Optimal Lysine:DE Ratio for Growing Pigs of Different Sexes[a]

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ABSTRACT : This study was conducted to evaluate changes in the lysine to digestible energy (DE) ratio on performance, apparent ileal and fecal nutrient digestibilities as well as blood urea nitrogen (BUN), and to estimate optimal lysine:DE ratios for growing pigs of different sexes. A total of 150 pigs ((Landrace×Yorkshire)×Duroc, 16.78 kg average body weight, 75 barrows and 75 gilts) was randomly allotted into a 2×3 (sex by diet) factorial design. Three diets were formulated to contain a crude protein level of 19%, a DE level of 3.5 Mcal/kg with three lysine:DE ratios of 3.2 (low), 3.5 (middle) and 3.8 (high) g lysine/Mcal DE per kg diet for both barrows and gilts throughout the study. With increasing dietary lysine:DE ratio, the average daily gain (ADG) of barrows decreased but there was no significant difference among treatments ($p>0.05$). However, ADG was significantly higher in gilts fed the diet containing the high lysine:DE ratio ($p<0.05$), followed by the middle and low lysine:DE ratio dietary groups. No significant effects of lysine:DE ratios on feed intake (ADFI) and feed conversion (F/G) were observed for barrows and gilts during overall period ($p>0.05$), while the optimal F/G was found in barrows fed diets of low and in gilts fed high lysine:DE ratio. Blood urea nitrogen had a positive relationship with growth rate. The results showed that the optimal lysine:DE ratios were 3.2 and 3.8 g lysine/Mcal DE per kg diet for barrows and gilts of 16 to 57 kg body weight, respectively. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 1 : 31-38*)

Key Words : Lysine:DE Ratio, Performance, Ileal Nutrient Digestibility, Blood Urea Nitrogen, Growing Pig

INTRODUCTION

Usually, lysine is regarded as a reference for other indispensable amino acids due to the fact that lysine is always the first limiting amino acid in cereal-soybean meal diets for growing pigs (Southern, 1991; Kerr, 1993). Furthermore, lysine plays an important role in protein accretion in relation to growth performance. There are a large number of estimates of lysine requirements. However, there is considerable variation in the estimates due to factors such as genotype (Stahly et al., 1991), gender (Stuewe et al., 1992) and balances with other limiting amino acids (Schutte et al., 1985; Yen et al., 1986a, b; Wang et al., 1989) or non-limiting amino acids (Henry et al., 1992).

The concept of expressing amino acid requirements relative to energy concentrations is valid only if the relationship between energy intake and rate of protein deposition is linear (SCA, 1987). Linear, linear/plateau and curvilinear relationships have been postulated (Williams, 1980; ARC, 1981), but the relationship seems to be linear for pigs weighing less than 50 kg (Close and Mount, 1976; Campbell and Dunkin, 1983; Campbell et al., 1983, 1985a, b).

The lysine:DE ratio for growing and finishing pigs were increased by ARC (1981) from 0.64 and 0.51 g/MJ (2.68 and 2.13 g/Mcal) (ARC, 1967) to 0.84 and 0.60 g/MJ (3.51 and 2.51 g/Mcal), respectively. Van Lunen et al. (1996) reported that the optimal lysine/DE ratio for the genotype tested from 25 to 90 kg live weight was in the order of 0.95 to 1.0 g/MJ (4.0~4.2 g/Mcal). Other studies suggested that the maximum performance could be achieved when pigs were provided diets with lysine:DE ratio of 2.9 to 3.0 g lysine/Mcal DE per kg diet (Batterham et al., 1985; Giles et al., 1986, 1987; Chiba et al., 1991; Gatel and Grosjean, 1992; Lawrence et al., 1994). Jung et al. (1999) showed that the optimal daily gain and digestibilities of amino acids occurred in pigs fed diets with lysine:DE ratio of 3.5 g lysine/Mcal DE per kg diet compared with another two groups containing 2.9 and 3.2 lysine:DE ratios, but feed intake was not affected by lysine:DE ratio.

