Use of Chinese Sunflower Meal as a Nonconventional Protein Feedstuff for Growing-Finishing Pigs[a]

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ABSTRACT : Two experiments were conducted to determine the ileal digestibility of the amino acids contained in sunflower 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% sunflower meal. For the growth trial, 80 crossbred (Yorkshire × Landrace × Beijing Black) growing pigs (21.5 kg) were fed corn-soybean meal diets supplemented with 0, 5, 10 or 15% sunflower meal. Five pens (2 gilts and 2 castrates) were assigned to each treatment. With the exception of arginine and valine, the digestibility coefficients for the indispensible amino acids declined as the level of sunflower meal in the diet increased. During both the growing (21.5-49.1 kg) and finishing (49.1-90.3 kg) periods and over the entire experiment (21.5-90.3 kg), average daily gain declined in a linear manner ($p<0.05$) with increasing amounts of sunflower meal. Feed intake was not significantly altered while feed conversion declined in a linear manner ($p<0.05$) during the grower period only. When the entire experimental period was taken into account, there would appear to be little penalty in either growth or feed conversion for including sunflower meal at levels up to 10% of the diet. Therefore, the price relationship between sunflower meal and other high-protein feedstuffs may provide an excellant opportunity for pork producers to use sunflower meal in order to reduce feed costs. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 5 : 666-672*)

Key Words : Sunflower Meal, Ileal Digestibility, Amino Acid, Growing-Finishing Pigs

INTRODUCTION

The production of sunflower seed (*Helianthus annus*) has increased dramatically in recent years with world production exceeding 26 million metric tons in 1998 (USDA, 1999). This interest in the sunflower is based on the fact that the oil contained in the sunflower seed supplies a very high level of polyunsaturated fatty acids and is highly sought after as a vegetable oil for human consumption. The meal produced as a by-product of this crushing process has been made available to the swine industry and provides an alternative feed resource that has considerable potential for use during all phases of production (Dinusson, 1990).

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 sunflower meal, an experiment was conducted to determine the ileal digestibility of amino acids in sunflower 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.

MATERIALS AND METHODS

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[a] This project was partially supported by the MAF-SGRP (Ministry of Agriculture and Forestry-Special Grants Research Program) in Korea and China Natural Science Foundation.

Received August 11, 1999; Accepted October 23, 1999

Table 1. Ingredient composition of diets fed to determine the ileal digestibility of amino acids in sunflower meal when fed to growing pigs

	Basal diet	75% Basal+25% Sunflower meal	50% Basal+50% Sunflower meal	25% Basal+75% Sunflower meal
Ingredients (%, as fed)				
Corn	71.74	53.41	34.85	16.28
Soybean meal	23.98	17.80	11.61	5.43
Sunflower meal	-	25.00	50.00	75.00
Limestone	0.80	0.80	0.90	1.00
Dicalcium phosphate	1.75	1.40	1.05	0.70
Salt	0.34	0.34	0.34	0.34
L-lysine HCl	0.14	-	-	-
Vitamin-mineral 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 sunflower meal and the experimental diets used to determine the ileal digestibility of amino acids in sunflower meal (digestibility trial)[1]

	Sunflower meal	Basal diet	75% Basal+25% Sunflower meal	50% Basal+50% Sunflower meal	25% Basal+75% Sunflower meal
Chemical analysis (%, as fed)					
Crude protein	33.91	16.19	20.51	24.08	29.08
Crude fiber	10.36	2.42	4.36	6.34	8.29
Ether extract	1.03	3.13	2.63	2.08	1.48
Calcium	0.25	0.74	0.72	0.71	0.72
Total phosphorus	1.01	0.62	0.73	0.83	0.94
Indispensible amino acids (%, as fed)					
Arginine	2.89	1.13	1.57	1.98	2.41
Histidine	0.72	0.45	0.53	0.57	0.64
Isoleucine	1.40	0.64	0.82	1.01	1.16
Leucine	2.06	1.47	1.63	1.76	1.88
Lysine	1.15	0.96	0.93	0.99	1.04
Methionine+cystine	1.21	0.55	0.72	0.87	1.03
Phenylalanine	1.44	0.84	0.99	1.13	1.25
Threonine	1.12	0.63	0.76	0.87	1.03
Tryptophan	0.37	0.18	0.23	0.28	0.31
Valine	1.58	0.77	0.95	1.14	1.37

[1] All values represent the mean of chemical analysis conducted in duplicate.

