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# Effects of Excess Arginine With and Without Supplemental Lysine on Performance, Plasma Amino Acid Concentrations and Nitrogen Balance of Young Swine

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## EFFECTS OF EXCESS ARGININE WITH AND WITHOUT SUPPLEMENTAL LYSINE ON PERFORMANCE, PLASMA AMINO ACID CONCENTRATIONS AND NITROGEN BALANCE OF YOUNG SWINE<sup>1,2</sup>

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### Summary

Three experiments were conducted to determine the effects of excess arginine on performance, plasma amino acid levels and N balance of young pigs (initial weights 6.9, 7.0 and 10.3 kg, respectively). In a 28-d growth trial, various amounts of arginine (0 to 1.6%) were added to a conventional starter diet. Addition of arginine decreased ( $P < .01$ ) average daily feed intake (ADFI) and gain (ADG), but had no effect on feed efficiency (G/F). Plasma urea, arginine and ornithine concentrations were elevated ( $P < .001$ ) by the increasing dietary arginine levels at d 14 and 28. Plasma histidine levels were reduced ( $P < .01$ ) at d 28. Plasma lysine levels exhibited a cubic response ( $P < .05$ ) at d 14, but were not affected by excess arginine at d 28. In a second growth trial ADFI and ADG were decreased ( $P < .05$ ), but G/F was not affected by the addition of 1.6% dietary arginine. Lysine supplementation (0, .15 or .30%) increased performance in the absence of excess arginine, but the main effect of lysine was not significant for any performance criteria. As in the first experiment, plasma concentrations of urea, arginine and ornithine were increased ( $P < .001$ ) by the addition of arginine. Plasma histidine was not affected by either arginine or lysine. Plasma lysine levels

were reduced ( $P < .001$ ) by dietary arginine and increased ( $P < .001$ ) by lysine. In a N balance experiment, addition of 1.6% dietary arginine increased N digestibility, but decreased apparent biological value. Nitrogen balance was not affected by added arginine. Lysine addition did not improve any of these three indices of N utilization. The inability of lysine supplementation to alleviate any of the adverse effects of excess arginine in young swine indicates that the reduced performance is caused by a generalized amino acid imbalance, and not by a specific interference with lysine utilization in the manner of a classical arginine-lysine antagonism.

(Key Words: Swine, Arginine, Lysine, Weight Gain, Plasma Amino Acids, Nitrogen Balance.)

### Introduction

Typical swine diets based on corn or sorghum grain and soybean meal contain arginine in amounts that far exceed the pig's requirement (NRC, 1979). In chicks, high levels of lysine interfere with arginine utilization (Snetsinger and Scott, 1961; Jones, 1964; Boorman and Fisher, 1966; D'Mello and Lewis, 1970), and there is some evidence that the antagonism is reciprocal (O'Dell and Savage, 1966). Consequently, there has been interest recently in the possibility that the high arginine content of swine diets may interfere with lysine utilization (Harmon, 1980; Baker, 1982).

Buraczewski et al. (1970) found that when they infused relatively large amounts of crystalline arginine or lysine into the small intestine of a pig fitted with reentrant cannulae, high concentrations of one amino acid lowered the absorption of the other. In contrast, recent experiments in which the arginine content of growing-finishing swine diets has been reduced by changing the feedstuff composition (primar-

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ily replacing some plant protein sources with animal sources) have been relatively unsuccessful in improving performance (Miller et al., 1981; Anderson et al., 1984).

Studies in which dietary arginine content is reduced by changing feedstuffs suffer from the limitation that other amino acid contents are also altered. This problem can be avoided by the use of crystalline amino acids, but there are differences in the absorption of crystalline amino acids and the amino acids from intact proteins (Matthews, 1975a,b). Recent experiments with young swine (Easter and Baker, 1977; Southern and Baker, 1982; Hagemeyer et al., 1983) have demonstrated that the addition of crystalline arginine to diets for young swine can reduce performance.

The purpose of the present research was to determine the effects of both small and large additions of crystalline arginine to diets of young pigs on performance, plasma amino acid concentrations and N balance. An additional goal was to test whether the reduced performance induced by excess arginine could be alleviated by supplemental lysine.

