utilization of barrows (B) and gilts (G) fed a basal or lysine supplemented diets. The efficiency of utilization for protein deposition (PD) of lysine intake above maintenance was calculated for individual pigs considering the lysine deposition (g/d) in the whole body divided by total lysine intake above maintenance. It was assumed that the maintenance lysine requirements were 36 mg/ kg BW$^{0.75}$ (NRC, 1998).

tions were also similar between dietary lysine sources.

Pigs fed crystalline or soybean meal-bound lysine had similar PD. The increased protein deposition rate observed as dietary lysine concentration increased in the crystalline-supplemented diets and the increasing lysine deposition in all supplemented diets imply that lysine was utilized with a constant efficiency over the range of limiting dietary lysine concentrations. Pigs fed the 0.30% SBM-supplemented diets (0.85% total lysine) had a decreased PD (compared to the 0.75% lysine group), which may be attributed to a concomitant decrease in body protein content. Although no significant differences in feed intake (Nebraska Swine Report 2003) were observed, the numerical decrease in feed intake possibly contributed to the reduced PD in these pigs.

The lack of difference between L-Lysine•HCl and SBM-bound lysine for PD is supported by previous studies. The data reported herein indicate that ad libitum access to feed provides a balanced supply of lysine at the sites of absorption and metabolism regardless of the dietary lysine source, thereby resulting in a similar utilization of L-lysine•HCl and SBM-bound lysine.

In the previous Nebraska Swine Report, it was reported that gilts had greater lean gain than barrows on a carcass basis. Therefore, a greater PD and lysine deposition in gilts were also expected. Contrary to these results, other studies have reported that barrows tended to have greater PD, which suggest that barrows had a greater capacity to deposit protein than gilts under ad libitum feeding conditions. However, in the aforementioned studies lysine was not limiting in the experimental diets. The similarity between barrows and gilts in the present study is explainable, because within the range of body weights studied, barrows and gilts had similar feed intakes. Differences observed in the efficiency of lysine utilization between pigs fed crystalline lysine and SBM-lysine at the two highest dietary lysine concentrations (0.75 and 0.85%) are related to the sex effect. Gilts were 5% more efficient utilizing lysine than barrows when 0.20 and 0.30% lysine was added from SBM. However, because of the similarity of both group of pigs at the lowest dietary lysine (0.65% total lysine), inferences about the differences between crystalline and SBM-lysine should be made cautiously.

Although significant differences were not observed, body fat deposition rate decreased for pigs fed the crystalline supplemented diets from the lowest to the greatest dietary lysine supplementation (0.10% to 0.30%). On the contrary, in pigs fed the SBM-supplemented diets, there was an increase followed by a subsequent decrease in fat deposition. This could be explainable because at low lysine concentrations, PD is minimal and a greater proportion of energy is retained as fat. However, as dietary lysine concentration increased, PD increased and the energy stored as fat decreased.

Conclusions

The results obtained in the present study confirm that when pigs have ad libitum access to feed there are no differences in body composition and protein deposition attributed to diets supplemented with L-lysine•HCl and lysine from SBM. The increasing response in protein and lysine deposition of pigs fed the crystalline-supplemented diets indicates that the diets fed were limiting in lysine. Although pigs fed the SBM-supplemented diets had a slight decrease in the concentration and deposition rates of protein at the greatest amount of added lysine (0.30% Lys), these differences were not significant when compared to pigs fed diets supplemented with L-lysine•HCl. In addition, observed differences in the efficiency of lysine utilization (based on carcass lysine deposition) between lysine sources did not equate to significant differences in protein deposition. Therefore, supplementing low-protein diets with crystalline amino acids at adequate concentrations can offer environmental benefits toward reducing nitrogen excretion without affecting protein deposition.

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[1]Janeth J. Colina is a graduate student, Phillip S. Miller is a professor, Robert L. Fischer is a research technologist and graduate student, and Ruth M. Diedrichsen is a laboratory supervisor in the Department of Animal Science.