Digestibility trial

Four crossbred (Yorkshire×Landrace×Beijing Black) barrows, weighing 20±0.3 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 soybean meal were removed from the diet and replaced with either 25, 50 or 75 % sunflower 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, 80 crossbred (Yorkshire×Landrace×Beijing Black) growing pigs, weighing 21.5 ±1.5 kg were allotted into 4 treatment groups on the basis of sex, weight and litter. The four test diets were based on corn and soybean meal and were supplemented with either 0, 5, 10 or 15% sunflower meal, added largely at the expense of the soybean meal (table 3). 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 49 days, the diets were formulated to provide 15.5% crude protein, 0.75% digestible lysine and 0.54% digestible sulfur containing amino acids. During the finishing phase, lasting 56 days, the diets were formulated to provide 14.5% crude protein, 0.67% digestible lysine and

Table 3. Composition of diets fed to determine the effect of different levels of sunflower meal on the performance of growing-finishing pigs (21.5~90.3 kg)

	Growing period (21.5~49.1 kg)				Finishing period (49.1~90.3 kg)			
	0	5	10	15	0	5	10	15
Ingredients (%, as fed)								
Corn	74.55	73.51	73.19	72.76	77.02	76.72	76.49	75.60
Soybean meal	21.08	17.10	12.40	7.80	18.90	14.20	9.40	5.20
Sunflower meal	0.00	5.00	10.0	15.00	0.00	5.00	10.00	15.00
Limestone	0.70	0.75	0.78	0.83	0.70	0.74	0.74	0.80
Salt	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Lysine-HCl	0.13	0.20	0.28	0.35	0.09	0.15	0.23	0.30
DL-methionine	0.10	0.10	0.11	0.12	0.05	0.05	0.05	0.06
Dicalcium phosphate	2.10	2.00	1.90	1.80	1.90	1.80	1.75	1.70
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chemical analysis (%, as fed)[2]								
Crude protein	15.46	15.42	15.37	15.41	14.69	14.58	14.61	14.63
Calcium	0.79	0.80	0.78	0.77	0.68	0.69	0.70	0.72
Phosphorus	0.67	0.68	0.69	0.71	0.59	0.60	0.62	0.64
Total lysine	0.89	0.89	0.87	0.86	0.80	0.79	0.79	0.78
Total sulfur amino acids	0.66	0.67	0.68	0.68	0.63	0.64	0.66	0.65
Digestible lysine	0.75	0.75	0.75	0.75	0.67	0.67	0.67	0.67
Digestible sulfur amino acids	0.54	0.54	0.54	0.54	0.49	0.49	0.49	0.49

[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.

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

0.49% digestible sulfur amino acids. 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 4, in an environmentally controlled building containing 1.2×2.0 m concrete-floored, partially-slatted pens equipped with self feeders. Five pens, containing 2 gilts and 2 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 using atomic absorption according to the description provided by Christian and Coup (1954).

Samples of both digesta and diets were hydrolyzed with 6 M 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 sunflower meal (x) using the model of Y=bx+c. The apparent ileal digestibility of the amino acids in sunflower meal was achieved by the extrapolation of this equation to a diet where sunflower 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 sunflower meal level on the various parameters measured (SAS, 1989).

