

Lysine Requirement of Piglets

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ABSTRACT : The experiment was conducted with 120 barrows weaned at 21 days of age to estimate their lysine requirement weaned at 21 days of age when other important amino acids were fortified to get optimal ratio to lysine. The treatments were 1.15% (control), 1.25%, 1.35%, 1.45%, 1.55%, 1.65% total lysine in the diet. Based on the growth performance total lysine requirement of 21-day old pigs appears to be 1.45%. The lowest digestibilities of dry matter and crude fat were found in pigs fed 1.15% total lysine diet and the highest were found in pigs fed 1.65% total lysine diet with no significant differences among treatments. Nitrogen digestibility increased as the total lysine level increased up to 1.35% ($p < 0.05$) and remained relatively constant beyond 1.35%. However, the best nitrogen digestibility was observed in pigs fed 1.45% total dietary lysine. Gross energy, crude ash and phosphorus digestibilities did not

differ due to the increase in total lysine level. The amounts of excreted dry matter and nitrogen differed significantly by the increase in lysine level up to 1.35% ($p < 0.05$), while phosphorus excretion was not influenced by the lysine level. Dry matter and nitrogen excretion were reduced by 13.6% and 18.4%, respectively, when 1.45% lysine was offered to the pigs compared to the those fed on 1.15% lysine diet. The amino acid digestibilities increased as the total lysine level increased up to 1.45% ($p < 0.05$), and remained constant beyond 1.45%. The lysine requirement for the pigs weighing 6 to 14 kg seems to be higher than the previous estimates and in order to reduce pollutant excretion the accurate nutrient requirement should be set and applied to the animal.

(Key Words : Pigs, Lysine Requirement, Growth, Nutrient Digestibilities and Excretion)

INTRODUCTION

Lysine has been known as the first limiting amino acid in diet for swine (Southern, 1991; Kerr, 1993). Recently, with the advent of the new technology in young pig rearing, such as SEW (segregated early weaning), the lysine requirement of young pigs has received an intense attention and many studies have showed that the lysine requirement would be much higher than the NRC (1988) estimates. The NRC (1988) recommended 1.15% of lysine for pigs weighing 5 to 20 kg. In the previous studies, lysine requirements of pigs weighing 5 to 20 kg were found to be 0.87% (Rogerson and Campbell, 1982), 0.95% (Weaver et al., 1988), 1.08% (Campbell, 1978), 1.10% (Thaler et al., 1986), 1.15% (Aherne and Nielsen, 1983), 1.11 to 1.27% (Lin and Jensen, 1985), 1.10 to 1.27% (Martinez and Knabe, 1990), 1.15 to 1.25% (Lewis et al., 1981), and 1.25% (Pollmann et al., 1983). Owen et al. (1995) reported approximately 1.65% total dietary

lysine was required to support maximum growth rate for pigs weighing 4.6 to 10.1 kg. Bergstrom et al. (1995) also noted an improvement in growth performance when the dietary lysine level increased from 1.4 to 1.8% when examining the optimal threonine:lysine ratio for early weaned pigs. Later on Owen et al. (1996) reviewed on the lysine requirements of pigs and recommended 1.5 to 1.6% total lysine for pigs weighing 5 to 7 kg. From the results of previous studies, it is apparent that the lysine requirements of pigs weighing 5 to 10 kg have been changed and the level of lysine needed for the maximum growth rate appears to be much higher than the NRC (1988) requirements.

Also, to estimate lysine requirements of pigs, the amino acid balance in the diets should be carefully considered (Tayler et al., 1979; 1981; 1982; 1983; 1984; 1985). Therefore, the ideal amino acid pattern was introduced (Cole, 1979; ARC, 1981; Chung and Baker, 1992; Wang and Fuller, 1987). Without appropriate amino acid balance, pigs' growth could be impaired by other amino acids rather than lysine. Since the pigs are

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improved genetically with the advances in nutrition, facility design and management practices, the amino acids requirements of young pigs needed to be reexamined. Thus, the objective of this experiment was to estimate the lysine requirement of pigs weighing 6 to 14 kg when methionine, threonine and tryptophan are fortified to get optimal ratio of essential amino acids to lysine.

