Performance of Growing-Finishing Pigs Fed Sesame Meal Supplemented Diets Formulated Using Amino Acid Digestibilities Determined by the Regression Technique*

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ABSTRACT : Two experiments were conducted to determine ileal digestibilities for the amino acids contained in sesame meal using the regression technique and then applying the values obtained in a growth trial using growing-finishing pigs. For the digestibility trial, four, 20 kg crossbred (Yorkshire × Landrace × Beijing Black) barrows were fitted with a simple T-cannula in the terminal ileum. After recovery, the barrows were fed one of four experimental diets according to a 4×4 Latin Square design. The pigs were fed corn-soybean meal based diets supplemented with 0, 25, 50 or 75 percent sesame meal. For the growth trial, 210 crossbred (Yorkshire × Landrace × Henan Min) growing pigs (21.8±1.4 kg), were fed corn-soybean meal based diets supplemented with 0, 3, 6, 9, or 12% sesame meal. Three pens (7 gilts and 7 castrates) were assigned to each treatment. With the exception of arginine and phenylalanine, the digestibility coefficients for the indispensible amino acids declined as the level of sesame meal in the diet increased. There was little agreement between the amino acid digestibilities determined with the regression technique and values previously published for sesame meal determined with the direct method. Daily gain and feed conversion both declined (linear effect p=0.02 and 0.06 respectively) as the level of sesame meal in the diet increased. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 2 : 213-219*)

Key Words : Sesame Meal, Ileal Digestibility, Amino Acids, Growth Performance, Pigs

INTRODUCTION

The demand for plant protein for use in human and animal nutrition is increasing, and is likely to continue to do so, owing to an ever-increasing world population, an increase in economic development in both the developed and less industrialized countries as well as international policies which limit offshore fishing (Aherne and Kennelly, 1982). This increased demand for protein is likely to lead to increased protein scarcity and cost. It is desireable, therefore, if not essential, that all protein sources be evaluated to determine their potential for use as livestock feed.

Sesame is a minor oilseed crop that is often available in Asian countries. Total world production in 1998 was 2.6 million metric tonnes with the major producers being India, China, Myanmar and the Sudan (Mieke, 1998). Sesame is considered a crop of the tropics and subtropics, but its extension into temperate zones is possible through breeding of suitable varieties (Ravindran, 1990).

The nutrient composition of sesame meal compares favourably with that of soybean meal but varies widely depending on the variety used, the degree of decortication and the processing method employed (Ravindran, 1990). Since the digestibility of amino acids fed to swine has been shown to be affected both by fibre content (Sauer et al., 1977; den Hartog et al., 1989) and by heat treatment (Wiseman et al., 1991; Batterham, 1994), an accurate estimate of the digestibility of the amino acids in sesame meal is essential in order to fully exploit its potential for use as an ingredient in swine rations.

The apparent digestibilities of amino acids for pigs have been determined by the ileal and fecal methods (Sauer and de Lange, 1989). The ileal method is considered a more accurate estimate of amino acid availability because it measures digestibility prior to microbial degradation and synthesis of amino acids in the large intestine (Knabe et al., 1989).

The determination ileal digestibility coefficients for amino acids is usually conducted using the direct method (e.g., Knabe et al., 1989; Herkelman et al., 1992). However, a regression technique had for measuring ileal digestibility (Fan and Sauer, 1995a, b; Fan et al., 1995). Since this technique has not been applied to sesame meal, an experiment was conducted to determine the ileal digestibility of amino acids in sesame meal using the regression technique and then to apply the values obtained, in a growth trial, to determine the performance of growing-finishing pigs fed diets formulated on an ileal digestible amino acid basis.