RESULTS AND DISCUSSION

The results of the chemical analysis conducted on the sunflower meal used in the present study are presented in table 2. The sunflower meal used had 33.91% crude protein, 10.36% crude fiber, 1.03% ether extract, 0.25% calcium and 1.01% phosphorus. With the exception of the crude fiber level, these finding are similar to the results of chemical analyses published for partially dehulled sunflower meal by Dale (1997), Rhone Poulenc (1993) and Dinusson (1990). In addition, the concentrations of the indispensible amino acids for the sunflower meal used in the present study were similar to those presented in the publications listed above.

The ileal digestibility of the amino acids in the diets containing graded levels of sunflower meal are shown in table 4. With the exception of arginine and valine, the digestibility coefficients for all the indispensible amino acids declined as the level of sunflower meal in the diet increased.

Table 4. Apparent ileal amino acid digestibility of diets containing various levels of sunflower meal[1]

	Basal diet	75% Basal+25% Sunflower meal	50% Basal+50% Sunflower meal	25% Basal+75% Sunflower meal	SEM[2]
Arginine	64.67	66.63	72.44	71.18	3.2
Histidine	91.35	83.32	78.17	76.07	1.4
Isoleucine	87.64	84.89	82.24	72.82	2.2
Leucine	88.12	77.88	79.31	78.23	3.2
Lysine	85.83	83.71	82.54	77.36	1.3
Methionine	90.97	85.75	89.12	82.91	2.1
Phenylalanine	84.54	82.23	80.17	78.07	4.6
Threonine	78.05	77.42	72.68	74.05	2.3
Tryptophan	86.81	84.09	82.16	78.20	1.9
Valine	75.92	76.48	76.42	77.10	0.2

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

The regression equations generated from the ileal digestibility data and the digestibility coefficients obtained when the equation was extrapolated to 100% sunflower meal are shown in table 5. These values are compared with previously published estimates of sunflower meal amino acid digestibility in table 6 (Heartland Lysine, 1998; NRC, 1998; Rhone Poulenc, 1993; Knabe et al., 1989; Jorgensen et al., 1984). For the amino acids most likely to be limiting in cereal grains (i.e. lysine, methionine, threonine and tryptophan: Sauer et al., 1977), the results from the current experiment showed good agreement with previously published values and differed by 5 or fewer percentage units for all these amino acids except methionine. For methionine, the value of 82% ileal digestibility obtained in the present experiment was lower than most previously published estimates which ranged from 83 to 88%. For other amino acids, the current regression method produced ileal digestibilities for arginine and histidine which were more than 10 percentage units lower when compared with previously published values. Values for leucine, isoleucine and phenylalanine were between 5 and 10 percentage units lower for the regression method.

During both the growing (21.5-49.1 kg) and finishing (49.1-90.3 kg) periods and over the entire experiment (21.5-90.3 kg), average daily gain declined in a linear manner ($p<0.05$) with increasing amounts of sunflower meal (table 7). Feed intake was not significantly altered while feed conversion declined in a linear manner ($p<0.05$) during the grower period only. When the entire experimental period was taken into account, there would appear to be little penalty in either growth or feed conversion for including sunflower meal at levels up to 10% of the diet. Therefore, the price relationship between sunflower meal and other high-protein feedstuffs may provide an excellant opportunity for pork producers to use sunflower meal in order to reduce feed costs.

The results of the present experiment are consistent with earlier work that showed that the best pig performance was obtained when sunflower meal

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

Amino acids	Regression equations[1]	R^2	Sunflower meal digestibility
Arginine	Y= 10.14x + 64.93	0.79	75.07
Histidine	Y=-18.40x + 87.88	0.72	69.48
Isoleucine	Y=-17.63x + 88.73	0.91	71.73
Leucine	Y= -8.30x + 82.12	0.58	73.82
Lysine	Y=-11.83x + 83.55	0.98	71.72
Methionine	Y= -8.32x + 90.31	0.56	81.99
Phenylalanine	Y= -5.64x + 80.98	0.62	75.34
Threonine	Y= -6.97x + 78.06	0.69	71.36
Tryptophan	Y=-11.10x + 86.98	0.98	75.88
Valine	Y= 1.39x + 75.96	0.86	77.35

