Nutritional Evaluation of Chinese Nonconventional Protein Feedstuffs for Growing-Finishing Pigs - 2. Rapeseed Meal*

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ABSTRACT : Two experiments were conducted to determine ileal digestibilities for the amino acids contained in rapeseed 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% rapeseed meal. For the growth trial, 80 crossbred (Yorkshire × Landrace × Beijing Black) growing pigs (20 ± 2.4 kg) were fed corn-soybean meal diets supplemented with 0, 3, 6, 9 or 12% rapeseed meal. Four pens (2 gilts and 2 castrates) were assigned to each treatment. With the exception of isoleucine and methionine, the digestibility coefficients for the indispensible amino acids declined as the level of rapeseed meal in the diet increased. There was little agreement between the amino acid digestibilities determined with the regression technique and values previously published for rapeseed meal. During the growing (22-42 kg) period, the addition of rapeseed meal had no significant effects on gain, feed intake or feed conversion. During the finishing period (58-91 kg), daily gain was not affected by rapeseed meal inclusion but feed conversion declined ($p<0.04$) as the level of rapeseed meal in the diet increased. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 1 : 46-52*)

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

INTRODUCTION

Rapeseed (*Brassica napus*) is the second most important oilseed produced worldwide with world supplies expected to reach 36 million metric tonnes in 1998 (Mieke, 1998). China is the world's largest producer of rapeseed meal with an annual production of 9.5 million metric tons, comprising about one-quarter of the world's total rapeseed meal production.

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 regarded to be the most limiting amino acids in diets composed predominately of cereal grains (Sauer et al., 1977). Soybean meal contains more lysine and threonine than rapeseed meal while rapeseed meal is a rich source of the sulfur containing amino acids (NRC, 1998).

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 digestibilties 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 rapeseed meal, an experiment was conducted to determine the ileal digestiblity of amino acids in rapeseed 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

Digestibility trial

Four crossbred (Yorkshire × Landrace × Beijing Black)

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Table 1. Ingredient composition of diet fed to determine the ileal digestibility of amino acids in rapeseed meal fed to growing pigs

	Basal diet	75% Basal+25% Rapeseed meal	50% Basal+50% Rapeseed meal	25% Basal+75% Rapeseed meal
Ingredients (% as fed)				
Corn	73.61	54.91	35.65	16.64
Soybean meal	22.14	16.16	10.82	5.03
Rapeseed meal	-	25.00	50.00	75.00
Limestone	0.80	0.80	0.80	0.80
Dicalcium phosphate	1.78	1.58	1.18	0.98
Salt	0.30	0.30	0.30	0.30
L-lysine HCl	0.12	-	-	-
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 μg 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 olaquidox; 8 mg antioxidant.

Table 2. Chemical composition (% as fed) of rapeseed meal and the experimental diet used to determine the ileal digestibility of amino acids in rapeseed

	Rapeseed meal	Basal diet	75% Basal+25% Rapeseed meal	50% Basal+50% Rapeseed meal	25% Basal+75% Rapeseed meal
Chemical analysis[1]					
Crude protein	35.60	15.86	19.27	25.12	29.54
Crude fiber	7.20	2.29	4.65	6.99	9.34
Ether extract	3.46	3.01	3.12	3.18	3.25
Calcium	0.98	0.78	0.79	0.82	0.89
Phosphorous	0.62	0.61	0.69	0.76	0.87
Indispensible amino acids[1]					
Arginine	1.81	1.08	1.24	1.42	1.59
Histidine	0.86	0.43	0.56	0.64	0.73
Isoleucine	1.29	0.62	0.77	0.93	1.10
Leucine	2.36	1.44	1.68	1.89	2.07
Lysine	1.02	0.97	0.99	1.18	1.43
Methionine+cyctine	1.62	0.54	0.66	0.79	0.91
Phenyalanine	1.42	0.82	0.95	1.11	1.24
Threonine	4.50	0.63	0.83	1.06	1.25
Tryptophan	0.41	0.19	0.22	0.28	0.35
Valine	1.73	0.74	0.96	1.21	1.39

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

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 bay 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 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% rapeseed 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 0.5×1.5 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, freeze-dried, then ground through a 1 mm screen.

