Determination of Optimal Dietary Sulfur Amino Acids Ratio Relative to Lysine for Growing Barrows and Gilts**

W. H. Chang, J. D. Kim[2], S. W. Kim*, Z. N. Xuan, Y. Y. Kim, I. K. Paik[3] and In K. Han[1]
School of Agricultural Biotechnology, Seoul National University, Suweon 441-744, Korea

ABSTRACT : This experiment was conducted to investigate the effects of dietary SAA (sulfur-containing amino acids) on growth performance, nutrient digestibility and blood urea nitrogen (BUN) content, and to determine the optimal SAA:lysine ratio for growing barrows and gilts. A total of 150 pigs (75 barrows and 75 gilts, Landrace×Yorkshire×Duroc) were assigned to 6 treatments with 5 replicates of 5 pigs per pen. All pigs were fed diets containing either 1.12 (for barrows) or 1.33% (for gilts) dietary lysine with increasing SAA levels (50, 55 and 60% of dietary lysine) in a 2×3 factorial design. Throughout the whole experimental period (15 to 54 kg body weight), there was no interaction between sexes and SAA:lysine ratios on ADG, ADFI and FCR. However, increasing the SAA:lysine ratio from 50 to 60% in a diet showed a trend to increase ADG and ADFI of barrows. None of differences in nutrient digestibilities except for calcium and phosphorus were observed and gilts showed higher digestibility of calcium and phosphorus ($p<0.05$). Among dietary SAA:lysine ratios, there were no differences in apparent nutrient digestibility. Mean values of the essential amino acids (EAA), non-essential amino acids (NEAA) and total amino acids (TAA) digestibilities were higher in gilts than barrows ($p<0.01$). However, no differences in mean value of EAA, NEAA and TAA digestibilities were observed among dietary SAA:lysine ratios. Between sexes and among SAA:lysine ratios, no significant difference in BUN concentration was observed. This study demonstrated that the optimal inclusion ratio of SAA:lysine was 55% and below 50% in barrows and gilts, respectively. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 7 : 1003-1007)***

Key Words : Blood Urea Nitrogen, Apparent Nutrient Digestibility, Gilts, Growth Performance, SAA:Lysine Ratio

INTRODUCTION

There still exists uncertainty from many studies regarding the requirement of sulfur amino acids for growing pigs for sulfur amino acids. The discrepancies of sulfur amino acids requirement estimates may be ascribed to the factors such as genotype, age, lean growth potential and environmental conditions. Due to those factors, it is not easy to draw definitive conclusion the optimum requirement of dietary SAA for growing pigs. The ideal protein concept has reduced this variability because estimated requirements now are expressed relative to lysine (ARC, 1981).

There have been several results from many studies regarding the optimum SAA:lysine ratio for growing pigs and the range of three vary widely from 49 to 65% of lysine. Yen et al. (1986) suggested that the optimum ratio of SAA:lysine was 49% for the maximum ADG of the pigs. Moughan and Smith (1984) showed that the optimum ratio of SAA:lysine was 54% for the maximum growth performance. ARC (1981) suggested that optimum SAA:lysine ratio for growing pigs is 55%. The ratio of SAA:lysine for growing pigs was increased by NRC from 55% (1988) to 57% (1998). Wang and Fuller (1990) indicated that dietary SAA:lysine ratio of 61% supported the maximum growth performance for growing pigs. Baker et al. (1993) suggested the ratio of SAA to lysine was 65% and the ratio should be increased with animal weight and the associated increase of maintenance requirements. Part of this variability of estimated dietary SAA:lysine ratio is due to differences in bioavailability of the basal diets, dietary lysine levels, body weight and age of pigs used in the experiment and their genetic potential. Because there exists genetic difference in growth response between sexes, it is assumed that optimal dietary SAA:lysine ratio could be different between barrows and gilts. However, little information has been available to confirm this hypothesis, especially in growing pigs. In our previous study (Chang et al., 2000), it was concluded that the optimal dietary lysine levels for barrows and gilts were 1.12 and 1.33% of diet, respectively.

