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Influence of Crystalline or Protein-Bound Lysine on Growth Performance, Body Protein Deposition and Lysine Utilization in Nursery Pigs

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Summary and Implications

Experiments have shown that the efficiency of utilization of crystalline amino acids may be lower than that of amino acids bound in protein. A four-week experiment was conducted to determine whether the efficiency of utilization of crystalline lysine was lower than that of lysine in soybean meal for growth and body protein deposition in nursery pigs. A total of 30 pigs (15 barrows and 15 gilts) with initial body weight of 13 lb were blocked by sex and randomly allotted, one per pen, to 30 pens in two nursery facilities. There were six replications per treatment. Six pigs (three barrows and three gilts) were killed at the beginning of the experiment to determine initial body composition. Pigs were fed five dietary treatments that consisted of a basal diet (1.05% lysine) and diets containing 1.15 and 1.25% lysine which were achieved by adding lysine to the basal diet from either soybean meal (SBM) or L-Lysine.HCl (crystalline). Blood samples were collected on the last day of the experiment and plasma was analyzed for urea concentration. Average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (ADG/ADFI) were similar ($P > 0.10$) among treatments. The total lysine intake increased as the lysine concentration in the diet increased ($P < 0.01$). Body protein content was affected by diet ($P < 0.01$). For pigs fed diets containing 1.15% lysine, body protein percentage was greater ($P < 0.01$) for pigs consuming crystalline lysine, versus SBM-supplemented diets. However, body deposition rates of protein were not different among treatments. Body fat concentration and body fat deposition were affected by

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diet (P = 0.05 and P < 0.10 respectively,) but were similar between the two sources of dietary lysine. No differences were observed among treatments for body lysine concentration or lysine deposition rate. The efficiency of lysine utilization for protein deposition was greatest in pigs fed the basal diet and the crystalline supplemented diet at 1.15% total lysine. However, at the dietary concentration of 1.25% lysine, the efficiency was similar between sources. Pigs fed diets supplemented with SBM had greater (P < 0.01) plasma urea concentrations than pigs supplemented with crystalline lysine. Based on these results, it is concluded that there are no differences in the efficiency of utilization between SBM-bound lysine and lysine from L-lysine•HCl for growth and protein deposition in nursery pigs.

Introduction

Nursery pigs require a diet with a balanced and unique pattern of indispensable amino acids for optimum performance. Protein supplements usually represent 20% of the diet but make up approximately 35% of diet cost. Therefore, it is important to maximize the efficiency with which dietary amino acids are used for protein deposition or lean gain in nursery pigs. Generally, it is less expensive to use intact proteins to provide most of the amino acid needs. Also, crystalline amino acids are now available at prices that allow their inclusion in the diet. However, it has been shown that the efficiency of utilization of crystalline amino acids for protein deposition may be lower than that of amino acids bound in protein. This is probably related to some evidence showing that the efficiency of utilization of crystalline amino acids is lower than the efficiency of amino acids in intact protein when feed is restricted. It has been reported that when feed intake is regulated by force-feeding pigs three times daily, it is possible that the infrequent feeding may have contributed to the lower efficiency. This is also true for lysine. Supplements of crystalline lysine in diets for growing pigs fed once daily are used with an efficiency of half that with which crystalline lysine is used when the pigs are fed frequently.

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

Source	Basal	Crystalline		Soybean Meal	
Lysine, %	1.05	1.15	1.25	1.15	1.25
Ingredient, %					
Corn	32.96	32.96	32.96	32.96	32.96
Cornstarch	7.00	6.87	6.74	3.50	0.00
Soybean meal, 46.5% CP	10.00	10.00	10.00	13.50	17.00
Spray-dried plasma protein	4.00	4.00	4.00	4.00	4.00
Fish meal, menhaden	4.00	4.00	4.00	4.00	4.00
Sunflower meal	17.50	17.50	17.50	17.50	17.50
Lactose	15.00	15.00	15.00	15.00	15.00
Dicalcium phosphate	1.35	1.35	1.35	1.35	1.35
Limestone	0.15	0.15	0.15	0.15	0.15
Corn oil	5.00	5.00	5.00	5.00	5.00
Vitamin premix[a]	1.00	1.00	1.00	1.00	1.00
Trace mineral premix[b]	0.10	0.10	0.10	0.10	0.10
Salt	0.25	0.25	0.25	0.25	0.25
Zinc oxide	0.42	0.42	0.42	0.42	0.42
Antibiotic (Mecadox-50)®	1.00	1.00	1.00	1.00	1.00
L-Tryptophan	0.05	0.05	0.05	0.05	0.05
L-Threonine	0.13	0.13	0.13	0.13	0.13
DL-Methionine	0.09	0.09	0.09	0.09	0.09
L-Lysine•HCl		0.13	0.26		
Nutrient composition,%					
Crude protein [c]	18.93	19.13	19.98	20.70	22.90
Lysine[c]	0.93	1.05	1.16	1.03	1.15
Calcium[d]	0.90	0.90	0.90	0.91	0.92
Phosphorus[d]	0.71	0.71	0.71	0.72	0.74
ME[e], Mcal/lb	1.46	1.46	1.46	1.45	1.43

