Nutritive Values of Chinese Peanut Meal for Growing-Finishing Pigs[a]

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ABSTRACT : Two experiments were conducted to determine the apparent ileal digestibility of the amino acids contained in peanut 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 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% peanut meal. For the growth trial, 200 crossbred (Yorkshire × Landrace × Beijing Black) growing pigs (20.9 kg) were fed corn-soybean meal diets supplemented with 0, 5, 10, 15 or 20% peanut meal. Five pens (4 gilts and 4 castrates) were assigned to each treatment. With the exception of arginine, histidine and phenylalanine, the digestibility coefficients for the indispensible amino acids declined as the level of peanut meal in the diet increased. There was a good agreement between the amino acid digestibilities for lysine, methionine, threonine and tryptophan determined using the regression technique and amino acid digestibilities previously published for peanut meal. During both the growing (21-54 kg) and finishing (54-99 kg) periods, the addition of peanut meal decreased average daily gain (p=0.01) and feed conversion in a linear manner (p<0.05). Feed intake was not significantly different among treatments. The overall results suggest that peanut meal can be used at levels up to 15% in diets fed to growing-finishing pigs provided that the diet has been balanced for digestible amino acids.
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INTRODUCTION

Cultivated varieties of the peanut (*Arachis hypogaea*) are grown extensively in tropical and subtropical regions of the world (Aherne and Kennelly, 1982) with world wide production exceeding 29 million metric tons in 1998 (USDA, 1999). Peanut meal is a readily available protein source produced as a by-product during the production of peanut oil and interest has been expressed in increasing the use of this meal in diets fed to swine (Newton et al., 1990).

For swine, the nutritive value of a protein supplement is determined to a large extent by its amino acid content. Of particular importance are the levels of lysine, threonine and the sulfur containing amino acids because these have been shown to be the most limiting amino acids in diets composed predominately of cereal grains (Sauer et al., 1977). Peanut protein is deficient in methionine, lysine and tryptophan with methionine being the first limiting amino acid (Newton et al., 1990).

Unfortunately, not all of the amino acids present in feeds are biologically available to the pig. The availability of amino acids can be reduced by incomplete digestion and absorption, by the presence of inhibitors of digestive enzyme or by heat damage (Thacker et al., 1984). Therefore, knowledge of the availability of the individual amino acids in a feed is essential in order to improve the accuracy of diet formulation.

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 of 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 has recently been proposed as an alternative method for measuring ileal digestibility (Fan and Sauer, 1995a, b; Fan et al., 1995). Since this technique has not been applied to peanut meal, an experiment was conducted to determine the ileal digestibility of amino acids in peanut 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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Table 1. Ingrediet composition of diets fed to determine the ileal digestibilty of amino acids in peanut meal when fed to growing pigs

	Basal diet	75% Basal+25% Peanut meal	50% Basal+50% Peanut meal	25% Basal+75% Peanut meal
Ingredients (%, as fed)				
Corn	71.74	53.36	34.71	16.05
Soybean meal	23.98	17.70	11.55	5.36
Peanut meal	-	25.00	50.00	75.00
Limestone	0.80	0.80	0.80	0.80
Dicalcium phosphate	1.75	1.55	1.35	1.20
Salt	0.34	0.34	0.34	0.34
L-lysine HCl	0.14	-	-	-
Premix[1]	1.00	1.00	1.00	1.00
Chromic oxide	0.25	0.25	0.25	0.25

[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 μg vitamin B_{12}; 30 mg Mn; 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 peanut meal and the experimental diets used to determine the ileal digestibility of amino acids in peanut meal[1]

	Peanut meal	Basal diet	75% Basal+25% Peanut meal	50% Basal+50% Peanut meal	25% Basal+75% Peanut meal
Chemical analysis (%, as fed)					
Crude protein	46.23	16.41	23.38	30.98	38.34
Crude fiber	6.14	2.35	3.25	4.17	5.08
Ether extract	1.47	3.08	2.57	2.21	1.87
Calcium	0.27	0.76	0.75	0.74	0.74
Total phosphorus	0.56	0.62	0.64	0.67	0.69
Indispensible amino acids (%, as fed)					
Arginine	4.82	1.14	2.05	2.93	3.84
Histidine	0.85	0.46	0.54	0.63	0.73
Isoleucine	1.23	0.65	0.78	0.91	1.05
Leucine	2.46	1.53	1.72	1.95	2.24
Lysine	1.38	0.97	0.98	1.09	1.21
Methionine+cystine	0.82	0.56	0.62	0.68	0.73
Phenylalanine	1.89	0.83	1.09	1.36	1.62
Threonine	1.08	0.65	0.80	0.84	0.95
Tryptophan	0.43	0.19	0.25	0.30	0.36
Valine	1.34	0.75	0.89	1.03	1.17