MATERIALS AND METHODS

Three way crossbreed (Landrace \times Large White \times Duroc) barrows weaned at 21 days of age were used as

experimental animals. At 21 days of age, a total of 120 pigs (averaged 6.1 kg body weight) were allotted in a completely randomized block design. Treatments were 1.15% (control), 1.25%, 1.35%, 1.45%, 1.55%, 1.65% total lysine with fortified methionine, threonine and tryptophan to get optimum inter-amino acid ratio suggested by Chung and Baker (1992). Each treatment had 4 replicates with 5 pigs per replicate.

Corn-soybean-dried whey based diets were used as an experimental diet. Each diet was formulated to contain 3.34-3.37 Mcal ME/kg, 0.9% Ca and 0.8% P. Experimental diets were presented in table 1.

Table 1. Composition of the experimental diets

Item	Lysine level (%)					
	1.15	1.25	1.35	1.45	1.55	1.65
Ingredients (%)						
Corn	42.42	40.36	38.26	36.26	34.18	32.09
Soybean meal	18.91	20.90	22.90	24.88	26.86	28.87
Dried whey	25.00	25.00	25.00	25.00	25.00	25.00
Spray-dried plasma protein	5.00	5.00	5.00	5.00	5.00	5.00
Corn oil	5.00	5.00	5.00	5.00	5.00	5.00
Mono calcium phosphate	2.40	2.35	2.25	2.30	2.25	2.20
Limestone	0.50	0.50	0.50	0.50	0.50	0.50
Salt	0.20	0.20	0.20	0.20	0.20	0.20
Vit. Min. ¹	0.25	0.25	0.25	0.25	0.25	0.25
Antibiotics	0.22	0.22	0.22	0.22	0.22	0.22
Lysine	0.01	0.07	0.13	0.19	0.25	0.31
Methionine	0.09	0.14	0.17	0.18	0.21	0.23
Threonine	—	—	—	—	0.05	0.09
Tryptophan	—	0.01	0.02	0.02	0.03	0.04
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition²						
ME (Mcal/kg)	3.37	3.37	3.36	3.36	3.35	3.34
Crude protein (%)	18.33	19.03	19.73	20.43	21.13	21.83
Calcium (%)	0.90	0.90	0.90	0.90	0.90	0.90
Phosphorus (%)	0.80	0.80	0.80	0.80	0.80	0.80
Lysine (%)	1.15	1.25	1.35	1.45	1.55	1.65
Methionine + cystine (%)	0.68	0.75	0.81	0.87	0.93	0.99
Threonine (%)	0.85	0.89	0.91	0.94	1.01	1.07
Tryptophan (%)	0.21	0.23	0.25	0.26	0.28	0.30

¹ Vit. min.-mixture contains per kg: Vitamin A, 2,000,000 IU; Vitamin D₃, 400,000 IU; Vitamin E, 250 IU; Vitamin K₃, 200 mg; Vitamin B₁, 20 mg; Vitamin B₂, 700 mg; Pantothenic acid, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 mg; Vitamin B₁₂, 13 mg; Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; sucrose to make 1 kg vit.-min. mixture.

² Calculated value.

³ Analyzed value.

The pigs were kept in concrete-floored pens, where feed and water were provided *ad libitum* during the entire experimental period of 3 weeks. The temperature was maintained within the range of 26 to 30°C throughout the experimental period. Body weight and feed intake were recorded weekly.

For the digestibilities of experimental diets, pigs were fed diets containing 0.25% Cr₂O₃ during the second week of the experimental period and feces were collected three days and three times (08:00, 14:00, 20:00) a day after four days of adjustment period. Fecal samples were dried in an air-forced drying oven at 60°C for 72 hours and ground with 1 mm mesh Wiley mill for chemical analysis.

Feed and fecal samples were analyzed for proximate analysis and mineral composition by AOAC methods (1990). Chromium was measured using Atomic Absorption Spectrophotometer (Shimadzu, AA6145F, Japan). For energy utilization, energy values of feed and

feces were measured by Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL) and amino acid contents were measured using Automatic Amino Acid Analyzer (Model 4150 alpha, LKB, UK) following acid hydrolysis with 6N HCl at 110°C for 16 hours.