[a]Supplied per kilogram of diet: retinyl acetate, 3,088 IU; cholecalciferol, 386 IU; alpha-tocopheryl acetate, 15 IU; menadione, 2.3 mg; riboflavin, 3.9 mg; d-pantothenic acid, 15.4 mg; niacin, 23.2 mg; choline, 77.2 mg; cyanocobalamin (vitamin B_{12}), 15.4 µg.
[b]Supplied per kilogram of diet: Cu (as $CuSO_4 \cdot 5H_2O$), 11 mg; I (as $Ca(IO_3) \cdot H_2O$), 0.22 mg; Zn (as ZnO), 110 mg; Fe (as $FeSO_4 \cdot H_2O$), 110 mg; Mn (as MnO), 22 mg; Se (as Na_2SeO_3), 0.3 mg.
[c]Analyzed composition.
[d]Calculated composition.
[e]ME = Metabolizable energy.

The efficiency of dietary protein utilization for muscle growth depends on a number of factors, including the amino acid balance in the protein source, the amino acids composing the protein, and the bioavailability and efficiency of utilization of lysine, (typically the first limiting amino acid in swine diets). Thus, when lysine is the first limiting amino acid, its dietary concentration may affect protein deposition. The objective of this study was to determine the efficiency of crystalline lysine utilization relative to the lysine in soybean meal (SBM) for growth and body protein deposition in nursery pigs. The hypothesis was that the metabolic efficiency of lysine utilization is lower for crystalline lysine than for lysine contained in soybean meal protein.

Procedures

Animals

Thirty-six crossbred nursery pigs (18 barrows and 18 gilts; weaned at 15 days of age; initial body weight of 13 lb) were used. At 21 days of age, 30 pigs (15 barrows and 15 gilts) were blocked by sex and randomly allotted, one per pen, to 30 pens in two nursery facilities. There were six replications per treatment. The remaining six pigs (three barrows and three gilts) were killed to determine initial body composition.

Dietary Treatments

During the first six days after weaning, all pigs were fed the same standard prestarter diet to allow them to adapt to the stress of weaning. For the next 28 days, pigs were fed one of five dietary

Table 2. Performance and plasma urea concentrations of pigs fed lysine-limiting diets at three different concentrations.

Source	Basal	Crystalline		Soybean Meal			P-Value			
Lys, %	1.05	1.15	1.25	1.15	1.25	SEM[a]	Diet [b]	Basal vs others[c]	CRYST vs SBM (1.15%)[c]	CRYST vs SBM (1.25%)[c]
Item										
ADG, lb	1.20	1.23	1.20	1.26	1.26	0.06	NS	NS	NS	NS
ADFI, lb	1.87	1.89	1.79	1.94	1.94	0.09	NS	NS	NS	NS
ADG/ADFI	0.64	0.62	0.67	0.65	0.65	0.04	NS	NS	NS	NS
TLI,[d] g/d	7.90	8.95	9.55	8.98	10.07	0.44	< 0.01	< 0.01	NS	NS
SLI,[e] g/d		1.03	1.87	0.88	1.94	0.06	< 0.01	< 0.01	=0.05	NS
PUC[f], mg/100 mL	29.75	26.26	30.54	37.43	38.00	2.59	< 0.01	NS	< 0.01	< 0.05