Growth trial

For a growth trial, 80 crossbred (Yorkshire×Landrace×Beijing Black) growing pigs, weighing 20±2.4 kg were allotted into 5 treatment groups on the bases 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% rapeseed 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 diets provided equal levels of digestible lysine and the sulfur containing amino acids.

The experiment was partitioned into two phases with 1 month break between phases during which all pigs were fed a common corn-soybean meal-based diet. During the growing phase, lasting 42 days, the diets were formulated to provide 17% crude protein, 1.0% digestible lysine and 0.58% digestible sulfur containing amino acids (table 3). During the finishing

Table 3. Composition of diets fed to determine the effect of different levels of rapeseed meal on the performance of growing pigs (20-42 kg)

	Level of rapeseed meal (%)				
	0	3	6	9	12
Ingredients (% as fed)					
Corn	69.77	69.52	69.06	68.32	68.15
Soybean meal	24.20	21.50	19.00	16.80	14.00
Rapeseed meal	0.00	3.00	6.00	9.00	12.00
Fish meal	1.50	1.50	1.50	1.50	1.50
Limestone	1.10	1.10	1.13	1.15	1.15
Dicalcium phosphate	1.43	1.35	1.25	1.15	1.10
Salt	0.30	0.30	0.30	0.30	0.30
L-lysine HCl	0.39	0.43	0.47	0.49	0.52
DL-methionine	0.19	0.18	0.17	0.16	0.15
Threonine	0.12	0.12	0.12	0.13	0.13
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00	1.00
Nutrient level (% as fed)					
Crude protein	17.06	16.83	16.91	16.78	17.15
Total lysine	1.11	1.13	1.11	1.14	1.16
Total sulfur amino acids	0.70	0.68	0.71	0.73	0.69
Digestible lysine	1.01	1.01	1.01	1.01	1.01
Digestible sulfur amino acids	0.58	0.58	0.58	0.58	0.58
Calcium	0.81	0.80	0.82	0.79	0.81
Total phosphorous	0.66	0.67	0.64	0.65	0.66

[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 ribiflavin; 13.8 mg pantothenic acid; 30.3 mg niacin; 551 mg choline; 27.6 μg 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 olaquidox; 8 mg antioxidant.

phase, lasting 40 days, the diets were formulated to provide 14.5% crude protein, 0.85% digestible lysine and 0.52% digestible sulfur amino acids (table 4). 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 4, in an environmentally controlled building containing 1.2×2.0 m concrete-slatted, partially-slatted pens equipped with self feeders. Four 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 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 high-performance liquid chromatography (Shimadzu LC 10 Liquid Chromotography, 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 apparent ileal digestibility of each amino acid (Y) and the replacement level of rapeseed meal (x) using the model of Y=bx+c. The apparent ileal digestibility of the amino acids in rapeseed meal was achieved by the extrapolation of this equation to a diet where rapeseed meal was achieved by the extrpolation of this equation to a diet where rapeseed meal of 100% of the tested feedstuff (i.e., x=1).

Table 4. Composition of diets fed to determine the effect of different levels of rapeseed meal on the performance of finishing pigs (59-91 kg)

	Level of rapeseed meal (%)				
	0	3	6	9	12
Ingredients (% as fed)					
Corn	78.40	77.87	77.36	76.90	76.46
Soybean meal	16.00	13.50	11.00	8.40	5.80
Rapeseed meal	0.00	3.00	6.00	9.00	12.00
Fosh meal	1.50	1.50	1.50	1.50	1.50
Limestone	0.80	0.80	0.80	0.80	0.80
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50
Salt	0.30	0.30	0.30	0.30	0.30
L-lysine HCl	0.35	0.38	0.40	0.45	0.48
DL-methionine	0.10	0.09	0.08	0.08	0.08
Threonine	0.05	0.06	0.06	0.07	0.08
Vitamin-mineral premix[1]	1.00	1.00	1.00	1.00	1.00
Nutrient level (% as fed)					
Crude protein	14.29	14.48	14.51	14.13	14.03
Total lysine	0.98	0.97	0.96	1.00	0.99
Total sulfur amino acids	0.62	0.63	0.63	0.65	0.67
Digestible lysine	0.85	0.85	1.85	0.85	0.85
Digestible sulfur amino acids	0.52	0.52	0.52	0.52	0.52
Calcium	0.74	0.73	0.76	0.77	0.79
Total phosphorous	0.61	0.61	0.62	0.64	0.66