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* This project was partially supported by the BASF Korea Ltd. and China Natural Science Foundation.
Received Jane 22, 1999; Accepted October 23, 1999

Table 1. Ingredient composition of diets fed to determine the ileal digestibility of amino acids in sesame meal (Digestibility trial)

	Basal diet	75% Basal+25% Sesame meal	50% Basal+50% Sesame meal	25% Basal+75% Sesame meal
Ingredients (% as fed)				
Corn	73.61	56.04	37.07	19.29
Soybean meal	22.14	16.04	10.55	4.11
Sesame meal	-	25.00	50.00	75.00
Limestone	0.80	-	-	-
Dicalcium phosphate	1.78	1.25	0.75	-
Salt	0.30	0.30	0.30	0.30
L-Lysine HCl	0.12	0.12	0.08	0.05
Chromic oxide	0.25	0.25	0.25	0.25
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00

[1] Supplied per kilogram of diet: 5,512 IU vitamin A; 551 IU vitamin D_3; 66 IU vitamin E; 2.2 mg vitamin K_3; 5.5 mg riboflavin; 13.8 mg pantothenic acid; 30.3 mg niacin; 551 mg choline; 27.6 ug vitamin B_{12}; 30 mg Mn; 100 mg Fe; 100 mg Zn; 10 mg Cu; 0.5 mg I; 1 mg Co; 0.3 mg Se; 50 mg olaquindox; 8 mg antioxidant.

Table 2. Chemical composition of sesame meal and the experimental diets used to determine the ileal digestibility of amino acids in sesame meal (Digestibility trial)

	Sesame meal	Basal diet	75% Basal+25% Sesame meal	50% Basal+50% Sesame meal	25% Basal+75% Sesame meal
Chemical analysis (% as fed)[1]					
Crude protein	41.37	16.01	21.68	27.13	29.54
Crude fiber	7.20	2.31	3.50	4.73	5.92
Ether extract	6.95	3.07	3.98	5.01	6.13
Calcium	1.86	0.77	0.80	1.06	1.38
Total phosphorus	1.21	0.63	0.75	0.89	0.95
Indispensible amino acids (% analyzed as fed)[1]					
Arginine	2.36	1.07	1.37	1.65	1.98
Histidine	0.79	0.44	0.51	0.59	0.68
Isoleucine	1.43	0.62	0.80	0.96	1.13
Leucine	2.52	1.45	1.69	1.97	2.16
Lysine	1.02	0.93	0.96	0.95	0.97
Methionine and cystine	1.81	0.54	0.86	1.09	1.47
Phenylalanine	1.66	0.81	1.03	1.22	1.39
Threonine	1.28	0.61	0.77	0.93	1.06
Tryptophan	0.47	0.18	0.24	0.30	0.37
Valine	1.84	0.73	0.99	1.27	1.45

[1] Each value represents the mean of an analysis conducted in duplicate.

MATERIALS AND METHODS

Digestibility trial

Four crossbred (Yorkshire × Landrace × Beijing Black) barrows, weighing 20±0.5 kg, were fitted with a simple T-cannula in the terminal ileum (12 to 15 cm anterior to the ileocecal junction). The nylon T-cannula, with a threaded 1.2 cm outside diameter tube and curved T-flange 6 cm long, were prepared at the Beijing Agricultural University Machine Shop from nylon rod stock purchased locally. A detailed description of the procedures used to install the cannulas has been published previously (Zhu et al., 1998). The pigs were allowed a 10 day recuperation period before starting the experiment during which they were fed a standard corn-soybean meal based diet.

After recovery, the barrows were fed one of four experimental diets (table 1) according to a 4×4 Latin Square design. Each test period lasted 12 days, consisting of a ten day adjustment period followed by a two day collection of ileal digesta. The basal diet was based on corn and soybean meal and was supplemented with sufficient lysine, vitamins and minerals to meet or exceed published requirements for pigs between 20 and 50 kg (NRC, 1998; table 2). For

the three test diets, increasing amounts of corn and soybean meal were removed from the diet and replaced with either 25, 50 or 75 percent sesame meal. Synthetic lysine was included in all diets to provide 0.95% total lysine. Chromic oxide (0.25%) was added as a digestibility marker.