## Materials and Methods

*General.* Three experiments were conducted utilizing a total of 228 pigs, weaned at 3 to 4 wk of age. In each experiment the dietary treatments were formulated from a basal starter diet (table 1), which was designed to meet the nutrient requirements of 5 to 10 kg pigs (NRC, 1979). Treatments were created by adding L-arginine free base and(or) L-lysine•HCl to the basal diet at the expense of corn.

*Exp. 1.* Ninety-six crossbred pigs were weaned at 3 to 4 wk of age and were fed a 22% protein prestarter diet during a 6-d acclimation period. They were then allotted to six treatment groups with four pens/treatment and four pigs (two gilts and two barrows)/pen in a randomized complete block design. Initial weight (avg 6.9 kg) was used as the blocking criterion. The dietary treatments consisted of the basal diet with 0, .1, .2, .4, .8 or 1.6% added arginine.

Pigs were housed in an environmentally controlled nursery, which contained 1.8 × 1.8 m pens with partially slatted floors. They were allowed ad libitum access to feed and

TABLE 1. COMPOSITION OF BASAL DIET<sup>a</sup>

Ingredient	%	
Corn, ground (IFN 4-02-935)	55.51	
Soybean meal (44% CP; IFN 5-04-604)	27.33	
Oats (IFN 4-03-309)	10.00	
Tallow (IFN 4-07-880)	3.00	
Dicalcium phosphate (IFN 6-01-080)	1.87	
Limestone (IFN 6-02-632)	.69	
Salt (IFN 6-04-151)	.50	
Trace mineral mix <sup>b</sup>	.05	
Selenium premix <sup>c</sup>	.05	
Vitamin premix + carbadox <sup>d</sup>	1.00	
Total	100.00	
Analysis, %	Exp. 1	Exp. 2 & 3
Protein	17.74	17.47
Ca	.80	.77
P	.74	.68
Arginine	1.11	1.09
Lysine	.89	.98

<sup>a</sup>In Exp. 1, diets contained 0, .1, .2, .4, .8 or 1.6% added arginine (as L-arginine free base). In Exp. 2 and 3, diets contained 0 or 1.6% added arginine (as L-arginine free base) and 0, .15 or .30% lysine (as L-lysine•HCl, 78% lysine). Additions of amino acids were made at the expense of corn.

<sup>b</sup>Provided the following in mg/kg of diet: Zn, 100; Fe, 50; Mn, 27.5; Cu, 5.0; I, .75.

<sup>c</sup>Provided .1 mg of selenium/kg of diet.

<sup>d</sup>Provided the following per kg of diet: vitamin A, 5,500 IU; vitamin D<sub>3</sub>, 440 IU; vitamin E, 22 IU; riboflavin, 2.9 mg; d-pantothenic acid, 22 mg; niacin, 22 mg; choline chloride, 220 mg; vitamin B<sub>12</sub>, 22 µg; menadione sodium bisulfate, 2.2 mg and carbadox, 55 mg.

water during the 28-d experiment. Feed intakes and pig weights were recorded weekly.

On d 14 and 28 of the experiment a blood sample was obtained from each pig by puncture of the anterior vena cava or an adjoining vein. Samples were collected in 10-ml evacuated tubes containing sodium heparin. Plasma was separated by centrifugation at  $1,116 \times g$  for 15 min. Individual plasma samples from each pig were analyzed for urea using the automated procedure described by Marsh et al. (1965). One milliliter of plasma from each pig was pooled by pen to make a composite sample for each pen. The pooled plasma samples were deproteinized using sulfosalicylic acid (30 mg/ml of plasma) according to the method of Perry and Hansen (1969). Deproteinized plasma was analyzed for arginine, histidine, lysine and ornithine using ion-exchange separation (Blackburn, 1978) and fluorimetric detection (Benson and Hare, 1975).

Data were analyzed as a randomized complete block design utilizing the Statistical Analysis System (SAS, 1979). Single degree-of-freedom orthogonal polynomials were calculated using coefficients appropriate for the unequally spaced arginine levels employed.

*Exp. 2.* After weaning at 4 wk of age, 96 crossbred pigs were fed a 22% protein prestarter diet for 4 to 7 d. They were then allotted to six treatments in a randomized complete block design in a manner similar to that described for Exp. 1. The average initial weight was 7.0 kg. Dietary treatments were arginine added at 0 or 1.6% of the diet and lysine added at 0, .15 or .30% of the diet in a  $2 \times 3$  factorial plan.

