Apparent Ileal Digestibility of Nutrient in Plant Protein Feedstuffs for Finishing Pigs

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ABSTRACT : Five barrows (average initial body weight 58.6 kg) were used to determine the apparent ileal digestibilities of amino acids, DM, N and energy in various soybean meal, rapeseed meal and coconut meal in finishing pigs. Dietary treatments included 1) KSBM (Korean soybean meal), 2) CSBM (Chinese soybean meal), 3) ASBM (Argentine soybean meal), 4) RSM (Rapeseed meal), and 5) CNM (Coconut meal). The diets were corn starch-based and formulated so that each protein source provided the same amount of total ME (3,490 kcal/kg), CP (15.70%), lysine (1.00%), Ca (0.80%) and P (0.60%). Protein content of the KSBM was higher than the CSBM and ASBM, with all values similar to those expected, and protein content of the CNM was lower than that of the SBM preparation and RSM. Apparent ileal digestibilities of histidine, lysine, threonine, alanine, asparatic acid, cystine, glutamic acid and serine were greater for the KSBM, CSBM, ASBM and RSM than for the CNM ($p<0.05$). Also, the apparent ileal digestibilities of methionine, leucine, phenylalanine, valine and tyrosine were greater for the KSBM than for the CSBM, ASBM, RSM and CNM ($p<0.05$). Overall, the apparent ileal digestibilities of total essential amino acids were greater for the KSBM than for the CSBM, ASBM, RSM and CNM ($p<0.05$), and the apparent ileal digestibilities of total non essential amino acids were greater for the KSBM, CSBM, ASBM and RSM than for the CNM ($p<0.05$). No difference ($p>0.05$) in apparent digestibility of DM at the small intestine was observed among the treatments. However, the apparent digestibility of DM at the total tract was greater for the KSBM than for the CSBM, ASBM, RSM and CNM ($p<0.05$). Also, apparent digestibilities of N and digestible energy at the small intestine and total tract were greater for the KSBM than for the RSM and CNM ($p<0.05$). In conclusion, nutrient digestibility values of SBM preparations and RSM were relatively high compared to CNM. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 7 : 1020-1024)***

Key Words : Soybean Meal, Rapeseed Meal, Coconut Meal, Ileal Digestibility, Pigs

INTRODUCTION

One of the major goals when formulating diets for pigs is to provide the essential amino acids in amounts needed to support maximal and efficient growth, and to minimize environmental pollution by reducing excreted nitrogen. It is known that nutrients in feedstuffs, as determined by chemical analyses, are not totally available to the pigs (Buraczewska et al., 1999). Ileal digestibility assays in pigs (Herkelman et al., 1992; Kim et al., 2000) are accepted procedures to determine digestibility of amino acids in feed ingredients. Just et al. (1985) reported that digestible amino acids determined from ileal digesta had a higher correlations to carcass protein than digestible protein and amino acids determined from feces.

Soybean meal (SBM) is the most commomly used source of supplemental protein in diets for nonruminants because of its excellent amino acid profile and dependable supply (Kim et al., 1999). In a typical broiler or pig diet, SBM supplies around 50% of the protein and amino acids and about 25% of the metabolizable energy. However, considerable variation in the nutrient digestibility or amino acids digestbilities has been observed among different SBM sources, such as U.S., Korea, China, India and Brazil-originated SBM.

Rapeseed meal (RSM) contains from 35.6% protein which compares favorably with SBM protein in amino acids balance (NRC, 1998). Protein of RSM is somewhat lower in lysine and higher in methionine than the protein of SBM (Cullison and Lowrey, 1987). RSM contains more sulfur amino acids, involved in the biosynthesis of glucosinolates. Previous investigations indicated that effects of RSM has already been attempted in weaned pigs (Im et al., 1995) and growing-finishing pigs (Li et al., 2000).