Throughout the experiment, the barrows were individually housed in 0.5×1.5 m^2 cast iron metabolic crates equipped with a 0.25 m^3 round bottom feeder located at the front of the crate. The crates were located in an environmentally controlled barn with the temperature set at 20℃. The barrows were fed at 0800 h and 2000 h each day. Feed intake was maintained at a constant level during each experimental period. The amount fed was the amount consumed by the pig eating the least during the first 3 days of the adjustment phase. Water was added to the diets prior to feeding to form a moist, crumbly mixture and the barrows typically consumed their ration within 30 minutes of feeding.

Collection of ileal digesta started one hour after the morning feeding on day 11 of each test period. The cannula were opened and a soft rubber tube was attached to the barrel of the cannula. The opposite end of the tube was inserted into a plastic bottle surrounded by crushed ice. Digesta was collected for three 12 h periods with a 2 h break between each collection. A 200 ml aliquot from each collection was placed in a freezer and stored at -20℃. The remainder of the chyme was warmed and put back into the ileum through the cannula. At the completion of the third collection, the two frozen digesta samples were thawed and mixed with the third collection and 200 ml of the mixed sample was refrozen and stored at -20℃. Prior to analysis, the digesta was thawed, freezedried then ground through a 1 mm screen.

Growth trial

For the growth trial, 210 crossbred (Yorkshire × Landrace × Henan Min) growing pigs, weighing 21.8 ± 1.4 kg were allotted into 5 treatment groups on the basis of sex, weight and litter. The five test diets were based on corn and soybean meal and were supplemented with either 0, 3, 6, 9, or 12% sesame meal, added largely at the expense of soybean meal (tables 3 and 4). The digestibility coefficients for lysine and the sulfur containing amino acids, which were calculated based on the results of the digestibility trial for a 100% sesame meal diet, were used in the ration formulation matrix so that all diets provided equal levels of digestible lysine and the sulfur amino acids.

The experiment was partitioned into two phases. During the growing phase, lasting 42 days, the diets were formulated to provide 3.29 Mcal of digestible energy, 16% crude protein, 0.79% digestible lysine and 0.46% digestible sulfur containing amino acids (table 3). During the finishing phase, lasting 63 days, the diets were formulated to provide 3.3 Mcal of digestible energy, 15% crude protein, 0.7% digestible lysine and 0.44% digestible sulfur amino acids (table 4). All diets were provided in mash form and contained sufficient vitamins and minerals to meet or exceed NRC (1998) requirements.

All pigs were housed in groups of 14, in an environmentally controlled building containing concrete-floored, partially-slatted pens equipped with self feeders. The pigs were housed in 2.8×3.5 m^2 pens during the grower phase and 3.5×4.6 m^2 pens during the finishing phase. Three pens, containing 7 gilts and 7 castrates were assigned to each treatment. Pigs were permitted *ad libitum* access to feed and water throughout the experiment. Pigs were weighed individually at the initiation and completion of the growing and finishing phases. Feed consumption was recorded on a pen basis and used to calculate feed conversion at the completion of the trial.

Chemical analysis

Samples of all feeds were analyzed for their nitrogen, calcium and total phosphorus content using the methods of the AOAC (1990). Nitrogen was analyzed using the Kjeldahl method (AOAC method 988.05), calcium by titration with 0.1 N $KMnO_4$ (AOAC method 927.02) and total phosphorus was determined colorimetrically using a molybodovanadate reagent (AOAC method 965.17). Chromic oxide analysis was conducted according to the description provided by Christian and Coup (1954).

Samples of both digesta and diets were hydrolyzed with 6 N HCl at 110℃ for 24 h and analyzed for their amino acid content using high-performance liquid chromatography (Shimadzu LC 10 Liquid Chromograph, Kyoto, Japan). Methionine was determined using formic acid (9 parts of 88% formic acid plus 1 part 30% hydrogen peroxide) protection before acid hydrolysis. Tryptophan was determined following sodium hydroxide (4.2 N NaOH) hydrolysis (20 h at 110℃). The apparent ileal digestibility of amino acids was calculated based on the relative concentration of chromic oxide in the diet and ileal digesta.