Due to the different hormones excreted in females and males, there should be a certain relationship between the optimal lysine:DE ratio and the sex of pig. Boars grow faster and deposit more protein than gilts and barrows (Campbell and Taverner, 1988; Friesen et al., 1994). Williams (1984) reported that developing boars required 0.15 to 0.25% more dietary lysine than gilts having a similar body weight. Likewise, Bae et al. (1998) showed that the optimal growth rates occurred at 1.10% lysine level for gilts and 1.25% lysine level for boars. The estimation of

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the optimal lysine:DE ratio shows great variation by different researchers. Thus, the objectives of this study were to determine the effects of lysine:DE ratio on the performance, apparent fecal and ileal digestibilities of nutrients and blood urea nitrogen (BUN) for growing gilts and barrows.

MATERIALS AND METHODS

Three way crossbreed ((Landrace × Yorkshire) × Duroc) pigs averaging 16.78 ± 0.31 kg body weight were used in this trial. Seventy-five barrows and seventy-five gilts were randomly alloted into 6 treatments with 5 replications each treatment by a 2 × 3 factorial arrangement. Three diets were formulated to meet or exceed nutrient requirements for growing pigs recommended by NRC (1998), with a crude protein level of 19%, a DE level of 3.5 Mcal/kg, and three lysine:DE ratios of 3.2, 3.5 and 3.8 g lysine/Mcal DE per kg diet for both barrows and gilts during the entire period of experiment (table 1).

Barrows and gilts were penned separately in a naturally ventilated growing unit. In this unit the floor was partially slotted. Pigs were allowed *ad libitum* access to diets from self-feeders and to water from nipple waterers. Pigs were weighed and feed intake was recorded at d 14, d 35 and d 49.

Blood samples were collected from five pigs per treatment and three times during the entire period. Pigs were bled via venipuncture from the jugular vein 4 h after feeding. Blood samples were obtained into tubes treated with heparin as an anticoagulant. They were centrifuged (Hanil, Korea) at 3,000 rpm for 15 minutes, and then plasma was carefully removed into plastic vials and stored at -20℃ for blood urea nitrogen (BUN) analysis.

Nine barrows and nine gilts (16 kg BW) cannulated at the terminal ileum by surgical operation were penned in individual metabolic cages to determine apparent fecal and ileal digestibilities of nutrients. Cr_2O_3 was added into the diets at a rate of 0.25% to provide an indigestible marker. The cannula and surgical procedures used in this study were conducted according to the methods suggested by Walker et al. (1986). Pigs were given four days of adjustment prior to allowing access to the test diets. On the fifth, sixth and seventh day, fresh feces and digesta samples were collected. Fecal samples were dried in an air-forced drying oven at 60℃ for 72 hours, while digesta samples were frozen immediately in a refrigerator at -4℃ before freeze drying (Ilsin Engineering Co., Korea); the feces and digesta samples were ground with a 1 mm mesh Wiley mill for chemical analysis.

Proximate analysis of experimental diets, digesta, fecal samples was carried out according to AOAC (1990) methods. Chromium and calcium were determined by an atomic absorption spectrophotometer (Shimadzu, AA625, Japan), and phosphorus was analysed using a UV-vis. Spectrophotometer (Hitach, U-1100, Japan). Gross energy value of diets, digesta and feces were measured using an Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL). Total blood urea concentration was analyzed by blood analyzer (Ciba-Corning model, Express Plus, Ciba Corning Diagnostics Co.). Amino acid contents were determined, following acid hydrolysis with 6N HCl at 110℃ for 16 hours (Mason, 1984), using amino acid analyzer (Biochrom 20, Pharmacia Biotech., England).