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

MATERIALS AND METHODS

Digestibility trial

Four crossbred (Yorkshire × Landrace × Beijing Black) barrows, weighing 20±0.5 kg, were fitted with 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 was 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 10 day adjustment to the diet followed by a 2 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

Table 3. Composition of diets fed to determine the effect of different levels of peanut meal on the performance of growing (21~54 kg) and finishing pigs (54~99 kg)

	Grower					Finisher				
	0	5	10	15	20	0	5	10	15	20
Ingredients (%, as fed)										
Corn	72.90	72.79	72.48	72.19	71.99	77.07	76.89	76.58	76.37	75.58
Soybean meal	23.40	18.40	13.60	8.80	4.00	18.90	14.00	9.20	4.30	0.00
Peanut meal	0.00	5.00	10.00	15.00	20.09	0.00	5.00	10.00	15.00	20.00
Limestone	0.68	0.69	0.69	0.69	0.68	0.70	0.70	0.70	0.70	0.70
Dicalcium phosphate	1.60	1.60	1.60	1.60	1.60	1.90	1.90	1.90	1.90	1.90
Lysine-HCl	0.08	0.16	0.25	0.32	0.39	0.09	0.17	0.26	0.33	0.40
DL-methionine	0.00	0.02	0.04	0.06	0.09	0.00	0.00	0.02	0.06	0.08
Salt	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Chemical analysis (%, as fed)[2]										
Crude protein	16.46	16.61	16.51	16.55	16.53	14.91	15.04	14.97	15.12	15.18
Total lysine	0.91	0.90	0.89	0.88	0.88	0.81	0.80	0.79	0.79	0.78
Total sulfur amino acids	0.55	0.56	0.55	0.57	0.56	0.52	0.50	0.51	0.52	0.51
Digestible lysine	0.76	0.76	0.76	0.76	0.76	0.67	0.67	0.67	0.67	0.67
Digestible sulfur amino acids	0.49	0.49	0.49	0.49	0.49	0.45	0.45	0.45	0.45	0.45
Calcium	0.69	0.68	0.69	0.67	0.68	0.74	0.76	0.75	0.75	0.74
Phosphorus	0.66	0.66	0.64	0.65	0.65	0.65	0.64	0.65	0.64	0.63

[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 μg vitamin B_{12}; 100 mg Mn; 100 mg Fe; 100 mg Zn; 10 mg Cu; 0.5 mg I; 1 mg Co; 0.3 mg Se; 110 mg chlortetracycline; 110 mg sulfathiazole.

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

soybean meal were removed from the diet and replaced with either 25, 50 or 75% peanut meal. Chromic oxide (0.25%) was added to all of the diets as a digestibility marker.

Throughout the experiment, the barrows were individually housed in 0.5 m×1.5 m 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 for all pigs during each experimental period. The amount fed was the amount consumed by the pig eating the least during the first 3 days of 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 frozen again 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, 200 crossbred (Yorkshire×Landrace×Beijing Black) growing pigs, weighing an average of 20.94±0.78 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, 5, 10, 15 or 20% peanut meal, added largely at the expense of the soybean meal. The digestibility coefficients for lysine and the sulfur containing amino acids, which were calculated based on the results of the digestibility trial, were used in the ration formulation matrix so that all diets provided equal levels of digestible lysine and the sulfur containing amino acids.

The experiment was partitioned into two phases. During the growing phase, lasting 42 days, the diets were formulated to provide 16.5% crude protein, 0.76% digestible lysine and 0.49% digestible sulfur containing amino acids (table 3). During the finishing phase, lasting 56 days, the diets were formulated to provide 15% crude protein, 0.67% digestible lysine and 0.45% digestible sulfur amino acids (table 3). All diets were provided in mash form and contained vitamins and minerals to meet or exceed NRC (1998) requirements.

All pigs were housed in groups of 8, in an environmentally controlled building containing concrete-floored, partially-slatted pens equipped with self feeders. The pen size was 2.8 m×3.9 m during the grower period and 3.2 m×4.5 m in the finisher period. Five pens, containing 4 gilts and 4 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 was conducted according to the description provided by Christian and Coup (1954).

Samples of both digesta and diets were hydrolyzed with 6 mol/l 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 hr 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 apparent ileal digestibility of each amino acid (Y) and the replacement level of peanut meal (x) using the model of Y=bx+c. The apparent ileal digestibility of the amino acids in peanut meal was achieved by the extrapolation of this equation to a diet where rapeseed meal consisted of 100% of the tested feedstuff (i.e., x=1).