Based on these results, this study was conducted to investigate the effects of different SAA:lysine ratios on growth performance, apparent digestibility, BUN content, and to estimate optimal SAA:lysine ratios for growing barrows and gilts.

* Corresponding Author: S. W. Kim. Department of Animal Science & Food Technology, Texas Tech University, Lubbock TX 79409, USA. Tel: +1-806-742-2532, Fax: +1-806-742-2335, E-mail: sungwoo.kim@ttu.edu.
[1] Address reprint request to Dr. In K. Han. Tel: +82-2-502-0757, Fax: +82-2-502-0758, E-mail: inkhan@kornet.net.
[2] Department of Animal Sciences, University of Illinois, Urbana, IL 61801, USA.
[3] Department of Animal Science, Chung-Ang University, Korea.
** This study was partially funded by the MAF-SGRP (Ministry of Agriculture and Forestry-Special Grants Research Program) in Korea.
Received October 26, 2000; Accepted February 12, 2001

MATERIALS AND METHODS

Three way crossbred (Landrace×Yorkshire×Duroc) pigs averaging 15.06±0.38 kg BW were used. Seventy-five barrows and seventy-five gilts were randomly allotted into 6 different treatments with 5 replications of each treatment. Three diets were formulated to meet or exceed nutrient requirements for growing pigs suggested by NRC (1998), which included two lysine levels of 1.12% for barrows and 1.33% for gilts, with DE level of 3.5 Mcal/kg and three SAA:lysine ratios of 50%, 55% and 60% for both barrows and gilts during the entire period of experiment (table 1).

Barrows and gilts were penned separately in a environmentally controlled growing unit with partially slotted concrete. Pigs were allowed *ad libitum* access to diets from self-feeders and to water from nipple waterers. Body weight and feed intake were recorded at d 14, d 35 and d 49 during the overall period of experiment.

Blood samples were collected from five pigs per treatment on the 14th and 49th day of experiment. Pigs were bled via puncture from the jugular vein 4 h after feeding. Blood samples were collected into tubes treated with heparin as anticoagulant. Those samples were centrifuged (Hanil, Korea) at 3,000 rpm for 15 minutes, and then the plasma portion was carefully removed into plastic vials and stored at -4°C for BUN analysis.

Fifteen barrows and gilts (averaging 16 kg body weight) were penned in individual metabolic cages to determine apparent nutrient digestibilities of pigs. Chromic oxide (Cr_2O_3) was added into the diets at a rate of 0.25% to provide as an indigestible marker. Pigs were given a four day of convalescence and adjustment period prior to allowing access to the test diets with Cr_2O_3. On the fifth, sixth and seventh days, fresh fecal samples were collected. Fecal samples were dried in an air-forced drying oven at 60°C for 72 h and then ground with a 1 mm mesh Wiley mill for chemical analysis.

Proximate analysis of experimental diets and fecal samples was carried out according to AOAC (1990) method. Chromium was determined by atomic absorption spectrophotometer (Shimadzu, AA625, Japan). Gross energy value of dietary and fecal samples was 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, after acid hydrolysis of samples with 6N HCl at 110°C for 16 h (Mason, 1984), using amino acid analyzer (Biochrom 20, Pharmacia Biotech. England). Statistical analysis was carried out by comparing means using Duncan's multiple range test (Duncan, 1955), by General Linear Model (GLM) Procedure of SAS package program.

RESULTS AND DISCUSSION

Growth performance

Throughout the whole experimental period (15 to 54 kg body weight), increasing the SAA:lysine ratio from 50 to 60% in diet had tendency to increase ADG and ADFI of barrows (table 2). When gilts were fed diets containing 55% SAA:lysine ratio showed numerically higher ADG and ADFI than those fed diet containing 50 and 60% SAA:lysine ratios, but the difference was not significant.