Table 1. Formula and chemical composition of diets

Lysine:DE ratio	3.2	3.5	3.8
Ingredients (%) :			
Corn, yellow	62.81	62.55	62.27
Soybean meal	31.01	30.37	29.83
Tallow	2.55	2.94	3.30
Limestone	0.99	0.99	1.00
Tricalcium hosphate	1.49	1.49	1.50
Salt	0.30	0.30	0.30
L-lysine	0.10	0.27	0.42
Methionine	0.19	0.36	0.49
Threonine	0.06	0.23	0.39
Choline chloride	0.05	0.05	0.05
Mineral mixture[1]	0.20	0.20	0.20
Vitamin mixture[2]	0.25	0.25	0.25
Total	100.00	100.00	100.00
Chemical composition[3] :			
Digestible energy	3.50	3.50	3.50
(Mcal/kg)	(3.50)[4]	(3.46)	(3.54)
Crude protein (%)	19.00	19.00	19.00
	(20.09)	(19.72)	(20.12)
Lysine (%)[a]	1.12	1.23	1.33
	(1.10)	(1.20)	(1.28)
Methionine+	0.73	0.80	0.86
cystine (%)[a]	(0.81)	(0.85)	(0.92)
Threonine (%)[a]	0.75	0.82	0.89
	(0.82)	(0.95)	(0.99)
Calcium (%)	0.80	0.80	0.80
	(0.75)	(0.75)	(0.76)
Phosphorus (%)	0.65	0.65	0.65
	(0.66)	(0.64)	(0.64)

[a] Patterned after ideal amino acid ratio of Baker and Chung (1992).
[1] Supplied per kg diet : Mn, 60 mg; Zn, 150 mg; Fe, 100 mg; Cu, 200 mg; Co, 0.5 mg; I, 1 mg; Se, 0.3 mg.
[2] Supplied per kg diet : vitamin A, 8,000 IU; vitamin D_3, 2,500 IU; vitamin E, 30 IU; vitamin K, 3 mg, thiamin, 1.5 kg; riboflavin, 10 mg; vitamin B_6, 2 mg; vitamin B_{12}, 40 μg; pantothenic acid, 30 mg; niacin, 60 mg; biotin, 0.1 mg; folic acid 0.5 mg.
[3] Calculated value.
[4] Chemically determined values.

Table 2. Effects of lysine:DE ratios on growth performance of growing pigs (16-57 kg)

Sex	Barrows			Gilts			Mean	SE[1]
Lysine:DE ratio	3.2	3.5	3.8	3.2	3.5	3.8		
ADG (kg/day)	0.850[a]	0.836[ab]	0.821[ab]	0.787[c]	0.813[bc]	0.825[ab]	0.822	9.09
ADFI (kg/day)	1.66	1.64	1.71	1.64	1.68	1.66	1.67	0.03
F/G	1.95	1.96	2.08	2.08	2.07	2.01	2.04	0.02
Interactions	ADG			ADFI			F/G	
Sex	0.0034			NS			NS	
Lys:DE ratio	NS[2]			NS			NS	
Sex × Ratio	0.0111			NS			NS	

[1] Pooled standard error. [2] No significant difference.
[a,b,c] Values with different superscripts within the same row are significantly different ($p<0.05$).
Abbreviations : ADG, average daily gain ; ADFI, average daily feed intake ; F/G, feed/gain.

Statistical analysis was carried out by comparing means using Duncan's multiple range (Duncan, 1955) test, by the General Linear Model (GLM) Procedure of SAS (1985) package program. Lysine:DE ratio and sex were used as main effects and their interaction was also examined.

RESULTS AND DISCUSSION

1. Growth performance

Effects of dietary lysine:DE ratio on growth performance are presented in table 2. Results showed that average daily gain (ADG) of barrows tended to decline with increasing ratio of lysine:DE, but no significant effects were observed ($p>0.05$). In contrast, growth rate was higher in gilts fed the diet containing the high lysine:DE ratio, followed by the middle lysine:DE ratio and low lysine:DE ratio, and the change in average daily gain (ADG) was significant between gilts in the high lysine:DE ratio group and the low lysine:DE ratio group ($p<0.05$). No variation in average daily feed intake (ADFI) and feed/gain (F/G) were found in either barrows or gilts ($p>0.05$). There was no interaction in ADFI and F/G, while ADG was influenced by sex ($p=0.0034$) and sex × lysine:DE ratio ($p=0.0111$). The best feed/gain (F/G) were obtained in the diets with low and high lysine:DE ratios for barrows and gilts, respectively.