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 peanut level on the various parameters measured (SAS, 1989).

RESULTS AND DISCUSSION

The results of the chemical analysis conducted on the peanut meal used in the present study are presented in table 2. The peanut meal used had 46.2% crude protein, 6.14% crude fiber, 1.47% ether extract, 0.27% calcium and 0.56% phosphorus. These data are similar to the results of chemical analyses published for peanut meal by Yin et al. (1994), Aherne and Kenelly (1982) and NRC (1998). However, the concentrations of the indispensible amino acids for the peanut meal used in the present study were generally lower than those in the publications listed above.

The ileal digestibility of the amino acids in the diets containing graded levels of peanut meal are shown in table 4. With the exception of arginine, histidine and phenylalanine, the digestibility coefficients for all of the indispensible amino acids declined as

Table 4. Apparent ileal amino acid digestibility of diets containing various levels of peanut meal

	Basal diet	75% Basal+25% Peanut meal	50% Basal+50% Peanut meal	25% Basal+75% Peanut meal	SEM[1]
Arginine	87.36	92.08	94.29	93.70	2.80
Histidine	85.42	86.99	86.83	88.52	3.10
Isoleucine	81.52	80.76	78.34	76.37	1.20
Leucine	91.15	83.46	81.03	77.70	1.90
Lysine	88.06	86.32	83.11	82.06	2.30
Methionine	87.80	85.84	84.45	82.59	2.80
Phenylalanine	72.51	76.24	78.35	82.98	3.30
Threonine	88.39	85.37	81.70	76.08	2.30
Tryptophan	81.52	79.63	78.04	75.68	1.50
Valine	85.75	84.79	82.01	78.26	2.30

[1] Standard error of the mean.

[2] Each value represents the mean of the analysis from four digesta samples conducted in duplicate.

the level of peanut 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% peanut meal are shown in table 5. These values are compared with previously published estimates of amino acid digestibility in table 6 (Rhone-Poulenc, 1993; Knabe et al., 1989; Yin et al., 1994; Heartland Lysine, 1998; NRC, 1998). For the amino acids most likely to be limiting in cereal grains (i.e., lysine, methionine, threonine and tryptophan), the results from the current experiment differed from previously published values by less than 5 percentage units. However, the results of the present experiment differed by 7 or more percentage units for histidine, isoleucine and leucine when compared with previously published values.

The effects of including graded levels of peanut meal on the performance of growing-finishing pigs are shown in table 7. During the growing (21-54 kg) period, pigs fed diets containing up to 15% peanut meal gained weight at a similar rate as those fed soybean meal. However, the growth of pigs fed 20% peanut meal was about 7.5% slower than pigs fed the control diet. Feed intake did not differ among treatments while feed conversion was linearly poorer (p=0.02) as the level of peanut meal in the diet increased with a noticeable decline at the 20% level of inclusion.

During the finishing period (54-99 kg), the addition of peanut meal decreased average daily gain in a linear fashion (p=0.01). The decline was most evident at 15 and 20% levels of inclusion with gain being reduced 8.2% and 18.8% for these treatments. Feed intake did not differ among treatments while feed conversion declined in a linear manner (p=0.03) as the level of peanut meal in the diet increased. Peanut meal inclusion rates of 10% or greater produced a noticeable decline in feed conversion during the finishing period.

During the entire experimental period (21-99 kg), average daily gain declined in a linear manner (p=0.01) with gain being reduced 14.6% for the 20% peanut meal diet compared with the control diet. Feed conversion also declined (p=0.05) with a 17%

Table 5. Regression equations to determine the apparent ileal digestibility of amino acids in peanut meal

Amino acids	Regression equations[1]	R^2	Peanut meal digestibility
Arginine	Y= 8.49x + 88.67	0.76	97.16
Histidine	Y= 3.66x + 85.57	0.87	89.23
Isoleucine	Y= -9.68x + 83.30	0.92	73.62
Leucine	Y=-17.11x + 89.75	0.93	72.64
Lysine	Y= -8.48x + 88.07	0.97	79.59
Methionine	Y= -6.81x + 87.72	1.00	80.91
Phenylalanine	Y= 13.41x + 72.49	0.98	85.99
Threonine	Y=-16.24x + 87.98	0.70	71.74
Tryptophan	Y= -7.64x + 81.58	0.99	73.94
Valine	Y=-10.10x + 86.49	0.94	76.39

[1] Y=apparent ileal digestibility of an amino acid, x= replacement level of peanut meal.