It is unclear in this study that the SAA:lysine ratio tends to increase as body weight and age of pigs increase. However, it is assumed that the basal diets used in this experiment were not deficient in methionine or total sulfur amino acids content. The trend of the change in ADG was similar to that of ADFI. This was similar to the findings of Chung et al. (1989), Owen et al. (1995) and Loughmiller et al. (1998), who observed increased ADFI of pigs with methionine concentrations up to the estimated requirement.

There have been various results from several studies regarding the optimum SAA:lysine ratio for growing pigs and the range of this ratio varies widely between 49 and 65% (Yen et al., 1986a; Moughan and Smith, 1984; ARC, 1981; NRC, 1998; Wang and Fuller, 1990; Baker et al., 1993). Even though the result of the present experiment did not show clear response of growth performance with increasing dietary SAA:lysine ratio in both sexes, the optimum SAA:lysine ratio obtained from this present experiment was within the range of dietary SAA:lysine ratio (49 to 65% of lysine) suggested by the past several researchers. Current estimated requirements did not support the hypothesis that the ratio of SAA to lysine should increase with animal body weight and the associated increased maintenance requirements (Baker and Chung, 1992). However, the increase in optimal SAA:lysine ratio is the most prominent during the growth period of 50 to 115 kg, feed intake and maintenance requirements continue to increase but the proportional rate of lean gain declines (Loughmiller et al., 1998). Thus, the requirement of SAA for growing pigs (20 to 50 kg) should be lower than that of finishing pigs.

The results of the present study indicate that dietary SAA requirements for growing barrows and gilts are not greater than 50% of dietary lysine content when dietary lysine level is adequate for the growth potential of modern fast-growing pigs.

Apparent digestibilities of proximate nutrients and amino acids

Apparent digestibilities of nutrient were not affected by dietary SAA:lysine ratio (table 3). Gilts had greater ($p<0.05$) apparent digestibilities for calcium and phosphorus than barrows (table 3) which can be explained partly from greater requirements for calcium and phosphorus by gilts than barrows (Cataborra et al., 1982).

Table 1. Formula and chemical composition of experimental diets

Sex	Barrows			Gilts		
SAA:lysine (%) (Lysine, %)	50 (1.12)	55 (1.12)	60 (1.12)	50 (1.33)	55 (1.33)	60 (1.33)
Ingredients (%)						
Corn	60.62	60.65	60.67	0.85	60.86	60.90
Soybean meal	25.72	25.58	25.45	24.92	24.78	24.61
Wheat	4.00	4.00	4.00	4.00	4.00	4.00
Barley	3.00	3.00	3.00	3.00	3.00	3.00
Tallow	2.75	2.74	2.74	2.81	2.81	2.80
Limestone	1.32	1.32	1.32	1.32	1.32	1.32
Monocalcium phosphate	1.57	1.57	1.57	1.57	1.57	1.57
L-Lysine·HCl	0.31	0.31	0.32	0.60	0.61	0.61
DL-Methionine	0.00	0.12	0.22	0.22	0.34	0.48
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Choline chloride	0.06	0.06	0.06	0.06	0.06	0.06
Min. premix[1]	0.20	0.20	0.20	0.20	0.20	0.20
Vit. mixture[2]	0.15	0.15	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition[3]						
DE (Mcal / kg)	3.50	3.50	3.50	3.50	3.50	3.50
Crude protein (%)	17.00	17.00	17.00	17.00	17.00	17.00
Lysine (%)	1.12	1.12	1.12	1.33	1.33	1.33
Methionine+cystine (%)	0.56	0.62	0.67	0.67	0.73	0.80
Threonine (%)	0.65	0.65	0.65	0.64	0.63	0.63
Tryptophan (%)	0.23	0.23	0.23	0.23	0.23	0.23
Ca (%)	0.80	0.80	0.80	0.80	0.80	0.80
P (%)	0.65	0.65	0.65	0.65	0.65	0.65

[1] Provided the following per kilogram of diet: Se, 0.1 mg; I, 0.3 mg; Mn, 24.8 mg; Cu, 54.1 mg; Fe, 127.3 mg; Zn, 84.7 mg; Co, 0.3 mg.
[2] Provided the following per kilogram of diet: vitamin A, 8,000 IU; vitamin D_3, 1,600 IU; vitamin E, 32 IU; d-biotin, 64 μg; riboflavin, 3.2 mg; calcium pantothenic acid, 8 mg; niacin, 16 mg; vitamin B_{12}, 2 μg; vitamin K, 2.4 mg.
[3] Calculated value, dry-matter basis.