Statistical analysis

A linear, least-squares regression analysis was conducted using SAS (1989) to produce the best-fit, linear regression equation between the apparent ileal digestibility of each amino acid (Y) and the inclusion level of sesame meal (x) using the model of $Y=bx+c$. The apparent ileal digestibility of the amino acids in sesame seed was achieved by the extrapolation of this equation to a diet where sesame meal consisted of 100% of the tested feedstuff (i.e., $x = 1$).

Table 3. Composition of diets fed to determine the effect of different levels of sesame meal on the performance of growing pigs (21.8 to 44 kg)

	Level of sesame meal (%)				
	0	3	6	9	12
Ingredients (% as fed)					
Corn	73.56	73.40	73.13	72.89	72.52
Soybean meal	21.90	19.20	16.60	14.00	11.50
Sesame meal	0.00	3.00	6.00	9.00	12.00
Limestone	0.76	0.67	0.57	0.47	0.39
Dicalcium phosphate	2.25	2.14	2.05	1.94	1.83
Salt	0.34	0.34	0.34	0.34	0.34
L-Lysine HCl	0.19	0.25	0.31	0.36	0.42
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00	1.00
Nutrient level (% analyzed as fed)					
Crude protein	15.92	16.01	15.98	16.07	16.14
Total lysine	0.93	0.91	0.94	0.93	0.91
Total sulfur amino acids	0.55	0.57	0.58	0.60	0.62
Digestible lysine	0.79	0.79	0.79	0.79	0.79
Digestible sulfur amino acids	0.46	0.46	0.46	0.46	0.46
Calcium	0.84	0.85	0.85	0.82	0.83
Total phosphorus	0.69	0.70	0.73	0.71	0.70

[1] Supplied per kilogram of diet: 5,512 IU vitamin A; 551 IU vitamin D_3; 66 IU vitamin E; 2.2 mg vitamin K_3; 5.5 mg riboflavin; 13.8 mg pantothenic acid; 30.3 mg niacin; 551 mg choline; 27.6 ug vitamin B_{12}; 30 mg Mn; 100 mg Fe; 100 mg Zn; 10 mg Cu; 0.5 mg I; 1 mg Co; 0.3 mg Se; 50 mg olaquindox; 8 mg antioxidant.

Table 4. Composition of diets fed to determine the effect of different levels of sesame meal on the performance of finishing pigs (44 to 90 kg)

	Level of sesame meal (%)				
	0	3	6	9	12
Ingredients (% as fed)					
Corn	75.98	75.63	75.45	75.46	75.09
Soybean meal	19.70	17.20	14.50	11.50	9.00
Sesame meal	0.00	3.00	6.00	9.00	12.00
Limestone	0.65	0.55	0.48	0.49	0.40
Dicalcium phosphate	2.20	2.10	1.98	1.90	1.80
Salt	0.34	0.34	0.34	0.34	0.34
L-Lysine HCl	0.13	0.18	0.25	0.31	0.37
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00	1.00
Nutrient level (% analyzed as fed)					
Crude protein	14.78	14.97	15.12	14.81	15.02
Total lysine	0.83	0.80	0.82	0.84	0.85
Total sulfur amino acids	0.52	0.54	0.56	0.57	0.60
Digestible lysine	0.70	0.70	0.70	0.70	0.70
Digestible sulfur amino acids	0.44	0.44	0.44	0.44	0.44
Calcium	0.79	0.77	0.79	0.80	0.81
Total phosphorus	0.67	0.66	0.68	0.69	0.70

[1] Supplied per kilogram of diet: 5,512 IU vitamin A; 551 IU vitamin D_3; 66 IU vitamin E; 2.2 mg vitamin K_3; 5.5 mg riboflavin; 13.8 mg pantothenic acid; 30.3 mg niacin; 551 mg choline; 27.6 ug vitamin B_{12}; 30 mg Mn; 100 mg Fe; 100 mg Zn; 10 mg Cu; 0.5 mg I; 1 mg Co; 0.3 mg Se; 50 mg olaquindox; 8 mg antioxidant.