[a]SEM= Standard error of the mean.
[b]Significance of main effect of diet.
[c]Significance of contrasts. CRYST = crystalline lysine and SBM = lysine from soybean meal.
[d]TLI = Total lysine intake.
[e]SLI = Supplemental lysine intake.
[f]PUC = Plasma urea concentration.

treatments. A basal diet was formulated based on a preliminary experiment that was conducted to identify the limiting range of dietary lysine concentrations for nursery pigs. Two additional diets were formulated by adding soybean meal, and the two remaining diets were supplemented with crystalline lysine in amounts that were equal to the total lysine concentration in the soybean meal diets. All diets were formulated to meet all nutrient requirements of nursery pigs except lysine. The following three limiting amino acid concentrations (threonine, methionine, and tryptophan) were supplemented in all diets to meet the requirements for these amino acids in the basal diet and in the remaining diets. Pigs were allowed *ad libitum* access to the five experimental diets. Diets (Table 1) used were: 1) lysine-deficient diet as basal (1.05% total lysine), 2) basal diet + 0.13% L-lysine•HCl (1.15% total lysine), 3) basal diet with + 0.26% L-lysine•HCl (1.25% total lysine), 4) basal diet + 3.5% soybean meal (1.15% total lysine), 5) basal diet + 7.0% soybean meal (1.25% total lysine).

Environmental Conditions

This experiment was conducted in two nursery facilities with a total of 30 slotted-floor pens. Each pen contained a nipple waterer and a three-hole stainless steel feeder. During the first two weeks, pigs were provided with comfort boards and heat lamps. A recorder was placed in the nursery facility to monitoring humidity and environmental temperature.

Growth Performance

To determine growth performance, pigs and feeders were weighed weekly. Average daily gain (ADG), average daily feed intake (ADFI), and ADG/ADFI were recorded. Total lysine intake (TLI) and supplemental lysine intake (SLI) were calculated based on ADFI and lysine concentrations of the diets.

Blood samples

At the end of the experiment, all pigs were bled from the jugular vein and blood samples were collected in heparinized evacuated tubes. On the day of collection, samples were centrifuged and plasma was separated and frozen at 0°F.

Slaughter Procedures

The six pigs at the start and the 30 pigs fed experimental diets were killed by injecting an overdose of sodium pentobarbital. Gut contents (any remaining digesta) were removed and the whole body of the pigs (including the gastrointestinal tract) were weighed (empty body weight; EBW) and frozen at 0°F until further processing. The frozen empty body was ground through 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 obtained. Subsequently, each sample was ground three times using a smaller grinder with successively smaller dies each time. Frequent grab samples of approximately 100 g were taken at random, mixed thoroughly to obtain a total sample of 500 g and frozen at 0°F until laboratory analyses were conducted. Samples were analyzed in duplicate for dry matter (DM), ash, CP, fat, and lysine.

Statistical Analyses

Initial EBW and chemical body composition of the pigs slaughtered at the start of the experiment 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, fat, ash, and lysine in the whole body were estimated as the difference between the total weight of chemical components at the end and start of the experiment divided by the number of days of the experiment (28 days). Data were analyzed as a randomized block design. Pig was considered the experimental unit. Linear contrasts were used to compare diets supplemented with crystalline lysine and soybean meal. The contrasts were: basal diet versus the other diets, and crystalline lysine

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Table 3. Effect of diet on body chemical composition and accretion rates of pigs slaughtered at the end of the experiment.