[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 ribiflavin; 13.8 mg pantothenic acid; 30.3 mg niacin; 551 mg choline; 27.6 μg 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 olaquidox; 8 mg antioxidant.

Table 5. Ileal amino acid digestibility of diet containing various level of rapeseed meal

	Basal diet	75% Basal+25% Rapeseed meal	50% Basal+50% Rapeseed meal	25% Basal+75% Rapeseed meal	SEM[1]
Arginine	88.68	88.64	85.62	83.27	3.7
Histidine	94.55	82.47	76.59	77.27	2.8
Isoleucine	73.99	77.30	84.30	85.44	0.9
Leucine	80.81	75.67	70.32	69.73	4.7
Lysine	87.53	86.90	86.77	80.57	2.8
Methionine	81.00	84.31	84.45	85.20	3.5
Phenylanine	88.19	84.24	75.11	76.61	1.3
Threonine	79.88	65.90	65.60	59.92	2.6
Tryptophan	80.95	76.79	74.18	70.98	0.9
Valine	75.91	81.48	86.42	87.40	0.9

[1] Standard error of the mean.

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

Table 6. Regression equation to determine the apparent ileal digestibility of amino acid in rapeseed meal

Amino acids	Regression equation[1]	R^2	Rapeseed meal digestibility
Arginine	Y=-7.70x+89.44	0.90	81.74
Histidine	Y=-23.09x+91.38	0.80	68.29
Isoleucine	Y=16.54x+74.06	0.94	90.60
Leucine	Y=-15.44x+79.92	0.92	64.48
Lysine	Y=-8.40x+88.59	0.69	80.19
Methionine	Y=5.36x+81.79	0.81	88.15
Phenylanine	Y=-17.55x+87.62	0.83	70.07
Threonine	Y=-24.55x+76.93	0.85	52.38
Tryptophan	Y=-13.01x+80.60	0.99	67.59
Valine	Y=15.75x+76.90	0.93	92.65

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

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

RESULTS AND DISCUSSION

The ileal digestibility of the amino acids in the diets graded levels of rapeseed meal are shown in table 5. With the exception of isoleucine and methionine, the digestibility coefficients for all the indispensible amino acids declined as the level of rapeseed 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% rapeseed meal are shown in table 6. Table 7 demonstrates that there was little agreement between the amino acid digestibilities determined with the regression technique and previously published amino acid digesgibilities obtained for rapeseed meal

Table 7. The apparent ileal digestibility (%) of amino acid in rapeseed meal determined with the regression technique compared with previously published values

Amino acids	Current regression method	Heartland Lysine (1998)	NRC (1998)	Fan et al. (1996)	Jondreville (1995)	Sauer et al. (1982)	Yin et al. (1993)	Rhone Poulenc (1993)
Arginine	82	83	81	79-84	86	85	80	84
Histidine	68	75	80	76-81	81	85	77	82
Isoleucine	91	79	74	66-71	77	78	81	75
Leucine	64	74	78	69-74	79	81	77	79
Lysine	80	71	74	68-75	63	73	74	75
Methionine	88	85	82	77-82	84	84	83	84
Phenylanine	70	79	76	69-76	83	82	66	78
Threonine	52	69	69	59-66	71	67	73	71
Tryptophan	68	74	73	61-67	75	-	-	76
Valine	93	71	71	65-72	74	69	76	72

(Rhone-Poulenc, 1993; Heartland Lysine, 1998, NRC, 1998; Fan et al., 1996; Jondreville, 1995; Sauer et al., 1982; Yin et al., 1993).