Statistical analyses were conducted using GLM procedure of SAS package (1985), and treatment means were compared using Duncan's multiple range test (Duncan, 1955)

RESULTS AND DISCUSSION

Growth performance

Table 2 summarizes the effects of graded levels of total lysine in the diets on the average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) for the experimental period.

Table 2. Growth performance of pigs fed different levels of lysine from 6 to 14 kg live weight

Item	Lysine (% of the diet)						SE ¹
	1.15	1.25	1.35	1.45	1.55	1.65	
0 to 7							
ADG (g)	220.5 ^d	233.8 ^{cd}	243.8 ^{cd}	259.0 ^{bc}	298.3 ^a	276.3 ^{ab}	19.15
ADFI (g)	273.5	266.3	270.5	265.0	274.0	244.0	22.45
FCR	1.24 ^a	1.13 ^b	1.11 ^b	1.02 ^c	0.92 ^d	0.88 ^d	0.04
7 to 14							
ADG (g)	300.7 ^c	336.0 ^b	369.8 ^a	387.3 ^a	381.5 ^a	377.5 ^a	21.60
ADFI (g)	418.3 ^b	452.0 ^{ab}	458.5 ^a	454.8 ^{ab}	451.5 ^{ab}	442.5 ^{ab}	22.44
FCR	1.39 ^a	1.34 ^b	1.24 ^c	1.18 ^d	1.17 ^d	1.17 ^d	0.01
0 to 14							
ADG (g)	260.5 ^d	284.8 ^{cd}	306.8 ^{bc}	323.0 ^{ab}	339.8 ^a	327.0 ^{ab}	16.96
ADFI (g)	345.8	359.3	364.8	359.8	363.5	343.5	19.14
FCR	1.32 ^a	1.26 ^b	1.19 ^c	1.11 ^d	1.07 ^e	1.05 ^e	0.02
14 to 21							
ADG (g)	466.5 ^c	510.0 ^b	548.0 ^{ab}	562.5 ^a	531.3 ^{ab}	537.5 ^{ab}	27.35
ADFI (g)	766.5	811.8	816.8	794.0	759.5	761.5	40.65
FCR	1.64 ^a	1.59 ^b	1.49 ^c	1.41 ^d	1.43 ^d	1.42 ^d	0.03
0 to 21							
ADG (g)	329.0 ^c	360.0 ^b	387.3 ^{ab}	403.0 ^a	404.5 ^a	397.3 ^a	18.51
ADFI (g)	486.0	510.3	515.3	504.8	495.3	482.5	23.41
FCR	1.47 ^a	1.41 ^b	1.33 ^c	1.25 ^d	1.22 ^d	1.21 ^d	0.03

¹ Pooled standard error; n=24.

^{a,b,c,d} Means with different superscript in the same row are significantly different at $p < 0.05$.

ADG: Average daily weight gain.

ADFI: Average daily feed intake.

FCR: Feed conversion ratio.

For the first week, daily gain was optimized at the 1.55% total lysine level. Up to the 1.55% total lysine, daily gain increased linearly as dietary lysine level increased ($p < 0.05$). At 1.65% total lysine level, growth rate was reduced, though there was no significant difference between 1.55% and 1.65% total lysine groups. Feed intakes were not significantly affected by the lysine levels during the experimental period except for the period of 7 to 14 days.

As the pigs aged, the lysine requirement appeared to be decreased. For the second week, pigs' growth rate was not significantly different beyond 1.35% lysine, however, feed efficiency was optimized at 1.45% total lysine ($p < 0.05$), and the same trend was found in the third week.

Through the entire experimental period, the growth rate of pigs was optimized at 1.45% total lysine. Beyond 1.45% total lysine, pigs did not respond to the increase in lysine contents of the diets. The FCR was also optimized at 1.45% total lysine as shown in table 2. Feed intake was not affected ($p > 0.05$) by the increase in total lysine contents in the diets through out the whole experimental period.