Source	Basal	Crystalline		Soybean Meal			P-Value			
Lys, %	1.05	1.15	1.25	1.15	1.25	SEM[a]	Diet [b]	Basal vs others[c]	CRYST vs SBM (1.15%)[c]	CRYST vs SBM (1.25%)[c]
Item										
Initial BW[d], lb	13.40	13.50	13.24	13.57	13.46	0.66	NS	NS	NS	NS
Initial EBW[d] lb	13.00	13.00	13.00	13.00	13.00	0.60	NS	NS	NS	NS
Final BW[d], lb	46.90	48.00	45.52	48.82	48.71	1.98	NS	NS	NS	NS
Final EBW[e], lb	44.44	45.76	43.12	45.91	45.80	1.96	NSN	S	NS	NS
Body composition, %										
Lysine	4.88	4.71	4.89	4.79	4.89	0.70	NS	NS	N	S
Water	66.79	66.87	67.62	67.15	67.42	0.48	NS	NS	NS	NS
Protein	15.13	15.92	15.99	14.73	15.88	0.24	< 0.01	< 0.10	< 0.01	NS
Fat	13.64	13.06	12.06	13.74	12.67	0.51	= 0.05	NS	NS	NS
Ash	2.59	2.65	2.49	2.40	2.44	0.07	NS	NS	< 0.05	NS
Body deposition, g/d										
Water	333.06	347.89	326.00	351.08	352.36	20.28	NS	NS	NS	NS
Protein	79.71	88.77	82.45	80.38	88.27	5.28	NS	NS	NS	NS
Fat	76.52	75.14	61.92	1.25	72.19	6.42	< 0.10	NS	NS	NS
Ash	18.70	19.82	17.40	17.96	18.12	1.10	NS	NS	NS	NS
Efficiency of lysine utilization. %[f]	50.44	48.44	44.35	44.11	44.51	1.93	< 0.05	< 0.05	= 0.08	NS

[a]SEM= Standard error of the mean.
[b]Significance of mean effect of diet.
[c]Significance of contrasts. CRYST = crystalline lysine and SBM = lysine from soybean meal.
[d]BW = body weight.
[e]EBW = empty body weight.
[f]Calculated as: (Lysine retained in the body)/(Total lysine intake-maintenance lysine requirements). It is assumed that the maintenance lysine requirements are 36 mg/kg BW $^{0.75}$.

versus SBM at the concentration of 1.15 and 1.25% total dietary lysine, respectively. Three linear regression equations were determined to evaluate the relationship of ADG, protein deposition, and lysine deposition versus total lysine intake. The efficiency of utilization of lysine intake above maintenance requirements for protein deposition (PD) was calculated for individual pigs from the observed PD multiplied by the lysine content in PD divided by total lysine intake above maintenance lysine requirements (36 mg/kgEBW$^{0.75}$).

Results

Growth Performance and Lysine Intake

Growth variables are shown in Table 2. The relationship between total lysine intake and ADG (Figure 1) shows that for each additional gram/day of lysine intake there was a 0.08 lb/day increase in gain. Although pigs fed the diets supplemented with soybean meal had slightly greater ADG and ADFI than pigs fed the basal diet or diets with crystalline lysine, these differences were not significant. Feed efficiency was also similar among treatments. The TLI increased as the dietary lysine concentration increased ($P < 0.01$), and was similar between lysine sources with the same dietary lysine concentration. The SLI was also affected by lysine concentration ($P < 0.01$). Pigs fed the SBM-supplemented diet at the level of 1.15% dietary lysine had a greater SLI than pigs fed the crystalline diets ($P < 0.05$) at the same concentration. However, the linear contrasts indicated no differences between sources at 1.25% dietary lysine.

Body Composition and Deposition

Body composition and deposition rates are shown in Table 3. The EBW was similar among dietary treatments. The percentage and deposition rates of body water and ash were similar among treatments. The body protein concentration was affected by diet ($P < 0.01$). Pigs fed the basal diet tended to have lower protein concentration than pigs fed the other diets ($P < 0.10$). At 1.15% total dietary lysine, pigs fed the crystalline-supplemented diets had a greater body protein concentration ($P < 0.01$) than pigs fed the SBM-supplemented diets. However, body protein deposition rates were similar among treatments. The linear relationship between total lysine intake and PD indicated that PD increased by 5.78 g/day of additional lysine intake (Figure 2). Body fat content was affected by dietary lysine concentration ($P = 0.05$) but was similar between the two sources of dietary lysine compared at the same concentration. Deposition rate of body fat tended to decrease as dietary lysine concentration increased within sources ($P < 0.10$), but was similar between sources. Body lysine concentration (Table 3) and daily lysine deposition (Figure 3), were similar when comparing the two sources of lysine.

The efficiency of lysine utilization for protein deposition is shown in Table 3. At 1.15% total dietary lysine concentration, the efficiency of utilization of crystalline lysine was greater than for the SBM-supplemented diet ($P = 0.08$). However, at 1.25% dietary lysine, the efficiency of utilization was similar for both sources.