Animal housing, management, data collection and sample analysis were identical to Exp. 1 except that pigs were bled only once (on d 28).

Data were analyzed as a randomized complete block with a factorial arrangement of treatments.

*Exp. 3.* Thirty-six crossbred barrows, with an initial weight of 10.3 kg, were used to determine N utilization and balance of young pigs fed the six diets used in Exp. 2. The barrows were allotted to three groups of 12 pigs; each group (block) containing two pigs fed each dietary treatment.

Pigs were housed in an environmentally controlled room containing  $1.5 \times 1$  m pens and circular metabolism crates. Each group of pigs was first assigned to a preliminary period in which they were individually fed the experimental diets in the pens for 5 d. Pigs were then moved to metabolism crates. After a 2-d

adjustment period in the crates, urine, feces and orts were collected daily for 5 d. Diets were offered ad libitum at all times and the daily intake of each pig was recorded.

Urine was collected by allowing it to flow down into a vessel containing 50 ml of a 10% (v/v) solution of technical grade concentrated HCl. Daily collections were measured, mixed well, sampled (2% of daily total) and stored at  $-20$  C until analyzed. Total feces and orts collections were made daily and were also stored at  $-20$  C.

Feces and orts were dried at 50 C for 72 h. After allowing them to equilibrate to room conditions, the entire dried samples were ground through a 4-mm screen in a Wiley mill. Subsamples were then reground in a laboratory micromill. The N contents of feed, orts, feces and urine were determined by a Kjeldahl procedure similar to that described by the AOAC (1980). Standard equations (Lassiter and Edwards, 1982) were used to compute the various indices of N utilization (table 6).

Statistical analyses were similar to those described for Exp. 2.

#### Results and Discussion

*Exp. 1.* The performance data are presented in table 2. Addition of increasing amounts (0 to 1.6%) of crystalline arginine to the basal diet (1.11% arginine) resulted in a linear ( $P < .01$ ) decrease in average daily feed intake (ADFI) and gain (ADG), but did not affect ( $P > .08$ ) feed efficiency (G/F). These results are similar to those of Southern and Baker (1982), who found that additions of .67, 1.33 or 2.00% arginine to a basal diet (calculated to contain 1.27% arginine) resulted in a linear depression in ADFI and ADG of 7.5 kg pigs, but did not alter G/F.

In other research, Easter and Baker (1977) reported that the addition of .5, 1.0 or 1.5% arginine depressed ADFI, ADG and G/F of 9.1-kg pigs fed diets containing 12 or 26% crude protein, but not pigs fed diets with 19% crude protein. Hagemeyer et al. (1983) found that additions of .35 or .69% arginine to diets of 8.0-kg pigs had little or no effect on ADFI and did not affect ADG. There was, however, a linear reduction in G/F in one experiment when arginine was added to a diet that was marginal in lysine.

Based on the research reported herein and that of others (Easter and Baker, 1977; Southern and Baker, 1982; Hagemeyer et al., 1983), it

TABLE 2. PERFORMANCE OF YOUNG SWINE FED VARIOUS LEVELS OF EXCESS ARGININE (EXP. 1)<sup>a</sup>

Item	Treatment: 1 Diet type: Basal (B) <sup>b</sup>	2 B+ .1% arg	3 B+ .2% arg	4 B+ .4% arg	5 B+ .8% arg	6 B+ 1.6% arg	CV <sup>c</sup>
Feed intake, g/d <sup>d</sup>	562	585	552	498	516	470	10.24
Weight gain, g/d <sup>d</sup>	312	343	324	300	278	268	11.99
Gain/feed	.555	.589	.585	.606	.540	.573	9.27

<sup>a</sup>Values represent the mean of four replicates of four pigs; average initial weight was 6.9 kg; 28-d experiment.

<sup>b</sup>The basal diet contained 1.11% arginine.

<sup>c</sup>Coefficient of variation, %.

<sup>d</sup>Linear effect ( $P < .01$ ).

seems that, although the addition of crystalline arginine to the diets of baby pigs usually reduces ADFI and ADG, the reductions are small unless relatively large amounts ( $>.4\%$ ) of arginine are added.