Coconut meal (CNM) has a residual oil content of about 8%, the variation in the nutrient content of CNM is fundamentally a function of differences in residual oil content (Thorne et al., 1990). Thorne et al. (1992) maintained the ideal amino acid balance with the use of synthetic amino acid at different CNM inclusion levels and found that there was a linear reduction in daily gain as the level of CNM in the diet increased 0 to 200 g/kg.

If accurate evaluation of imported plant protein sources determined by ileal digestibility, it should ensure help to make pig diet. Therefore, the objective of this study was to determine the apparent ileal digestibilities of amino acids, DM, N and energy in various SBM, RSM and CNM in finishing pigs.

MATERIALS AND METHODS

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Table 1. Diet composition (as-fed basis)

Ingredients	KSBM[1]	CSBM[1]	ASBM[1]	RSM[1]	CNM[1]
Corn starch	62.38	58.55	59.16	53.86	47.78
Soybean meal	31.55	35.14	34.16	-	-
Rapeseed meal	-	-	-	31.92	-
Coconut meal	-	-	-	-	31.88
Animal fat	0.44	0.99	1.27	5.50	5.80
Casein	-	-	-	4.83	11.52
Cellulose	2.70	2.46	2.51	1.45	0.23
Tricalcium phosphate	2.09	1.97	2.00	1.18	1.58
Limestone	0.14	0.19	0.19	0.55	0.50
Vitamin premix	0.20	0.20	0.20	0.20	0.20
Mineral premix	0.10	0.10	0.10	0.10	0.10
Salt	0.20	0.20	0.20	0.20	0.20
L-Lysine·HCl	-	-	-	0.01	0.01
Chromic oxide[2]	0.20	0.20	0.20	0.20	0.20
Chemical composition[3]					
ME, kcal/kg	3,490	3,490	3,490	3,490	3,490
Crude protein, %	15.70	15.70	15.70	15.70	15.70
Lysine, %	1.00	1.00	1.00	1.00	1.00
Calcium, %	0.80	0.80	0.80	0.80	0.80
Phosphorus, %	0.60	0.60	0.60	0.60	0.60

[1]Abbreviated KSBM, Korean soybean meal; CSBM, Chinese soybean meal; ASBM, Argentine soybean meal; RSM, Rapeseed meal; CNM, Coconut meal. [2] Used as an indigestible marker. [3] Calculated values.

Five barrows [(Duroc×Yorkshire)×Landrace], with an average initial body weight 58.6 kg, were surgically fitted a simple T-cannulas approximately 15 cm prior to the ileo-cecal junction. The pigs were fasted for 16 to 20 h prior to surgery. Anesthesia was induced using Stresnil™ (Janssen Pharmaceutica, Belgium) and Yuhan Ketamine 50 Injection (Yuhan Co., Korea). After surgery, the barrows were individually housed in stainless steel metabolism crates in a temperature controlled (22°C) room. The pigs were allowed 14 d of recovery before initiation of the experiments.

The experimental designs were 5×5 latin squares with pigs and periods as blocking criteria. Each period consisted in 4 d of adjustment to the experimental diets, 2 d of total feces collection and 2 d (12 h/d) of ileal digesta collection. The daily feed allowance was $0.05\times BW^{0.9}$, as proposed by Armstrong and Mitchell (1955). The daily feed was offered in two meals at 12 h intervals (8:00 a.m. and 8:00 p.m.). Dietary treatments included 1) KSBM (corn-starch based diet+Korean soybean meal), 2) CSBM (corn-starch based diet+Chinese soybean meal), 3) ASBM (corn-starch based diet+Argentine soybean meal), 4) RSM (corn-starch based diet+Rapeseed meal), 5) CNM (corn-starch based diet+Coconut meal). Experimental diet was formulated to contain 3,490 kcal/kg of ME, 15.70% of CP, 1.00% of lysine, 0.80% of Ca and 0.60% of P for the finishing pigs (Table 1). The diet was formulated to meet or exceed the nutrient requirements recommended by NRC (1998). Chromic oxide was added (0.2% in the diet) as an indigestible marker to allow digestibility determinations.