In this study, results showed that the optimum lysine:DE ratio for growth of barrows was 3.2 g lysine/Mcal DE. This result is similar to earlier observations (Campbell et al., 1988a; Giles et al., 1986; Yen et al., 1986a, b; Rao and McCraken, 1990), but slightly higher than the estimate of lysine:DE ratio suggested by NRC (1998) for 20 to 50 kg pigs (2.8 g lysine/Mcal DE). Campbell et al. (1985a) indicated that a lysine concentration of 3.39 g lysine/Mcal DE was required to maximize protein deposition in boars weighing 20 to 45 kg. For gilts, the optimal lysine:DE ratio was determined at 3.8 g lysine/Mcal DE per kg diet. This result exceeded the previous estimates and NRC's recommendation (1998) and it may be said that this higher requirement was caused by improved genetic potential, feeding strategy and other conditions. The ARC (1981) suggested that growing pigs need a minimum of lysine:DE ratio of 3.51 g lysine/Mcal DE for maximal weight gain. Recently, Jung *et al.* (1999) also reported that optimum growth could be achieved when lysine:DE ratio was over 3.5 g lysine/Mcal DE per kg diet for growing pigs.

Cromwell et al. (1993) demonstrated that the differences in amino acid requirements between barrows and gilts resulted from the fact that gilts had a greater accretion rate of lean tissue than barrows. Neither average daily feed intake (ADFI) nor feed/gain (F/G) was significantly affected by sex of pig but had a treatment effect with the fastest growing pigs having the best feed conversion rate as reported by Van Lunen (1996). According to this result, it could be concluded that the optimal lysine:DE ratio was higher for gilts than for barrows.

2. Apparent fecal digestibilities of nutrients

The effects of the three different lysine:DE ratios on fecal digestibilities of nutrients of growing pigs are shown in table 3. Fecal digestibilities of proximate nutrients showed opposite trends for barrows and gilts. For barrows, digestibilities of gross energy, dry matter, crude protein, crude fat, crude ash and phosphorus (P) increased as lysine:DE ratio decreased. With gilts, in contrast, digestibilities of the nutrients increased with increasing lysine:DE ratio. However, digestibility of Ca showed a different trend compared with those of other nutrients for barrows and gilts. Proximate nutrient digestibilities were found to be influenced only by sexes and no interactions of sex × lysine:DE ratio were found. Digestibilities of essential amino acids were significantly ($p=0.0040$) influenced by sex × lysine:DE

Table 3. Effects of lysine:DE ratios on apparent fecal digestibilities of nutrients of growing pigs