Plasma urea and amino acid concentrations are presented in table 3. Addition of arginine resulted in linear ( $P < .001$ ) increases in urea, arginine and ornithine at both bleeding periods. Mitchell et al. (1968; and many others) have reported that when young pigs are fed supra-optimal dietary levels of an amino acid, there is an accumulation of that amino acid in the plasma. Thus, the increase in the plasma arginine is consistent with previous findings. The increases in plasma urea and ornithine levels presumably reflect catabolism of the excess arginine via the urea cycle. Southern and Baker (1982) and Hagemeyer et al. (1983) also observed significant increases in plasma arginine and ornithine when dietary arginine was increased. Neither group measured plasma urea concentrations.

Plasma histidine levels were not affected by dietary arginine at the first bleeding, but at the second bleeding there was a small but significant ( $P < .01$ ) reduction in plasma histidine as dietary arginine increased. Similar small decreases in plasma histidine were recorded by both Southern and Baker (1982) and Hagemeyer et al. (1983).

In the present experiments, plasma lysine levels exhibited a cubic response ( $P < .05$ ) to dietary arginine at the first bleeding; the overall tendency being a decrease (linear component  $P < .08$ ). There were, however, no significant differences in plasma lysine concentrations at the second bleeding. Previous reports have also described changes in plasma lysine. Southern

and Baker (1982) consistently found a depression in plasma lysine (as well as other amino acids) when young pigs were fed excess dietary arginine. Hagemeyer et al. (1983) observed a depression in plasma lysine when arginine was added to a diet containing adequate lysine (1.26%), but not when it was added to diets marginal in lysine (1.03 and .92%). Thus, the various reports are in agreement that excess arginine can affect plasma lysine concentration. But, other amino acids are also affected (e.g., histidine in the present experiment) and consequently, it is not clear from these data whether the changes in plasma lysine reflect a specific arginine-lysine antagonism or whether they are associated with a more general type of amino acid imbalance.

*Exp. 2.* Addition of 1.6% crystalline arginine to a basal diet containing 1.09% arginine reduced ( $P < .05$ ) ADFI and ADG of young pigs (table 4). The excess arginine did not affect ( $P > .10$ ) G/F. The influence of dietary arginine was consistent regardless of the level of lysine added. These data are also consistent with the results of Exp. 1.

The main effect of lysine was not significant ( $P > .10$ ) for any of the performance criteria, although there was a trend ( $P < .06$ ) toward a linear effect of lysine on G/F. This indicates that when considered across both dietary arginine levels, supplemental lysine had little effect on performance. Although there was no arginine  $\times$  lysine interaction ( $P > .10$ ) for any of the traits, there was a consistent increase in ADFI, ADG and G/F when lysine was added to the basal diet without additional arginine. A response to supplemental lysine when the diet

TABLE 3. CONCENTRATIONS (MG/DL) OF UREA AND AMINO ACIDS IN PLASMA OF YOUNG SWINE FED VARIOUS LEVELS OF ARGININE (EXP. 1)<sup>a</sup>

Metabolite	Treatment: 1		2	3	4	5	6	CV <sup>c</sup>
	Time	Diet type: Basal (B) <sup>b</sup>	B+ .1% arg	B+ .2% arg	B+ .4% arg	B+ .8% arg	B+ 1.6% arg	
Urea	14 d <sup>d</sup>	28.57	28.87	28.68	33.72	36.38	41.96	6.70
	28 d <sup>d</sup>	29.12	31.36	30.61	34.86	35.20	43.06	9.98
Arginine	14 d <sup>d</sup>	4.41	5.13	4.48	4.73	5.78	8.21	16.27
	28 d <sup>d</sup>	4.72	5.63	5.78	6.62	6.84	10.65	16.38
Histidine	14 d	2.23	2.30	2.00	1.89	2.54	2.02	20.37
	28 d <sup>e</sup>	2.80	2.80	2.62	2.79	2.18	2.28	12.92
Lysine	14 d <sup>f</sup>	2.55	2.18	1.76	1.95	2.06	1.83	16.82
	28 d	2.32	2.80	2.74	2.37	2.47	2.37	25.01
Ornithine	14 d <sup>d</sup>	2.75	3.27	2.92	3.12	4.44	5.37	18.19
	28 d <sup>d</sup>	2.46	2.77	3.06	3.49	3.99	5.83	10.89

<sup>a</sup>Values represent the mean of four replicates of four pigs for urea, and the mean of four replicates of a pooled sample of plasmas from four pigs for amino acids. The pigs were bled on d 14 and 28 of the experiment.