The feces were collected twice daily during the 2 d of collection. At the end of the experiment, all feces were dried and ground prior to analyses. Ileal digesta were collected during the 12 h period between the morning and evening feeding for the last 2 d of each collection period. Ileal digesta were collected into plastic bags attached to the cannulas. Every 20 min the digesta were emptied into plastic containers and placed on ice. The collected digesta were pooled and frozen until being lyophilized and ground. Feed and feces were analyzed for DM and N content (AOAC, 1995), and gross energy content was measured using the Adiabatic Bomb Calorimeter (Model 1241, Parr Instrument Co., USA). Chromium was determined by UV absorption spectrophotometry (Shimadzu, UV-1201, Japan) and apparent digestibilities of DM and N were calculated using the indirect-ratio method. Amino acids digestibility of the experimental feed was determined, following acid hydrolysis with 6 N HCl at 110°C for 24 h, using an amino acid analyzer (Biochrom 20, Pharmacia Biotech, England). Sulfur-containing amino acids were analyzed after cold performic acid oxidation overnight and subsequent hydrolysis.

The data were analyzed as latin squares using the ANOVA of SAS (1996). The statistical model included range test (Duncan, 1955) was used to determine significant differences among treatments.

RESULTS AND DISCUSSION

Chemical composition of the SBM, RSM and CNM is given in Table 2. Protein content of the KSBM was higher than the CSBM and ASBM, with all values similar to those

Table 2. Analyzed amino acid compositions of soybean meal, rapeseed meal and coconut meal

Item	KSBM[1]	CSBM[1]	ASBM[1]	RSM[1]	CNM[1]
Crude protein, %	49.12	44.44	45.59	34.88	16.32
Essential amino acids					
Arginine	3.71	3.49	3.33	2.35	2.23
Histidine	1.37	1.26	1.26	1.04	0.36
Isoleucine	2.18	1.94	2.02	1.47	0.54
Leucine	3.75	3.33	3.51	2.66	1.11
Lysine	3.17	2.90	2.92	2.01	0.45
Methionine	0.61	0.52	0.56	0.64	0.28
Phenylalanine	2.38	2.11	2.28	1.44	0.74
Threonine	2.04	1.83	1.89	1.78	0.62
Valine	2.22	2.01	2.06	1.83	0.93
Non essential amino acids					
Alanine	2.13	1.95	2.01	1.63	0.75
Asparatic acid	5.85	5.31	5.41	2.85	1.54
Cystine	0.67	0.56	0.58	0.75	0.27
Glutamic acid	9.78	8.84	9.22	7.06	3.69
Glycine	2.12	1.91	1.98	1.91	0.79
Proline	2.86	2.56	2.35	2.59	0.67
Serine	2.64	2.39	2.47	1.73	0.84
Tyrosine	1.64	1.53	1.74	1.14	0.51

[1]Abbreviated KSBM, Korean soybean meal; CSBM, Chinese soybean meal; ASBM, Argentine soybean meal; RSM, Rapeseed meal; CNM, Coconut meal.

expected (NRC, 1998), and protein content of the CNM was lower than that of the various SBM and RSM. Protein and energy content vary in SBM depending on protein level of the beans, residual fat after processing and whether or not hulls have been removed. The protein content of dehulled materials ranges from 47.5 to 49% or more and material with hulls ranges from 40 to 50% with 44% considered the norm. Fan et al. (1995) showed that protein content in SBM was 46.13%, also, Woodworth et al. (2001) reported that protein content of the solvent-extracted with hulls SBM and without hulls SBM were 45.40% and 47.14%, respectively. In our experiment, the high protein content of KSBM may have resulted from the without hulls of SBM. Protein content of the RSM was demonstrated by Im et al. (1995). The authors measured that protein content in Chinese RSM and Indian RSM were 35.29% and 37.52%, respectively. Li et al. (2000) suggested that protein content in RSM was 35.60% and RSM contains more sulfur amino acids and slightly higher lysine values. Since the protein content of RSM is lower than SBM, higher levels of RSM must be included in the diet to provide the same level of dietary protein as that which would be supplied by SBM (Thacker, 1990). Also, our data indicated that the protein and lysine content in CNM were 16.32% and 0.45%, respectively.