Sex	Barrows			Gilts			Mean	SE[1]
Lysine:DE ratio	3.2	3.5	3.8	3.2	3.5	3.8		
Proximate nutrients (%)								
Gross energy	72.10^{ab}	69.41^{ab}	65.62^{b}	72.71^{ab}	76.52^{a}	78.32^{a}	72.45	1.37
Dry matter	73.63^{ab}	70.65^{ab}	67.68^{b}	74.16^{ab}	77.78^{a}	79.27^{a}	73.86	1.30
Crude protein	74.36^{ab}	68.35^{ab}	65.06^{b}	74.28^{ab}	77.76^{a}	78.75^{a}	73.09	1.69
Crude fat	82.48^{a}	79.66^{ab}	72.15^{b}	83.87^{a}	85.42^{a}	83.19^{a}	81.13	1.35
Crude ash	61.22^{ab}	54.75^{b}	51.59^{b}	59.33^{ab}	67.04^{a}	68.39^{a}	60.39	1.82
Calcium	55.06^{b}	57.99^{ab}	59.37^{ab}	67.22^{a}	58.84^{ab}	65.62^{a}	60.68	1.65
Phosphorus	66.84^{abc}	61.41^{bc}	58.20^{c}	67.21^{abc}	72.23^{ab}	72.58^{a}	66.41	1.65
Amino acids (%)								
THR	71.89^{abc}	64.59^{c}	64.64^{c}	66.66^{bc}	81.34^{ab}	83.14^{a}	72.05	2.74
VAL	72.70^{ab}	60.66^{b}	57.49^{b}	73.24^{ab}	78.65^{a}	80.21^{a}	70.50	3.01
MET	75.58^{a}	62.49^{ab}	48.46^{b}	57.69^{ab}	71.78^{a}	75.01^{a}	65.17	3.18
ILE	74.90^{ab}	66.94^{ab}	62.44^{b}	67.62^{ab}	78.45^{a}	79.25^{a}	71.60	2.38
LEU	74.18^{abc}	66.56^{bc}	61.33^{c}	72.40^{abc}	78.64^{ab}	82.06^{a}	72.53	2.47
PHE	76.31^{ab}	73.01^{ab}	68.63^{b}	70.63^{ab}	79.64^{ab}	81.29^{a}	74.92	1.94
HIS	78.90^{abc}	80.14^{ab}	74.74^{bc}	69.70^{c}	87.54^{a}	88.19^{a}	79.87	1.82
LYS	77.42^{ab}	61.55^{c}	71.34^{abc}	65.76^{bc}	83.36^{a}	78.39^{a}	72.97	2.32
ARG	85.46	77.49	70.74	75.21	81.58	75.37	77.64	2.94
EAA	$\mathbf{76.37^{ab}}$	$\mathbf{68.16^{ab}}$	$\mathbf{64.42^{b}}$	$\mathbf{68.77^{ab}}$	$\mathbf{80.11^{a}}$	$\mathbf{80.32^{a}}$	**73.03**	**2.25**
ASP	84.43^{ab}	70.44^{bc}	67.85^{c}	82.47^{ab}	83.75^{ab}	87.66^{a}	79.43	2.46
SER	76.55^{abc}	71.46^{bc}	71.09^{c}	75.82^{abc}	85.10^{ab}	88.09^{a}	78.02	2.28
GLU	81.54^{abc}	77.56^{c}	79.87^{bc}	80.57^{abc}	89.52^{ab}	91.30^{a}	83.39	1.89
PRO	83.42^{ab}	77.88^{b}	78.69^{b}	85.27^{ab}	88.72^{a}	88.16^{a}	83.68	1.51
GLY	77.54^{ab}	66.91^{b}	65.42^{b}	74.52^{ab}	82.66^{a}	84.92^{a}	75.30	2.59
ALA	71.80^{ab}	56.90^{b}	59.48^{b}	70.40^{ab}	79.34^{a}	79.10^{a}	69.50	3.17
TYR	72.72^{a}	71.74^{a}	52.68^{b}	61.71^{b}	78.33^{a}	76.62^{a}	68.97	2.27
NEAA	$\mathbf{78.28^{ab}}$	$\mathbf{70.39^{b}}$	$\mathbf{67.87^{b}}$	$\mathbf{75.82^{ab}}$	$\mathbf{83.92^{a}}$	$\mathbf{85.13^{a}}$	**76.90**	**2.16**
TOTAL	**77.21**	**69.28**	**66.14**	**71.86**	**81.78**	**83.23**	**74.72**	**2.19**

Interactions	GE	DM	CP	FAT	ASH	CA	P
Sex	0.0091	0.0106	0.0193	0.0177	0.0067	0.0161	0.0073
Lys:DE ratio	NS[2]	NS	NS	NS	NS	NS	NS
Sex × Ratio	NS	NS	NS	NS	0.0456	NS	NS

Interactions	THR	VAL	MET	ILE	LEU	PHE	HIS	LYS	ARG	EAA
Sex	0.0275	0.0066	NS	NS	0.0122	NS	NS	NS	NS	NS
Lys:DE ratio	NS	NS	NS	NS	NS	NS	0.0137	NS	NS	NS
Sex × Ratio	0NS	NS	0.0072	0.0265	NS	NS	0.0053	NS	NS	0.0040