Based on the growth performance of the pigs used in this study, total lysine requirement of 21 day old pig appears to be approximately 1.45% of the diet. However, for the first week postweaning 1.55% total lysine seems to be needed to get optimal growth rate. These values are higher than the NRC (1988) estimates and other previous estimates (Rogerson and Campbell, 1982; Weaver et al., 1988; Campbell, 1978; Thaler et al., 1986; Aherne and Nielsen, 1983; Lin and Jensen, 1985; Martinez and Knabe, 1990; Lewis et al., 1981; Pollman et al., 1983) but in close agreement with the results reported by Owen et al. (1995; 1996), Bergstrom et al. (1995) and Williams and Stahly (1995). This can be explained partly by a better balance between the main essential amino acids which enabled the piglets to make a better use of diets with higher contents of amino acids and these results may be a reflection of a substantial genetic improvement of pigs obtained during the last decade. Stahly et al. (1994) evaluated three genotypes (high, medium, and low capacity for lean tissue growth) and fed diets containing 0.60, 0.90, 1.20, 1.50, and 1.80% total lysine levels from 5.6 to 25.5 kg. They reported that feed efficiency was optimized by 1.8, 1.5, and 1.2% total dietary lysine for high-, medium- and low-lean growth genotypes, respectively. These data indicate that the dietary amino acid needs of weanling pigs are influenced by its genetic capacity for lean tissue growth.

The NRC (1988) estimates for the 5 to 10 kg pig are 1.15% lysine. The NRC (1988) suggests that a pig of this

weight needs 5.3 g/d of lysine to support 249 g/d ADG, 458 g/d ADFI, and 1.84 F/G, respectively. However, in this study, approximately 5.63 g/d of total lysine was required to support 340 g/d ADG, 364 g/d ADFI, and 1.17 F/G, respectively. Owen et al. (1995) also reported the similar trend with the pigs weighing 4.6 to 10.1 kg. Owen et al. (1995) reported that approximately 1.65%, or 6.2 g/d total dietary lysine was required to support ADG, ADFI, and G/F of 400 g/d, 381 g/d, and 1.04, respectively. This comparison also demonstrates that the lysine requirement should be elevated to higher level than NRC (1988) recommendation due to the genetic improvement of pigs raised in modern pig production. Owen et al. (1996) also reviewed on the lysine requirement for early weaned piglets and suggested that 1.5 to 1.6% of lysine is required for the pigs weighing 5 to 7 kg, and 1.4 to 1.5 % of lysine for the pigs weighing 7 to 11 kg and these values are in close agreement with our findings.

Nutrient digestibilities

Nutrient digestibilities of pigs fed different total dietary lysine levels are presented in table 3. The lowest digestibilities of dry matter and crude fat were found in pigs fed 1.15% total lysine diet and the highest were found in pigs fed 1.65% total lysine diet. The pigs fed above 1.45% total lysine diets showed better digestibilities than the pigs fed under 1.35% total lysine diets. However, no significant difference was found among treatments.

Nitrogen digestibility increased as the total lysine level increased up to 1.35% ($p < 0.05$) and remained relatively constant beyond 1.35%. However, the best nitrogen digestibility was observed in pigs fed 1.45% total dietary lysine. Results reported by Hansen and Lewis (1993) also indicated that during the growing period, N digestibility increased linearly as CP level (diets containing 11 to 23% CP) increased ($p < 0.05$). Similar responses were noted during the finishing period. Others have reported that N digestibility was increased with increasing dietary CP concentration (Rutledge et al., 1961; Just, 1982; Fuller, 1983). The positive relationship between N digestibility and CP concentration has been attributed to the greater digestibility of protein supplements than of cereal grains (Just, 1982). Also, N digestibility increases as CP level increases because metabolic fecal N becomes a smaller proportion of total fecal N.

Gross energy, crude ash and phosphorus digestibilities did not respond to the increased total lysine level.