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

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

	Current regression method	Heartland Lysine (1988)	NRC (1998)	Rhone-Poulenc (1993)	Knabe et al. (1989)	Jorgensen et al. (1984)
Arginine	75	90	89	90	90	87
Histidine	69	78	79	80	75	81
Isoleucine	71	79	78	78	79	76
Leucine	73	79	78	78	76	76
Lysine	71	74	74	74	73	69
Methionine	82	88	87	87	-	83
Phenylalanine	75	82	80	80	83	72
Threonine	71	73	71	73	69	67
Tryptophan	76	78	76	-	76	-
Valine	77	76	75	75	78	70

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

	Level of sunflower meal (%)				SEM[2]	Polynomial contrast[1]		
	0	5	10	15		L	Q	C
Growing period (21.5~49.1 kg)								
Average daily gain (kg)	0.57	0.57	0.56	0.54	0.01	0.05	NS	NS
Average daily feed (kg)	1.54	1.57	1.59	1.49	0.03	NS	NS	NS
Feed conversion	2.70	2.75	2.84	2.77	0.02	0.05	NS	NS
Finishing period (49.1~90.3 kg)								
Average daily gain (kg)	0.78	0.76	0.73	0.67	0.02	0.01	NS	NS
Average daily feed (kg)	2.65	2.47	2.51	2.46	0.03	NS	NS	NS
Feed conversion	3.40	3.23	3.43	3.67	0.05	NS	NS	NS
Entire experiod (21.5 to 90.3 kg)								
Average daily gain (kg)	0.68	0.67	0.65	0.61	0.03	0.02	NS	NS
Average daily feed (kg)	2.13	2.05	2.08	2.01	0.04	NS	NS	NS
Feed conversion	3.14	3.05	3.20	3.30	0.09	NS	NS	NS

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

supplies only a portion of the supplementary protein for growing-finishing pigs (Baird, 1981; Delic et al., 1964; Dinusson et al., 1980; Moser et al., 1985; Seerley et al., 1974). The principle factor limiting pig performance is usually the low lysine content of sunflower meal (Dinusson, 1990). However, since the diets used in the present experiment were formulated to supply equal levels of digestible lysine and the sulfur amino acids, it is unlikely that a deficiency of these amino acdis can account for the failure of sunflower meal to support pig growth at a similar level as was obtained with soybean meal. Wahlstrom et al. (1985) suggested that the most limiting amino acids for growing swine in a lysine-supplemented corn-sunflower meal diet are tryptophan and threonine. Therefore, it is possible that a deficiency of these amino acids may explain the poorer response to sunflower meal in the present trial.

Sunflower meal is not known to contain any anti-nutritional factors (Dinusson, 1990). However, the relatively high crude fiber content and the resulting lower digestible energy may also account for the poorer performance of the pigs fed diets containing higher levels of sunflower meal.

IMPLICATIONS

There was good agreement between the amino acid digestibilities for lysine, threonine and tryptophan determined using the regression technique and amino acid digestibilities previously published for sunflower meal. For methionine, the value of 82% ileal digestibility obtained in the present experiment was lower than most previously published estimates which ranged from 83 to 88%. These amino acid digestibility values were then applied in a growth trial to determine the performance of growing-finishing pigs fed graded levels of sunflower meal in diets formulated on an ileal digestible amino acid basis. When the entire experimental period was taken into account, there would appear to be little penalty in either growth or feed conversion for including sunflower meal at levels up to 10% of the diet. Therefore, the price relationship between sunflower meal and other high-protein feedstuffs may provide an excellent opportunity for pork producers to use sunflower meal in order to reduce feed costs provided that the diet has been balanced for digestible amino acids.

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