<sup>b</sup>The basal diet contained 1.11% arginine.

<sup>c</sup>Coefficient of variation, %.

<sup>d</sup>Linear effect ( $P < .001$ ).

<sup>e</sup>Linear effect ( $P < .01$ ).

<sup>f</sup>Cubic effect ( $P < .05$ ).

contains less than 1% total lysine has been reported by us previously (Lewis et al., 1980).

It is clear that lysine, at the levels added in this experiment, did not alleviate any of the adverse effects on ADFI or ADG caused by feeding 1.6% added arginine. Similarly, Southern and Baker (1982) found that neither .5% nor 2.5% supplemental lysine ameliorated the reduced ADFI and ADG caused by the addition of 2.0% crystalline arginine. Taken together, these data provide strong evidence that any negative effects in young swine caused by large additions of crystalline arginine are due to a general type of amino acid imbalance and not a specific arginine-lysine antagonism.

Addition of excess arginine increased ( $P < .001$ ) plasma concentrations of urea, arginine and ornithine (table 5). This effect was similar to that observed in Exp. 1. Lysine addition did not alter the plasma levels of these three metabolites and there were no arginine  $\times$  lysine interactions.

Plasma histidine was not affected ( $P > .10$ ) by addition of either arginine or lysine. In contrast, plasma lysine concentrations were influenced

by both dietary arginine and dietary lysine. As would be expected, adding lysine to the diet resulted in a linear increase ( $P < .001$ ) in plasma lysine. The overall effect of adding arginine was to reduce ( $P < .001$ ) plasma lysine, but there was an arginine  $\times$  lysine interaction ( $P < .01$ ). Although dietary arginine tended to decrease plasma lysine at all levels of dietary lysine, it is clear that the reduction was most pronounced at the highest dietary lysine level. Other researchers have noted somewhat similar effects. Hagemeyer et al. (1983) found that plasma lysine was decreased by dietary arginine in pigs fed 1.26% lysine, but not in pigs fed 1.03% lysine. They commented that the lack of a reduction in plasma lysine of pigs fed 1.03% was 'not surprising, because lysine was already at baseline levels.'

Although the changes observed in plasma lysine are suggestive of a specific antagonism between arginine and lysine, this was not borne out by the performance data. In fact, there seems to be little correlation between the ADG data and the changes in plasma lysine. Thus, ADG and plasma lysine appeared to be positively

TABLE 4. PERFORMANCE OF YOUNG SWINE FED VARIOUS LEVELS OF ARGININE AND LYSINE (EXP. 2)<sup>a</sup>

Criterion	Level of added arginine, %	Level of added lysine, % <sup>b</sup>			Avg effect of arginine	CV <sup>c</sup>
		0	.15	.30		
Feed intake, g/d <sup>d</sup>	0	645	658	696	667	
	1.6	574	542	587	567	
Avg effect of lysine		609	600	641		14.16
Weight gain, g/d <sup>d</sup>	0	378	400	426	401	
	1.6	348	329	362	347	
Avg effect of lysine		363	365	394		14.09
Gain/feed <sup>e</sup>	0	.585	.607	.614	.602	
	1.6	.612	.608	.615	.612	
Avg effect of lysine		.598	.607	.615		2.60

<sup>a</sup>Values represent the mean of four replicates of four pigs; average initial weight was 7.0 kg; 28-d experiment.

<sup>b</sup>The basal diet contained 1.09% arginine and .98% lysine.

<sup>c</sup>Coefficient of variation, %.

<sup>d</sup>Arginine effect ( $P < .05$ ).