Plasma urea concentration (Table

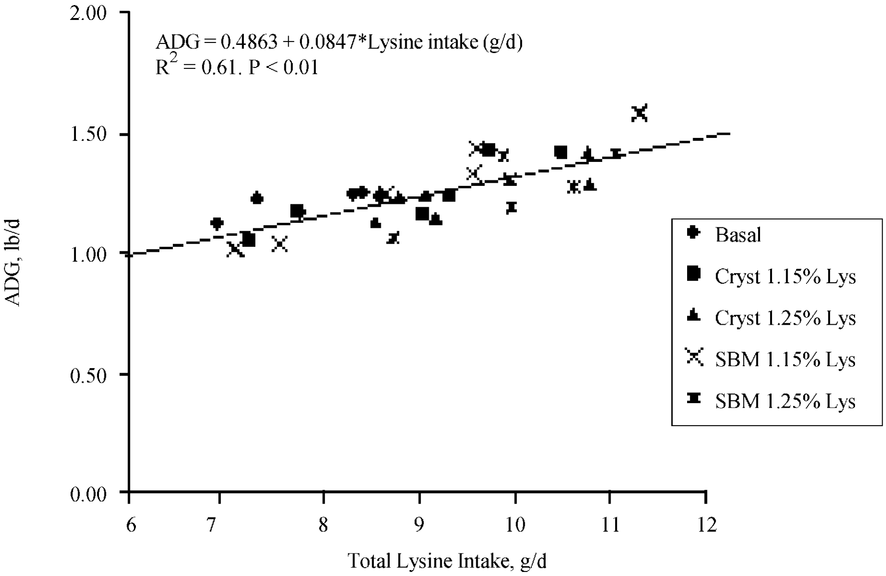

Figure 1. The response of average daily gain (ADG) to total lysine intake.

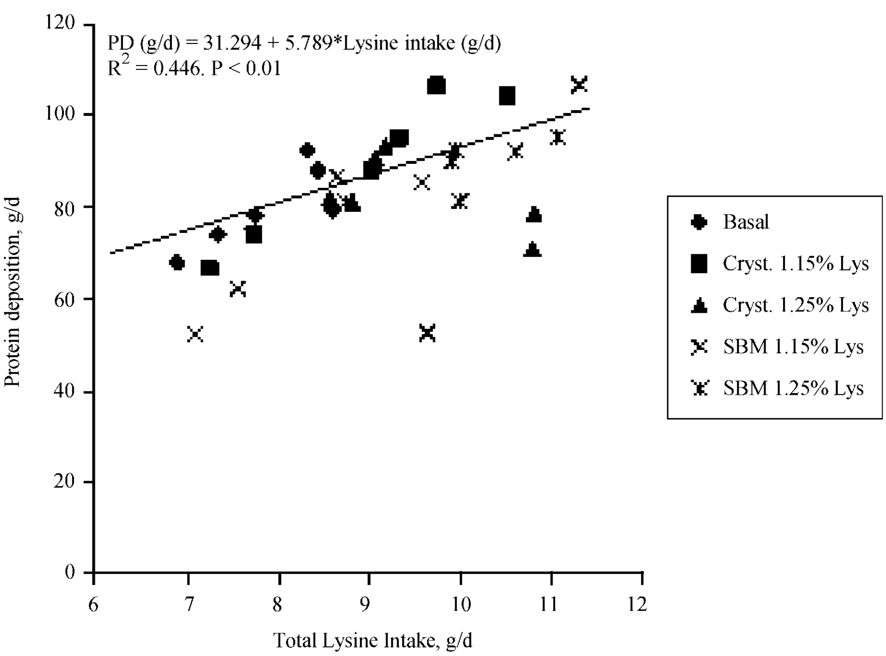

Figure 2. The response of protein deposition (PD) to total lysine intake.

2) was higher for pigs supplemented with SBM than those supplemented with crystalline lysine (P < 0.01).