Interactions	ASP	SER	GLU	PRO	GLY	ALA	TYR	NEAA	TAA
Sex	0.0119	0.0111	0.0141	0.0049	0.0088	0.0116	0.0252	0.0083	0.0023
Lys:DE ratio	NS	NS	NS	NS	NS	NS	0.0377	NS	NS
Sex × Ratio	NS	NS	NS	NS	0.0487	NS	0.0002	NS	0.0258

[1] Pooled standard error. [2] No significant difference.

[a,b,c] Values with different superscripts within the same row are significantly different ($p<0.05$).

Abbreviations : THR, threonine; VAL, valine; MET, methionine; ILE, isoleucine; LEU, leucine; PHE, phenylalanine; HIS, histidine; LYS, lysine; ARG, arginine; ASP, arparagine; SER, serine; GLU, glutamine; PRO, proline; GLY, glycine ALA, alanine; TYR, tyrosine.

ratio.

Apparent fecal digestibilities of all amino acids tested for barrows were significantly affected by lysine:DE ratios except for arginine ($p<0.05$). However, mean values for digestibilities of the essential amino acids (EAA), non-essential amino acids (NEAA) and total amino acids decreased with increasing lysine:DE ratio in the diet. For gilts, there was an opposite trend in amino acid digestibilities compared with barrows. The results demonstrated that a well balanced diet with accurate lysine:DE ratio should be fed to the animal to improve feed utilization and also to reduce

Table 4. Effects of lysine:DE ratios on apparent ileal digestibilities of nutrients of growing pigs

Sex	Barrows			Gilts			Mean	SE[1]
Lysine:DE ratio	3.2	3.5	3.8	3.2	3.5	3.8		
Proximate nutrients (%)								
Gross energy	68.44^{ab}	68.78^{ab}	68.14^{ab}	61.44^{b}	72.30^{a}	74.86^{a}	68.99	1.23
Dry matter	67.14^{ab}	66.64^{ab}	65.83^{ab}	60.08^{b}	70.96^{a}	74.35^{a}	67.50	1.29
Crude protein	73.39^{ab}	71.51^{ab}	74.29^{ab}	68.19^{b}	77.15^{ab}	79.02^{a}	73.93	1.20
Crude fat	85.98	87.16	85.99	84.24	89.50	88.10	86.83	1.66
Crude ash	67.06^{ab}	60.16^{bc}	60.75^{bc}	54.24^{c}	64.71^{ab}	72.99^{a}	63.32	1.57
Calcium	85.58^{b}	84.68^{b}	86.05^{b}	85.64^{b}	86.43^{b}	90.66^{a}	86.51	0.49
Phosphorus	61.84^{b}	52.34^{cd}	54.70^{cd}	49.18^{d}	57.58^{bc}	71.12^{a}	57.79	1.67
Amino acids (%)								
THR	78.66	80.21	77.28	72.42	81.96	82.85	78.91	0.85
VAL	74.71^{ab}	71.98^{ab}	61.23^{c}	69.07^{bc}	67.26^{bc}	79.21^{a}	70.57	1.06
MET	86.97^{a}	76.48^{abc}	66.73^{bc}	67.14^{bc}	62.70^{c}	83.31^{ab}	74.09	1.10
ILE	85.02^{a}	79.42^{ab}	73.62^{ab}	71.23^{b}	74.61^{ab}	84.21^{a}	78.02	0.36
LEU	82.91^{ab}	82.11^{ab}	76.23^{b}	77.35^{b}	78.85^{ab}	85.56^{a}	80.50	0.98
PHE	84.12^{ab}	81.01^{ab}	68.89^{c}	74.24^{bc}	75.28^{bc}	86.56^{a}	78.35	2.24
HIS	79.93^{ab}	84.91^{a}	77.13^{ab}	67.83^{b}	83.00^{a}	87.09^{a}	79.98	1.06
LYS	81.04	80.07	75.03	74.33	79.63	81.31	78.57	1.36
ARG	82.19	77.42	62.16	67.81	69.16	71.79	71.77	0.93
EAA	**81.73**	**79.43**	**70.92**	**71.27**	**74.72**	**82.45**	**76.75**	**1.59**
ASP	88.11^{a}	86.79^{a}	80.20^{b}	85.91^{ab}	84.74^{ab}	86.65^{a}	85.40	3.19
SER	83.07	84.79	81.35	77.91	85.11	86.44	83.11	2.80
GLU	86.72	89.52	87.59	85.00	90.41	91.93	88.53	1.72
PRO	81.76^{ab}	84.76^{ab}	76.81^{b}	79.16^{ab}	84.88^{ab}	86.31^{a}	82.28	1.02
GLY	82.37^{ab}	80.63^{ab}	75.23^{ab}	73.41^{b}	81.50^{ab}	84.22^{a}	79.56	1.71
ALA	83.28^{a}	80.83^{ab}	75.19^{b}	76.72^{ab}	80.05^{ab}	82.83^{a}	79.69	1.88
TYR	77.03^{ab}	74.81^{ab}	66.09^{ab}	68.00^{ab}	62.24^{b}	80.99^{a}	71.53	1.49
NEAA	**83.19**	**83.05**	**77.50**	**78.01**	**81.28**	**85.62**	**81.44**	**1.60**
TOTAL	**82.37**	**81.02**	**74.21**	**74.22**	**77.59**	**83.84**	**78.80**	**1.34**