Table 2. Effects of SAA:lysine ratios on growth performance in growing pigs

Sex	Barrows			Gilts			Mean	SE[1]
SAA:lysine ratio	50	55	60	50	55	60		
ADG[2] (g/day)	762	794	808	757	769	738	771	14.7
ADFI (kg/day)	1.74	1.75	1.87	1.72	1.76	1.69	1.76	0.05
F/G	2.28	2.20	2.30	2.27	2.29	2.28	2.27	0.03

[1] Pooled standard error. [2] ADG : Average daily gain, ADFI : Average daily feed intake, F/G : Feed/gain.

Table 3. Effects of SAA:lysine ratios on apparent digestibilities of proximate nutrients (%) of growing pigs

Sex	Barrows			Gilts			Mean	SE[1]
SAA:lysine ratio	50	55	60	50	55	60		
Gross energy	67.86	73.28	69.79	76.36	71.92	76.06	67.73	1.49
Dry matter	68.19	73.20	70.43	77.24	72.22	76.87	73.02	1.31
Crude protein	59.51	68.01	63.85	70.12	66.53	70.65	66.44	1.60
Crude fat	67.67	70.53	66.44	68.97	62.04	67.24	67.15	1.85
Crude ash	46.10[b]	56.10[ab]	57.42[ab]	64.29[a]	54.16[ab]	61.35[ab]	56.57	2.08
Calcium	63.71[bc]	67.55[abc]	62.67[c]	71.85[ab]	67.79[ab]	72.83[a]	67.73	1.49
Phosphorus	38.81	44.06	45.28	53.62	51.87	55.27	48.15	2.59

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

Table 4. Effects of SAA:lysine ratios on apparent digestibilities of amino acids (%) of growing pigs

Sex	Barrows			Gilts			Mean	SE[1]
SAA:lys ratio	50	55	60	50	55	60		
THR[2]	70.97^{b}	78.11^{ab}	71.52^{b}	76.98^{ab}	86.47^{a}	87.43^{a}	78.58	2.12
VAL	74.60^{b}	90.84^{a}	83.45^{ab}	92.53^{a}	86.43^{ab}	85.10^{ab}	85.49	2.91
MET	60.05^{b}	82.36^{a}	68.62^{ab}	79.31^{a}	60.91^{b}	64.84^{ab}	69.35	3.16
CYS	40.27	44.65	41.69	50.19	40.73	73.86	43.56	3.71
ILE	56.87^{b}	76.36^{a}	71.16^{a}	85.69^{a}	78.19^{a}	81.28^{a}	74.92	3.08
LEU	69.44^{c}	82.33^{ab}	71.36^{bc}	84.37^{a}	78.79^{abc}	83.47^{a}	78.29	1.81
PHE	69.01	80.89	77.95	79.74	76.11	81.17	77.48	2.44
HIS	56.02	60.12	72.72	75.04	62.12	63.04	64.84	3.69
LYS	57.01^{b}	70.81^{ab}	67.52^{ab}	85.02^{a}	81.32^{a}	83.37^{a}	74.17	3.18
ARG	61.85	68.57	74.59	82.50	70.09	80.18	72.96	3.16
EAA	61.61^{b}	73.50^{a}	70.06^{ab}	79.14^{a}	72.12^{ab}	75.38^{a}	71.97	2.18
ASP	68.23^{b}	80.93^{a}	78.56^{a}	83.91^{a}	84.97^{a}	82.60^{a}	79.86	1.67
SER	68.05^{c}	84.91^{ab}	78.60^{b}	85.38^{ab}	86.16^{ab}	87.29^{a}	81.73	1.66
GLU	82.92^{b}	89.13^{a}	86.14^{ab}	89.84^{a}	90.98^{a}	91.25^{a}	88.38	1.05
PRO	65.26^{a}	73.75^{ab}	79.63^{a}	85.53^{a}	84.80^{a}	83.85^{a}	78.80	2.12
GLY	63.23^{c}	78.76^{ab}	71.04^{bc}	80.37^{ab}	79.52^{ab}	84.68^{a}	76.27	1.84
ALA	53.52^{c}	69.20^{ab}	59.65^{bc}	78.32^{a}	72.69^{ab}	82.30^{a}	69.28	2.67
TYR	66.02^{c}	69.20^{ab}	59.65^{bc}	78.32^{a}	72.69^{ab}	82.30^{a}	74.37	2.98
NEAA	66.75^{c}	79.38^{ab}	75.32^{b}	84.20^{a}	80.88^{ab}	83.78^{a}	78.38	1.56
TAA	64.18^{b}	76.44^{a}	72.69^{ab}	81.67^{a}	76.50a	79.58^{a}	75.18	1.78