Discussion

The results reported herein indicate that growth performance variables were similar for pigs fed the crystalline lysine and SBM-supplemented diets. Average daily gain did not respond to supplemental lysine intake. On the contrary, ADG numerically decreased with increasing dietary lysine from crystalline source and was similar for SBM supplemented diets. Although pigs fed the SBM-supplemented diets had the greatest feed intake, it was not different from the crystalline diets. Feed efficiency was similar between lysine sources. The lack of a growth response to increasing dietary lysine concentrations may be related to the high feed intake observed in this study. Pigs were fed individually, and this may have accounted for the greater feed intakes. This greater feed intake is a result of a total lysine intake that includes the lysine content of the ingredients in the basal diet (corn, sunflower meal, and soybean meal) plus the amount of supplemented lysine, 0.10 and 0.20% coming from SBM or L-lysine.HCl to equalize the total lysine content to 1.10 and 1.25% in both sources. However, as feed intake increases, the amount of lysine from the basal diet (1.05% total lysine) is greater than that of pigs fed the supplemented-diets. Therefore, the amount of weight gain attributed to lysine supplemented (above the basal diet) from SBM or L-lysine•HCl was very low.

In general, these responses indicate that lysine was absorbed and utilized similarly by pigs fed either of the two lysine sources. Body fat content and fat deposition decreased with increasing dietary lysine. However, these variables were similar between sources indicating that probably fat deposition is not uniquely affected by feeding nursery pigs with crystalline lysine or SBM-supplemented diets.

As expected the efficiency of lysine utilization was numerically greater for the basal diet. Although the efficiency of utilization of lysine was greater for the crystalline–supplemented diets at the concentration of 1.15% dietary lysine, this response was not observed at the level of 1.25% dietary lysine. In addition, a linear response of ADG to graded amounts of lysine did not result in an increased efficiency of lysine utilization. According with this result, a difference between the two sources of lysine can not be established.

The low level of plasma urea for diets supplemented with L-lysine.HCl is the result of the low protein content of these diets. For diets in which supplemental lysine was provided by SBM, urea concentrations were greater, because of the higher protein content of these diets compared to the crystalline supplemented diets.

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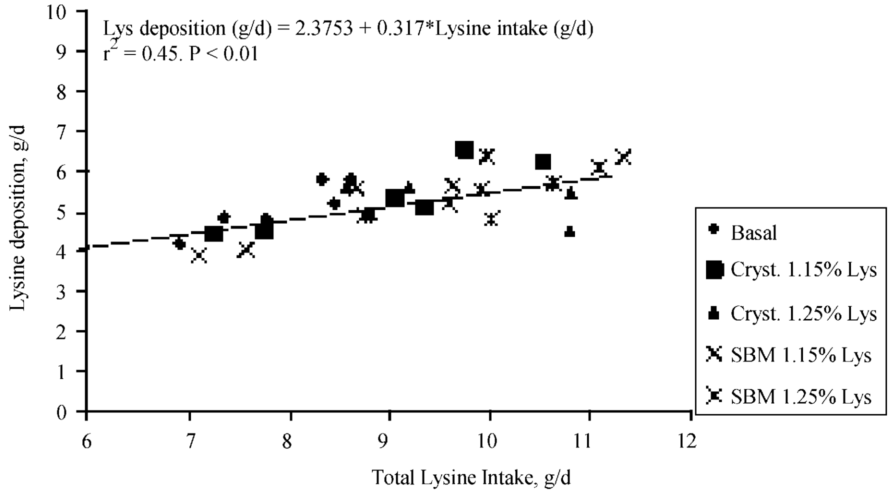

Figure 3. The response of lysine deposition to total lysine intake.

Conclusions

Based on these results, there are no differences in the efficiency of utilization between SBM-bound lysine and L-lysine•HCl for growth and protein deposition in nursery pigs. Because this study was conducted using individually fed pigs (resulting in a greater feed intakes) the data derived should be applied cautiously to pigs raised in commercial conditions. The lack of differences in these criteria between pigs fed crystalline lysine and SBM-supplemented diets suggest that incomplete utilization of crystalline amino acids occurs when pigs are given restricted access to feed and that difference in utilization is minimal when pigs are given *ad libitum* access to feed. Possibly, when pigs are allowed *ad libitum* access to feed, an improved balance of amino acids is absorbed, leading to similar rates of oxidation of excess indispensable amino acids from diets containing either free or protein-bound lysine. Pork producers have to take into account that the use of crystalline amino acids in nursery diets depends on amino acid cost and the cost of grain and supplemental protein sources. Also, it is important to consider that several factors can affect the utilization of crystalline amino acids.

[1]Janeth J. Colina is a graduate student, Phillip S. Miller is an associate professor, Austin J. Lewis is a professor emeritus, and R. L. Fischer is a research technologist in the Department of Animal Science.