Table 3. Effects of different dietary lysine levels on nutrient digestibilities in weaned pigs (%)

Dietary lysine (%)	GE	Dry matter	Nitrogen	Crude fat	Crude ash	Phosphorus
1.15	78.71	79.53	75.37 ^c	78.84	59.58 ^a	40.74
1.25	79.59	80.12	75.96 ^{bc}	79.64	57.51 ^c	40.27
1.35	76.48	80.92	76.56 ^{abc}	79.39	59.70 ^a	41.03
1.45	78.71	81.29	77.98 ^a	81.05	57.88 ^{bc}	40.94
1.55	77.55	81.86	77.79 ^a	80.99	59.66 ^a	39.56
1.65	78.87	82.06	77.66 ^{ab}	81.70	59.30 ^{ab}	40.41
SE ¹	0.56	0.39	0.28	0.37	0.26	0.54

¹ Pooled standard error, n=24.

^{a,b,c} Means in the same column with different superscript are significantly different at $p < 0.05$.

Nutrient excretion

The values of nutrient excretion are presented in table 4. These values were calculated on the basis of the feed intake and nutrient digestibilities and expressed as g/1,000 g body weight gain. The amounts of excreted dry matter and nitrogen were significantly affected by the increase in lysine level up to 1.35% ($p < 0.05$), while the phosphorus excretion was not influenced. Dry matter and nitrogen excretion were improved by 13.6% and 18.4%, respectively, when 1.45% lysine was offered to the pigs compared to the pigs fed on 1.15% lysine diet. These data well demonstrate that the well balanced diet with accurate nutrient content should be fed to the animal to reduce the environmental pollution caused nitrogen excretion by the animal. Paik et al. (1996) suggested that nitrogen excretion could be reduced by 10 to 15% through formulating feed closer to requirements.

Table 4. Effects of different lysine level on nutrient excretion in weaned pigs (g/1000 g body weight gain)

Dietary lysine (%)	Dry matter	Nitrogen	Phosphorus
1.15	270.13 ^c	10.70 ^d	4.47
1.25	249.25 ^b	10.35 ^c	4.36
1.35	236.08 ^a	9.55 ^b	4.46
1.45	237.75 ^a	9.04 ^a	4.42
1.55	235.56 ^a	9.11 ^a	4.43
1.65	236.56 ^a	9.02 ^a	4.41
SE ¹	3.05	0.15	0.04

¹ Pooled standard error, n=24.

^{a,b,c} Means with different superscript in the same column are significantly different at $p < 0.05$.

Amino acid digestibilities

Data on Amino acid digestibilities recorded from this study are shown in table 5. Essential amino acid digestibilities increased as the total lysine level increased up to 1.45% ($p < 0.05$). Essential amino acid and lysine digestibilities increases from 77.69% to 83.38% and 76.05% to 85.60%, respectively. The digestibilities of threonine, valine, leucine and histidine showed the same trend. However, methionine and phenylalanine did not respond in the same way to the increased lysine level. The increases in apparent digestibilities of amino acids with increasing CP content were greatest at the lower CP levels; the increases become negligible at the higher CP levels, because endogenous CP accounts for a smaller proportion of CP in digesta. Differences in the apparent digestibilities of CP and amino acids in relation to their dietary content were also observed by Furuya and Kaji (1989). From the literature cited by Eurolysine (1988) the estimated average amino acid digestibility coefficients for lysine in the experimental diets may be taken as 0.88. However, there are large differences in amino acid digestibility between foodstuffs and among different samples of the same foodstuff (Sauer and Ozimek, 1986) which should have led to actual digestibility coefficients different from these previously estimated.

A similar improvement in digestibilities of non essential amino acids were found. The best amino acid digestibility was found in pigs fed on 1.55% lysine diet, with no significant differences above 1.45% lysine level. Initially, the apparent amino acid digestibilities increased sharply; thereafter, the increases became smaller and reached their plateau values, after which there were no further increases and the digestibility values became independent of the dietary amino acid levels. These quadratic with plateau relationships between dietary amino acid contents and apparent digestibilities were not

observed in the studies by Furuya and Kaji (1989) and Li et al. (1993). This likely resulted from the limited number of dietary treatments (three or four). In addition, the dietary treatments were not evenly designed from low to high amino acid content, as in the present study.