[1] Pooled standard error.

[2] THR : Threonine, VAL : Valine, MET : Methionine, CYS : Cystine, ILE : Isoleucine, LEU : Leucine, PHE : Phenylalanine, HIS : Histidine, LYS : Lysine, ARG : Arginine, EAA : Essential amino acids, ASP : Asparagine, SER : Serine, GLU : Glutamine, PRO : Proline, GLY : Glycine, ALA : Alanine, TYR : Tyrosine, NEAA : None essential amino acids, TAA : Total amino acids.

Table 5. Effects of SAA:lysine ratios on blood urea nitrogen for growing barrows and gilts (mg/dL)

Sex	Barrows			Gilts			Mean	SE[1]
SAA:lysine ratio (%)	50	55	60	50	55	60	12.12	0.44
D 14	11.42	13.20	13.54	10.75	11.70	11.84	12.12	0.44
D 49	11.38^{b}	15.02^{a}	11.88^{b}	10.58^{b}	11.38^{b}	11.58^{b}	12.01	0.45
Total mean	11.40^{ab}	14.10^{a}	12.71^{ab}	10.66	11.54^{ab}	11.71^{ab}	12.06	0.40

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

Between barrows and gilts, mean values of the essential amino acids (EAA), non-essential amino acids (NEAA) and total amino acids (TAA) digestibilities were higher ($p<0.01$) in gilts than barrows (table 4). However, there was no differences in apparent digestibilities of EAA, NEAA and TAA observed among dietary SAA:lysine ratios (table 4). For barrows, 55% SAA:lysine ratio group showed higher digestibilities of NEAA and TAA than those of other groups. Digestibility of methionine was also higher ($p<0.05$) in 55% SAA:lysine ratio group. For gilts, 50% SAA:lysine ratio group showed higher ($p<0.05$) digestibilities of EAA, NEAA and TAA than other SAA:lysine ratio groups.

Based on these data, it is likely that dietary SAA levels required to induce maximum nutrient utilization are 55 and 50% of dietary lysine for barrows and gilts, respectively.

Blood urea nitrogen concentration

The lowest BUN concentrations were in gilts fed on diets containing SAA:lysine ratio of 50% (table 5). Between sexes and among SAA:lysine ratios, no significant differences in BUN concentration were observed.

Measurements in BUN concentration in response to altered dietary levels of amino acids have also been utilized previously to estimate amino acid requirements of growing-finishing pigs (Lewis et al., 1980; Yen et al., 1986a, b; Coma et al., 1995). Tegegne and Mugerwa (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. However, in the present study, BUN concentration was not affected by increasing dietary SAA:lysine ratios.

CONCLUSION

Based on the present result, it is likely that dietary SAA requirement for growing barrows is around 55% of lysine (1.12%) while that for growing gilts is not greater than 50% of dietary lysine content (1.33%).

REFERENCES

AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Arlington, VA.

ARC. 1981. The Nutrient Requirement of Pigs. Commonwealth Agricultural Bureaux, Slough, UK.