For the growth trial, the GLM procedures of SAS (1989) were used to determine treatment effects using a one way analysis of variance. Polynomial contrasts (linear, quadratic and cubic) were used to test the effect of sesame meal level on the various parameters measured (SAS, 1989).

Table 5. Ileal amino acid digestibility (%) of diets containing various levels of sesame meal

	Basal Diet	75% Basal+25% Sesame meal	50% Basal+50% Sesame meal	25% Basal+75% Sesame meal	SEM[1]
Indispensible amino acids					
Ariginine	70.92	72.48	75.56	82.85	2.5
Histidine	80.03	76.81	78.05	68.86	0.5
Isoleucine	85.86	77.09	76.64	74.74	0.1
Leucine	82.08	78.91	80.08	77.40	0.3
Lysine	86.94	85.45	85.54	82.05	2.0
Methionine	87.34	83.98	82.59	83.47	0.9
Phenylalanine	83.22	87.65	90.30	92.11	0.8
Threonine	74.23	75.12	73.54	66.96	1.4
Tryprtophan	87.93	85.31	81.19	82.25	1.7
Valine	83.01	75.75	77.24	70.92	1.1

[1] Standard error of the mean.
[2] Each value represents the mean of the analysis from for digesta samples conducted in duplicate.

Table 6. Regression equations for th apparent ileal digestibility of amino acids in sesame meal

Amino acids	Regression equation[1]	R^2	Sesame meal digestibility
Ariginine	Y=15.55x+69.62	0.90	85.17
Histidine	Y=-12.91x+80.78	0.72	67.87
Isoleucine	Y=-10.33x+83.12	0.57	72.79
Leucine	Y=-5.11x+81.56	0.69	76.45
Lysine	Y=-5.83x+87.18	0.82	81.35
Methionine	Y=-6.00x+87.10	0.78	81.10
Phenylalanine	Y=11.73x+83.92	0.96	95.65
Threonine	Y=-9.36x+75.97	0.66	66.61
Tryprtophan	Y=-8.46x+87.34	0.80	78.88
Valine	Y=-13.91x+81.95	0.81	68.04

[1] Y=Apparent ileal digestibility of an amino acid, x=Replacement level of sesame meal.

Table 7. The apparent ileal digestibility of amino acids in sesame meal determine with the regression technique compared with previously published value determined with the direct technique

	Regression method	Heartland lysine (1995)	Rhone-poulenc (1993)	NRC (1998)
Indispensible amino acids				
Ariginine	85	94	94	94
Histidine	68	62	90	86
Isoleucine	73	82	87	85
Leucine	76	82	88	85
Lysine	81	79	79	76
Methionine	81	91	91	90
Phenylalanine	96	90	90	89
Threonine	67	84	84	78
Tryprtophan	79	-	-	85
Valine	68	85	85	84

RESULTS

The ileal digestibility of the amino acids in the diets containing graded levels of sesame meal are shown in table 5. With the exception of arginine and phenylalanine, the digestibility coefficients for all the indispensible amino acids declined as the level of sesame meal in the diet increased.

The regression equations generated from the ileal digestibility data and the digestibility coefficients obtained when the equation was extrapolated to 100% sesame meal are shown in table 6. There does not appear to be much agreement between the amino acid digestibilities determined with the regression technique and previously published values for sesame meal determined with the direct method (table 7). With the exception of lysine and phenylalanine, all of the values determined with the regression method were lower than values published using the direct technique.