Table 6. The apparent ileal digestibility (%) of amino acids in peanut meal determined with the regression technique compared with previously published values

	Current regression method	NRC (1998)	Heartland Lysine (1988)	Yin et al. (1994)	Rhone-Poulenc (1993)	Knabe et al. (1989)
Arginine	97	93	92	92	95	90
Histidine	89	81	78	80	87	73
Isoleucine	74	83	82	75	87	77
Leucine	73	85	83	73	89	78
Lysine	80	78	78	76	80	66
Methionine	81	85	83	75	84	-
Phenylalanine	86	89	87	80	-	85
Threonine	72	74	75	79	80	61
Tryptophan	74	73	75	-	-	71
Valine	76	82	79	60	85	76

Table 7. Effect of graded levels of peanut meal on the performance of growing-finishing pigs

	Level of peanut meal (%)					SEM[2]	Polynomial contrast[1]		
	0	5	10	15	20		L	Q	C
Growing period (21~54 kg)									
Average daily gain (kg)	0.78	0.79	0.78	0.77	0.72	0.03	0.01	NS	NS
Average daily feed (kg)	1.81	1.87	1.78	1.88	1.90	0.11	NS	NS	NS
Feed conversion	2.31	2.36	2.28	2.44	2.63	0.03	0.02	NS	NS
Finishing period (54~99 kg)									
Average daily gain (kg)	0.85	0.84	0.84	0.78	0.69	0.04	0.01	NS	NS
Average daily feed (kg)	2.64	2.64	2.79	2.68	2.42	0.13	NS	NS	NS
Feed conversion	3.11	3.14	3.30	3.41	3.51	0.03	0.03	NS	NS
Entire experiod (21 to 99 kg)									
Average daily gain (kg)	0.82	0.82	0.81	0.78	0.70	0.04	0.01	NS	NS
Average daily feed (kg)	2.28	2.31	2.36	2.34	2.36	0.14	NS	NS	NS
Feed conversion	2.78	2.81	2.91	2.99	3.35	0.12	0.05	NS	NS

[1] NS=nonsignificant.
[2] SEM=Standard error of the mean.

reduction for the 20% peanut meal diet.

It is well established that peanut meal is not a satisfactory source for swine (Newton et al., 1990). Peanut meal has been reported to be deficient in lysine, methionine and tryptophan with methionine being the first limiting amino acid (Newton et al., 1990). As a result, pigs fed diets containing peanut meal as the sole source of supplementary protein generally do not perform as well as pigs fed soybean meal-based diets (Brooks and Thomas, 1969; Orok et al., 1975). This finding is not universal as Ostrowski et al. (1971) reported similar growth rates for pigs fed peanut meal and soybean meal but the experiment involved a very limited number of animals.

As a result of its poor amino acid balance, use of crytalline amino acids has been suggested to be necessary when feeding peanut meal diets to swine (Newton et al., 1990). Supplementation of peanut meal diets with lysine and methionine has been shown to improve daily gain of pigs to a level similar to that obtained when soybean meal was fed (Brooks and Thomas, 1969). In the present experiment, all diets were formulated to provide equal levels of digestible lysine and the sulfur containing amino acids. Despite this supplementation, it was not possible to completely remove all of the soybean meal from the diet without reducing pig performance. However, satisfactory performance was obtained when peanut meal was used to provide between half and two thirds of the supplementary protein. These findings agree with those of Sewell et al. (1957) who reported that at least half of the soybean meal can be replaced by peanut meal in rations fed to growing pigs.

Since the diets used in the present experiment were formulated to supply equal levels of digestible lysine and the sulfur amino acids which are the most limiting in peanut meal protein (Newton et al., 1990), it is unlikely that an amino acid deficiency can account for the failure of peanut meal to support pig growth at a similar level as was obtained with soybean meal. However, peanut meal does contain some anti-nutritional factors such as tannins, trypsin inhibitors and aflatoxin (Newton et al., 1990) and it is possible that one or more of these may account for the poorer performance of pigs fed high levels of peanut meal.

IMPLICATIONS

There was a good agreement between the amino acid digestibilities for lysine, methionine, threonine and tryptophan determined using the regression technique and amino acid digestibilities previously published for peanut meal. These values were then applied in a growth trial to determine the performance of growing-finishing pigs fed graded levels of peanut meal in diets formulated on an ileal digestible amino acid basis. The overall results suggest that peanut meal can be used at levels up to 15% in diets fed to growing-finishing pigs provided that the diet has been balanced for digestible amino acids.

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