Baker, D. H. and T. K. Chung. 1992. Ideal protein for swine and poultry. Biokyowa Technical Review 4, Chesterfield: Nutri., Quest, Inc.

Baker, D. H., J. D. Hahn, T. K. Chung and Y. Han. 1993. Nutrition and growth: the concept and application of an ideal protein for swine growth. In: Growth of the pig (Ed. G. H. Hollis). pp. 133-139.

Catabotta, D. F., E. T. Kornegay, H. R. Thomas, T. W. Knight, D. R. Notter and H. P. Veit. 1982. Restricted energy intake and elevated calcium and phosphorus intake for gilts during growth. 1. Feedlot performance and foot and leg measurements and scores during growth. J. Anim. Sci. 54:565~575.

Chang, W. H., J. D. Kim, Z. N. Xuan, W. T. Cho, In K. Han, B. J. Chae and In K. Han. 2000. Optimal lysine:DE ratio for growing pigs of different sexes. Asian-Aus. J. Anim. Sci. 13(1):31-38.

Chung, T. K., O. A. Izquierdo, K. Hashimoto and D. H. Baker. 1989. Methionine requirement of the finishing pig. J. Anim. Sci. 67:2677~2683.

Coma, J., D. Carrion and D. R. Zimmerman. 1995. Use of plasma urea nitrogen as a rapid response criterion to determine the lysine requirement of pigs. J. Anim. Sci. 73:472~481.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Guan, W. T. and D. F. Li. 1994. Mechanism of plasma protein meal and whey meal on growth performance for weaning pigs. Shanxi Agric. University, China. A thesis for master degree. pp. 23-27.

Lewis, A. J., E. R. Peo, Jr, B. D. Moser and T. D. Crenshaw. 1980. Lysine requirement of pigs weighing 5 to 15 kg fed practical diets with and without added fat. J. Anim. Sci. 51:361~366.

Loughmiller, J. A., J. L. Nelssen, R. D. Goodband, M. D. Tokach, E. C. Titgemeyer and I. H. Kim. 1998. Influence of dietary total sulfur amino acids and methionine on growth performance and carcass characteristics of finishing gilts. J. Anim. Sci. 76:2129~2137.

Moughan, P. J. and W. C. Smith. 1984. Assessment of a balance of dietary amino acids required to maximize protein utilization in the growing pig (20~80 kg live weight). N. Z. J. Agric. Res. 30:341~347.

NRC. 1988. Nutrient Requirements of Swine (9th Ed.). National Academy Press, Washington, D. C.

NRC. 1998. Nutrient requirements of swine (10th Ed.). National Academy Press, Washington, D. C.

Owen, K. Q., R. D. Goodband, J. L. Nelssen, M. D. Tokach and S. S. Dritz. 1995. The effect of dietary methionine and its relationship to lysine on growth performance of the segregated early-weaned pig. J. Anim. Sci. 73:3666~3672.

SAS. 1985. SAS User's Guide: Statics, SAS Inst. Inc., Cary, NC.

Tegegne, A. and M. E. Mugerwa. 1995. Body growth and blood metabolite concentrations in boran and boran × friesian bulls grazed on natural pastures: Effect of dry season dietary supplementation. Ethiopian Society of Animal Production, Addis Abeba (Ethiopia). Third National Conference of the Ethiopian Society of Animal Production. pp. 13-23.

Wang, T. C. and M. F. Fuller. 1990. The effect of the plane of nutrition on the optimum dietary amino acid pattern for growing pigs. J. Anim. Sci. 50:155~164.

Yen, H. T., D. J. A. Cole and D. Lewis. 1986a. Amino acid requirements of growing pigs. 9. The response of pigs from 25~35 kg live weight to dietary ideal protein. Anim. Prod. 43:141~154.

Yen, H. T, D. J. A. Cole and D. Lewis. 1986b. Amino acid requirements of growing pigs. 8. The responses of pigs from 50 to 90 kg live weight to dietary ideal protein. Anim. Prod. 43:155~165.