<sup>e</sup>Linear effect of lysine ( $P < .10$ ).

associated in the absence of arginine addition, but there was no such relationship when supplemental arginine was included. Although

not significant, the addition of lysine without arginine tended to decrease the plasma concentrations of arginine, histidine and ornithine,

TABLE 5. CONCENTRATIONS (MG/DL) OF UREA AND AMINO ACIDS IN PLASMA OF YOUNG SWINE FED VARIOUS LEVELS OF ARGININE AND LYSINE (EXP. 2)<sup>a</sup>

Metabolite	Level of added arginine, %	Level of added lysine, % <sup>b</sup>			Avg effect of arginine	CV <sup>c</sup>
		0	.15	.30		
Urea <sup>d</sup>	0	33.14	30.50	30.73	31.46	
	1.6	47.31	47.44	50.67	48.47	
Avg effect of lysine		40.22	38.97	40.70		11.68
Arginine <sup>d</sup>	0	4.86	4.20	4.14	4.40	
	1.6	7.92	11.06	9.78	9.59	
Avg effect of lysine		6.39	7.63	6.96		21.58
Histidine	0	2.59	2.43	2.36	2.46	
	1.6	2.21	2.35	2.45	2.34	
Avg effect of lysine		2.40	2.39	2.40		12.23
Lysine <sup>def</sup>	0	3.10	5.14	6.87	5.04	
	1.6	2.09	4.45	2.97	3.17	
Avg effect of lysine		2.60	4.79	4.92		21.50
Ornithine <sup>df</sup>	0	3.39	3.09	2.62	3.04	
	1.6	6.16	7.13	7.25	6.85	
Avg effect of lysine		4.78	5.11	4.94		10.67

<sup>a</sup>Values represent the mean of four replicates of four pigs for urea, and the mean of four replicates of a pooled sample of plasmas from four pigs for amino acids. The pigs were bled at the end of the 28-d experiment.

<sup>b</sup>The basal diet contained 1.09% arginine and .98% lysine.

<sup>c</sup>Coefficient of variation, %.

<sup>d</sup>Arginine effect ( $P < .001$ ).

<sup>e</sup>Lysine effect ( $P < .001$ ).

<sup>f</sup>Arginine × lysine interaction ( $P < .01$ ).

supporting the concept that lysine was limiting in the basal diet. In the presence of supplemental arginine, addition of lysine tended to increase the plasma concentrations of these three amino acids.

*Exp. 3.* In the N balance experiment (table 6) there was a linear reduction ( $P < .05$ ) in ADFI as supplemental lysine was added to the diet. This response was in contrast to that observed in Exp. 2 where supplemental lysine increased feed intake. The reason for the discrepancy is not known; perhaps the shorter experimental period and the fact that the pigs were heavier were involved. Despite the reduction in feed intake there was an increase in lysine intake. The daily intakes of lysine for pigs fed 0, .15 and .30% added lysine were 10.28, 11.04 and 12.13 g/d, respectively. Arginine addition did not alter ( $P > .10$ ) ADFI during the 12-d period that

the pigs consumed the diets. Pigs fed diets with added arginine consumed more ( $P < .001$ ) N, because of the higher total N content of the diets.

Fecal N excretion was similar ( $P > .10$ ) for all pigs regardless of arginine or lysine content of the diet. Differences in N excretion were exhibited in urinary N levels. Pigs fed diets with added arginine had greater ( $P < .001$ ) daily urinary N than pigs fed the basal diet. The quantity of urinary urea (the major metabolite of N excretion in swine), is greatly influenced by protein quality and amino acid balance (Brown and Cline, 1974). Evidently, the imbalance created by the excess arginine increased urinary N, but the imbalance was not alleviated by supplemental lysine.

Apparent N digestibility was higher ( $P < .05$ ) in diets containing added arginine. This would be expected if one assumes that the crystalline