Interactions	GE	DM	CP	FAT	ASH	CA	P
Sex	NS[2]	NS	NS	NS	NS	NS	NS
Lys:DE ratio	0.0432	NS	NS	NS	NS	0.0009	0.0022
Sex × Ratio	0.0399	0.0238	NS	NS	0.0014	NS	0.0001

Interactions	THR	VAL	MET	ILE	LEU	PHE	HIS	LYS	ARG	EAA
Sex	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lys:DE ratio	NS	0.0066	0.0454	NS	0.0300	0.0075	0.0242	NS	NS	NS
Sex × Ratio	NS	NS	NS	NS	NS	0.0364	NS	NS	NS	NS

Interactions	ASP	SER	GLU	PRO	GLY	ALA	TYR	NEAA	TAA
Sex	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lys:DE ratio	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sex × Ratio	NS	NS	NS	NS	NS	0.0420	NS	NS	NS

[1] Pooled standard error. [2] No significant difference.

[a,b,c] Values with different superscripts within the same row are significantly different ($p<0.05$).

Abbreviations : See table 3.

the environmental problems caused by the animal. In this study, apparent fecal digestibilities of proximate nutrients and amino acids were higher in low (3.2) and high (3.8) lysine:DE ratio in barrows and gilts respectively. These results are in agreement with the growth performances.

3. Apparent ileal digestibilities of nutrients

For barrows, ileal digestibilities of nutrients were higher in groups fed the diet with the low lysine:DE ratio although no significant differences were observed ($p>0.05$) except for phosphorus (table 4). Barrows showed a significantly higher ileal digestibility of

Table 5. Effect of lysine:DE ratios on blood urea nitrogen of growing pigs*

Sex	Barrows			Gilts			Mean	SE[1]
Lysine:DE ratio	3.2	3.5	3.8	3.2	3.5	3.8		
D 14	13.06	13.69	14.22	12.50	14.30	13.63	13.57	0.41
D 28	14.50	15.38	16.74	15.68	15.57	14.61	15.41	0.49
D 42	16.85[b]	21.89[a]	19.65[ab]	21.37[a]	18.67[ab]	18.39[ab]	19.47	0.57
Total mean	**14.80**	**16.99**	**16.87**	**16.62**	**16.18**	**15.54**	**16.17**	**0.60**