The effects of including grades levels of sesame seed meal on the performance of growing-finishing pigs are shown in table 8. During the growing (22-44 kg) period, the addition of sesame meal depressed growth (linear effect p=0.03). The reduced growth rate appeared to be due, at least partially, to a reduction in feed intake at the higher levels of inclusion (linear

effect (p=0.09).

During the finishing period (44-89 kg), daily gain also declined as the level of sesame meal in the diet increased (linear effect p=0.01). However, feed intake was not affected, although feed conversion was significantly decreased (linear effect p=0.05). When performance over the entire experimental period was evaluated, daily gain and feed conversion both declined (linear effect p=0.02 and 0.06, respectively).

DISCUSSION

There was little agreement between the amino acid digestibilities determined with the regression technique and previously published amino acid digestibilities obtained for sesame meal determined with the direct method (Rhone-Poulenc, 1993; Heartland Lysine, 1995; NRC, 1998). Two possible explanations can be given for this discrepancy. Firstly, it is possible that the regression technique underestimates the digestibility of amino acids. However, previous studies have reported good agreement between apparent ileal amino acid digestibilities determined with the direct and regression methods (Fan et al., 1995; Fan and Sauer, 1995). The second possibility is that the sesame meal used in the present study differed from those previously studied.

The results of the growth trial, in which a reduction in gain and feed conversion were obtained when sesame meal was included at levels higher than 3% of the diet, contrast with previous findings of Squibb and Salazar (1951) and Gallo and Maner (1970) who reported that sesame could be substituted for soybean meal at dietary levels between 10 and 15%. In the present trial, diets were formulated to provide equal amounts of digestible lysine and sulfur containing amino acids. Despite this, the performance of pigs fed more than 3% sesame meal was inferior to that of pigs fed lower levels indicating that factors other than lysine and the sulfur containing amino acids are limiting performance.

During the grower phase, feed intake declined in a linear manner as the inclusion level of sesame meal increased. Sesame seed contains approximately 5% phytate and 35 mg/100 g oxalates (Toma et al., 1979) and these compounds have been suggested to impart a bitter taste to the meal (Aherne and Kennelly, 1985) which may partially account for the poorer performance of the sesame meal-fed pigs in the present experiment.

In poultry fed sesame meal, responses to supplemental threonine has been reported (Smith and Scott, 1965; Cuca and Sunde, 1967) and therefore threonine has been suggested to be the second limiting amino acid in sesame meal-based rations (Ravindran, 1990). Future experiments should be conducted to assess whether adjustment of diets for ileal digestible threonine will improve the performance of pigs fed sesame meal.

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Table 8. Effect of graded levels of sesame meal on performance of growing-finishing pigs

	Level of sesame meal (%)						Polynomial contrast		
	0	3	6	9	12	SEM	L	Q	C
Growing period (22-44 kg)									
Daily gain (kg)	0.55	0.55	0.53	0.51	0.49	0.06	0.03	NS	NS
Daily feed intake (kg)	1.49	1.49	1.48	1.43	1.39	0.10	0.09	NS	NS
Feed conversion	2.71	2.72	2.79	2.81	2.84	0.16	NS	NS	NS
Finishing period (44-89 kg)									
Daily gain (kg)	0.75	0.75	0.74	0.71	0.68	0.05	0.01	NS	NS
Daily feed intake (kg)	2.49	2.46	2.55	2.49	2.46	0.10	NS	NS	NS
Feed conversion	3.32	3.28	3.45	3.51	3.62	0.22	0.05	NS	NS
Entire experiment (22-89 kg)									
Daily gain (kg)	0.67	0.67	0.65	0.63	0.61	0.05	0.02	NS	NS
Daily feed intake (kg)	2.09	2.08	2.13	2.07	2.04	0.18	NS	NS	NS
Feed conversion	3.13	3.08	3.28	3.30	3.37	0.12	0.06	NS	NS

[1] Standard error of the mean.

[2] Polynomial contrasts (NS=not significant at p<0.05).

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