TABLE 6. NITROGEN BALANCE OF YOUNG SWINE FED VARIOUS LEVELS OF ARGININE AND LYSINE (EXP. 3)<sup>a</sup>

Criterion	Level of added arginine, %	Level of added lysine, % <sup>b</sup>			Avg effect of arginine	CV <sup>c</sup>
		0	.15	.30		
Feed intake, g/d <sup>d</sup>	0	1,062.92	996.26	941.56	1,000.25	
	1.6	1,035.85	958.51	954.40	982.92	
Avg effect of lysine		1,049.38	977.38	947.98		10.42
N intake, g/d <sup>e</sup>	0	29.54	27.88	26.37	27.93	
	1.6	33.28	31.01	31.46	31.92	
Avg effect of lysine		31.41	29.45	28.92		10.67
Fecal N, g/d	0	4.71	4.75	4.59	4.68	
	1.6	4.78	4.86	4.61	4.75	
Avg effect of lysine		4.74	4.80	4.60		16.44
Urinary N, g/d <sup>e</sup>	0	6.20	5.67	6.35	6.07	
	1.6	10.76	9.65	9.93	10.11	
Avg effect of lysine		8.48	7.66	8.14		23.21
N digestibility, % <sup>f</sup>	0	83.79	83.03	81.96	82.93	
	1.6	85.51	83.94	84.93	84.80	
Avg effect of lysine		84.65	83.49	83.45		2.48
N balance, g/d <sup>d</sup>	0	18.63	17.46	15.43	17.17	
	1.6	17.75	16.50	16.92	17.06	
Avg effect of lysine		18.19	16.98	16.18		13.49
Apparent biological value, % <sup>e</sup>	0	74.95	75.51	70.59	73.75	
	1.6	62.99	64.01	63.30	63.44	
Avg effect of lysine		68.97	69.86	66.95		7.21

<sup>a</sup>Values represent the mean of six pigs; average initial weight was 10.3 kg.

<sup>b</sup>The basal diet contained 1.09% arginine and .98% lysine.

<sup>c</sup>Coefficient of variation, %.

<sup>d</sup>Linear lysine effect ( $P < .05$ ).

<sup>e</sup>Arginine effect ( $P < .001$ ).

<sup>f</sup>Arginine effect ( $P < .05$ ).

arginine is completely absorbed. Increasing lysine levels did not affect N digestibility at either level of arginine. Lysine additions may not have been substantial enough to produce a significant increase in digestibility.

Nitrogen balance was not different ( $P > .10$ ) between pigs fed diets with high and normal arginine contents. As mentioned previously, fecal N excretion was similar. The marked difference in urinary N between pigs fed the different arginine levels was nearly the same as the difference in total N intake (4.04 vs 3.99 g/d, respectively). Thus, it seems that the excess arginine was absorbed, but was catabolized to urea and the extra N was excreted without affecting N balance. It is significant that ADFI was not different between arginine levels (in contrast to Exp. 1 and 2 where longer feeding periods reduced ADFI). When feed intake differences are absent, the effects on N balance and, presumably, ADG were essentially eliminated. Harper et al. (1970), in their extensive review, concluded that the negative effects associated with amino acid imbalance are eliminated when the intake of the control and imbalanced diets are equalized. The fact that both ADFI and ADG decreased in Exp. 1 and 2 but G/F was not affected supports that conclusion. In contrast, in chicks, where a specific antagonism exists between arginine and lysine, birds fed diets with excess lysine had a lower growth rate than birds fed control diets when ADFI was equalized (Allen et al., 1972). A model of the various mechanisms involved in the arginine-lysine antagonism in chicks has been presented by Austic and Scott (1975). In the present experiment, the similar N balance values indicate that the excess arginine caused a general type of amino acid imbalance in the experimental diets.

Lysine supplementation decreased ( $P < .05$ ) N balance in a linear fashion. The reduction in ADFI and N intake was responsible for these differences, because fecal and urinary N excretion rates were similar regardless of the dietary lysine level.

Apparent biological value was lower ( $P < .001$ ) in diets that contained added arginine. The greater urinary N excretion accounted for the decrease in apparent biological value. Lysine additions were ineffective in increasing the biological value of the diets at either level of dietary arginine. It seems that young growing pigs are capable of catabolizing arginine at levels far greater than those found in conven-

tional starter diets through normal urea cycle activity, with little or no effect on lysine needs.

Thus, although it is quite evident that the addition of relatively large amounts of crystalline arginine to conventional diets for young pigs reduces ADFI and ADG, these effects are not alleviated by lysine additions. The lack of improvement in N status of pigs fed excess arginine when lysine was supplemented is further evidence that, although an amino acid imbalance can be created by arginine additions to a normal swine diet, it is not caused by a specific interference with lysine utilization in the manner of a classical arginine-lysine antagonism.

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