Interactions	D 14	D 28	D 42	Total
Sex	NS[2]	NS	NS	NS
Lys:DE ratio	NS	NS	NS	NS
Sex×Ratio	NS	0.0428	NS	0.0098

* Corrected BUN based on mean BUN before treatment as a covariance.
[1] Pooled standard error. [2] No significant difference.
[a,b] Values with different superscripts within the same row are significantly different ($p<0.05$).

phosphorus when a low lysine:DE ratio diet was provided compared with those in the middle and high lysine:DE ratio dietary groups ($p<0.05$). For gilts, ileal digestibilities of gross energy, dry matter, crude protein, calcium and phosphorus were significantly higher in the low lysine:DE ratio dietary treatment ($p<0.05$). Differences in ileal digestibilities of crude fat and crude ash were not significantly related to lysine:DE ratio ($p>0.05$). According to the interaction analyses gross energy, dry matter, crude ash and phosphorus were significantly influenced, however, no interaction was found in most of the amino acids except for phenylalanine and alanine.

Average values of essential amino acid (EAA), non-essential amino acid (NEAA) and total amino acids ileal digestibilities were not significantly influenced by dietary treatments. However, in barrows, there was a trend for these to decrease as lysine:DE ratio increased in the diets. In contrast, a reverse tendency was found in gilts. For barrows, apparent ileal digestibilities of valine, methionine, phenylalanine, aspartic acid and alanine were significantly higher in the high lysine:DE ratio group, followed by middle lysine:DE ratio and low lysine:DE ratio groups ($p<0.05$). For gilts, significantly higher ileal digestibilities of valine, methionine, leucine, phenylalanine, histidine, glycine and alanine were observed in pigs that were supplied with diets with a high lysine:DE ratio ($p<0.05$).

The data suggested that the lysine:DE ratio of 3.2 g lysine/Mcal DE was sufficient for 16 to 57 kg barrows. However, for gilts in the same growth stages, a higher lysine:DE ratio up to 3.8 g lysine/Mcal DE should be contained in the diets to optimize the utilization of nutrients.

4. Blood urea nitrogen

Effects of lysine:DE ratio on BUN of barrows and gilts are presented in table 5. For barrows in each and over all periods, the lowest BUN concentration was observed in the pigs fed the diet with low lysine:DE ratio, and especially at d 42 it was significantly lower than that in middle lysine:DE ratio dietary treatment groups ($p<0.05$). Among two groups with middle and high lysine:DE ratio, no significant difference was observed during this period ($p>0.05$). As for gilts, the differences in BUN were not significant among three different lysine:DE ratio regardless of periods ($p>0.05$). However, there was a trend that BUN was reduced with increasing lysine:DE ratio. Over all periods, the minimum BUN concentration was associated with the high lysine:DE ratio diet for gilts. There was no interrelation with BUN between sexes. However, BUN concentration on day 28, the sex×lysine:DE ratio interaction was found to be p=0.0428.

Yi et al. (1998) showed that the concentration of BUN could respond to the balance state among amino acids or protein in the body accurately and immediately. Dietary imbalance due to deficiency or excess of some indispensable amino acid to other nutrients would cause a sharp rise in BUN. This can be explained as an excess or deficiency of one amino acid may limiting the utilization of other amino acids. For a well-balanced diet, BUN is likely to be low. Tegegne et al. (1995) found that there was a significant negative correlation between lean tissue accretion and BUN concentration. Likewise, some experiments (Guan and Li, 1994) further demonstrated that there was a significant negative interrelation between BUN and lean tissue increment or body weight gain.

Thus, based on the results of this experiment, 3.2 and 3.8 appeared to be the optimum lysine:DE ratios for barrows and gilts in the range of 16-57 kg body weight, respectively. The current estimate of National Research Council (1998), approximately 2.8 g lysine/Mcal DE per kg diet, seems to be somewhat low for barrows and gilts. It was suggested that gilts required a higher dietary lysine:DE ratio than do barrows to maximize growth rate and feed utilization.

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