Two possible explanations can be given for this discrepancy. Firstly, it is possible that the regression technique either underestimates or overestimate 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 rapeseed meal used in the present study differed from those previously studied. Yin et al. (1994) have reported that Chinese oil seeds are smaller in size than those produced in North America and Europe so that the rapeseed meals have a higher lenel of cell wall constituents and a lower level of crude protein and amino acids. Liu et al. (1994) also reported differences in chemical composition between Chinese and Canadian rapeseed.

Of particular concern are the large differences in digestibility for lysine, threonine, methionine and tryptophan between the current technique and previously published values (table 7). The 80% digestibility coefficient for lysine is 5 to 10 percentage units higher than previously published values. The 88% digestibility coefficient for methionine is 4 to 6 percentage units higher than previously published values. In contrast, the values for threonine (52%) are 15 to 21 percentage units lower while the digestibility coefficient for tryptophan (68%) is 5 to 8 percentage units lower.

These amino acids are important because they have been shown to be the most limiting amino acids in diets composed predominately of cereal grains (Sauer et al., 1977). Liu et al. (1994) reported that, in many rural oil mills in China, heating time and temperature cannot be easily regulated leading to overheating of the meal. They discussed a report in which the ileal digestibility of the lysine in Chinese rapeseed meal was 61% which would indicate that the regression method is overestimating the ileal digestibility of lysine to an even greater degree than is indicated in table 7.

The effects of including graded levels of rapeseed meal on the performance of growing-finishing pigs are shown in table 8. During the growing (22-42 kg) period, the addition of rapeseed meal had no significant effects on gain, feed intake or feed conversion. These findings are consistent with a large body of literature which suggests that rapeseed meal can be used to provide at least half of the supplementary protein in diets formulated for growing pigs (Mckinnon and Bowland, 1977; Bell et al., 1981; Bell and Keith, 1987; Siljander-Rasi et al., 1996).

During the finishing period (59-91 kg), daily gain was not affected by rapeseed meal inclusion but pigs fed the diets containing higher levels of rapeseed meal consumed more feed (linear effect, $p<0.01$) but had a poorer feed conversion (linear effect, $p<0.04$) than pigs fed lower levels of rapeseed meal. These findings are consistent with those of Bell et al. (1988) and Narendran et al. (1981). Rapeseed meal has also been reported to be a satisfactory substitute for soybean meal in the studies of Aherne and Lewis (1978), Baidoo et al. (1987), Boudron and Aumaitre (1990), Corino et al. (1991) and Castell and Cliplef (1993).

In conclusion, the regression technique used for the present experiment provided dramatically different estimates of the apparent ileal digestibility of amino acids than has been previously reported. These discrepancies may reflect differences in the chemical composition of Chinese rapeseed and that used in other areas but may also indicate that it should be prudent by using the regression technique with feeds containing high level of protein. The study also confirms much earlier works, indicating that rapeseed meal is a useful substitute for at least a portion of the

Table 8. Effect of graded level of rapeseed meal on the performance of growing-finishing pigs

	Level of rapeseed meal (%)						Polynomial contrast[1]		
	0	3	6	9	12	SEM[2]	L	Q	C
Growing period (20-42 kg)									
Average daily gain (kg)	0.47	0.46	0.44	0.45	0.45	0.01	NS	NS	NS
Average daily feed intake (kg)	1.27	1.43	1.15	1.15	1.14	0.03	NS	NS	NS
Feed conversion	2.67	3.10	2.61	2.55	2.53	0.06	NS	NS	NS
Finishing period (59-91 kg)									
Average daily gain (kg)	0.78	0.80	0.79	0.81	0.79	0.22	NS	NS	NS
Average daily feed intake (kg)	2.41	2.49	2.37	2.51	2.55	0.12	0.01	NS	NS
Feed conversion	3.09	3.03	2.98	3.12	3.24	0.21	0.04	NS	NS

[1] Poynomial contrasts: L=liner, Q=quadratic, C=cubic (NS=not significant at $p<0.05$).

[2] Stadard erroe of the mean.

soybean meal in diets fed to growing-finishing swine.

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