Apparent digestibility of some amino acids tended to decrease as its dietary lysine content increased from 1.45 to 1.65%. Studies by Li et al. (1993) with early-weaned pigs fed corn-starch-based SBM diets also showed trends toward decreases in the apparent ileal digestibilities of CP and the majority of the amino acids as the dietary CP

content was increased from 19.5 to 25.5%. As was discussed by these authors, these decreases, with an increase in the efficiency of protein digestion and amino acid and peptide absorption, because the uptake of free amino acids and small peptides into the enterocytes is an active process involving a multiplicity of transport systems (Hoper, 1987; Webb, 1990), it is possible that the total supply of amino acids and small peptides from the high-protein diets may have exceeded the maximum capacity of efficiency of transport.

Table 5. Effects of different lysine levels on amino acids digestibilities in weaned pigs (%)

AA	Dietary lysine level (%)						SE ¹
	1.15	1.25	1.35	1.45	1.55	1.65	
THR	74.81 ^b	70.78 ^b	74.90 ^b	83.03 ^a	81.62 ^a	83.25 ^a	1.11
VAL	76.86 ^c	76.55 ^c	77.92 ^{bc}	80.50 ^{ab}	83.28 ^a	83.35 ^a	0.70
MET	75.67 ^{bc}	68.97 ^c	81.21 ^{ab}	75.77 ^{bc}	84.69 ^a	81.78 ^{ab}	1.54
ILE	76.55	78.98	78.01	76.93	76.53	80.51	0.70
LEU	79.17 ^b	81.40 ^{ab}	82.39 ^a	82.49 ^a	83.48 ^a	84.00 ^a	0.47
PHE	79.00 ^{bcd}	86.18 ^a	81.76 ^{abc}	74.58 ^d	84.65 ^{ab}	78.20 ^{cd}	1.25
HIS	77.46 ^b	75.82 ^b	79.72 ^{ab}	83.50 ^a	83.56 ^a	82.80 ^a	0.82
LYS	76.05 ^c	80.38 ^b	82.30 ^b	85.60 ^a	85.12 ^a	85.68 ^a	0.79
ARG	83.68 ^d	89.45 ^{ab}	86.78 ^c	90.83 ^a	87.53 ^{bc}	91.33 ^a	0.62
EAA :	77.69 ^d	78.72 ^{cd}	80.56 ^{bc}	81.47 ^{ab}	83.38 ^a	83.43 ^a	0.53
ASP	80.41 ^b	78.82 ^b	80.24 ^b	81.96 ^{ab}	81.69 ^b	85.30 ^a	0.63
SER	82.47 ^{bc}	80.31 ^c	83.35 ^b	86.15 ^a	84.10 ^{ab}	86.66 ^a	0.53
GLU	84.56 ^{bc}	83.60 ^c	85.57 ^{bc}	86.76 ^{ab}	86.11 ^{ab}	88.06 ^a	0.38
PRO	81.33 ^{bc}	80.61 ^{bc}	79.50 ^c	87.98 ^a	87.98 ^a	86.51 ^{ab}	1.13
GLY	72.84 ^b	71.82 ^b	74.94 ^b	79.64 ^a	79.15 ^a	79.51 ^a	0.82
ALA	67.74 ^b	69.67 ^b	75.33 ^a	78.64 ^a	76.05 ^a	76.15 ^a	0.94
TYR	68.75	75.01	78.12	68.84	76.34	66.74	2.61
NEAA :	76.91 ^b	77.12 ^b	79.58 ^{ab}	81.28 ^a	81.42 ^a	81.64 ^a	0.57
Total	78.14 ^c	78.12 ^c	80.13 ^b	81.45 ^{ab}	82.63 ^a	82.49 ^a	0.45

¹ Pooled standard error, n=24.

^{a,b,c,d} Means in the same row with different superscript are significantly different at p < 0.05.

IMPLICATION

Based on the results of this study, the lysine requirement for the pigs weighing 6 to 10 kg appears to be higher than the NRC (1988) estimates and this study clearly showed that the accurate nutrient requirement is extremely important in reducing pollutant excretion.

Though this study was based on the assumption that Illinois ideal amino acid pattern can be applied to the all stages of growth of pig, since there are some reports that Illinois ideal amino acid pattern can not be applied to the different stages of the growth of pig, more studies are needed to set accurate amino acid requirement for the young pigs.

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