Apparent ileal digestibilities of histidine, lysine, threonine, alanine, asparatic acid, cystine, glutamic acid and serine were greater for the KSBM, CSBM, ASBM and RSM than for the CNM ($p<0.05$, Table 3). Also, the apparent ileal digestibilities of methionine, leucine, phenylalanine, valine and tyrosine were greater for the KSBM than for the CSBM, ASBM, RSM and CNM ($p<0.05$). Overall, the apparent ileal digestibilities of total essential amino acids were greater for the KSBM than for the CSBM, ASBM, RSM and CNM ($p<0.05$), and the apparent ileal digestibilities of total non essential amino acids were greater for the KSBM, CSBM, ASBM and RSM than for the CNM ($p<0.05$). No difference ($p>0.05$) in apparent digestibility of DM at the small intestine was observed among the treatments. However, the apparent digestibilities of DM at the total tract was greater for the KSBM than for the CSBM, ASBM, RSM and CNM ($p<0.05$). Also, apparent digestibility of N and digestible energy at the small intestine and total tract were greater for the KSBM than for the RSM and CNM ($p<0.05$).

Apparent ileal digestibilities of amino acids for SBM were similar to or lower than those reported in other research and literature reviews (NRC, 1998; Ko et al., 1999; Woodworth et al., 2001). Likewise, the apparent ileal digestibilities of amino acids for RSM and CNM have previously been shown to be similar or lower than those reported in other research and literature reviews (NRC, 1998; Buraczewska et al., 1999; Li et al., 2000). Sauer et al. (1982) demonstrated that true ileal availabilities of amino acids were higher in SBM than in canola meal or RSM. Also, Fan et al. (1996) reported that essential amino acids in canola meal, the digestibility values of arginine, histidine and methionine were relatively high, ranging from 79.4 to 84.4, 76.5 to 81.0% and 77.3 to 82.4%, respectively, while the digestibility values of threonine and tryptophan were relatively low, ranging from 59.7 to 66.5 and 61.7 to 67.5%, respectively. Buraczewska et al. (1999) demonstrated that crude protein and amino acids digestibilities were higher in

Table 3. Apparent ileal digestibility of amino acids of the corn starch-based diets containing soybean meal, rapeseed meal and coconut meal as the vegetable protein source in finishing pigs[1]

Item, %	KSBM[2]	CSBM[2]	ASBM[2]	RSM[2]	CNM[2]	SE[3]
Essential amino acids						
Arginine	82.81[b]	86.22[ab]	87.56[a]	85.34[ab]	69.68[c]	1.43
Histidine	82.08[a]	77.56[a]	79.45[a]	77.67[a]	69.57[b]	1.57
Isoleucine	79.31[a]	75.42[ab]	76.18[ab]	73.36[b]	63.34[c]	1.81
Leucine	84.08[a]	75.26[b]	75.10[b]	72.72[b]	66.66[c]	1.83
Lysine	79.23[a]	76.15[a]	76.66[a]	74.60[a]	56.35[b]	1.97
Methionine	83.52[a]	70.58[b]	73.29[b]	75.19[b]	72.29[b]	1.51
Phenylalanine	83.68[a]	77.88[b]	78.31[b]	76.35[b]	66.60[c]	1.57
Threonine	65.45[a]	60.48[a]	64.38[a]	60.23[a]	50.30[b]	3.01
Valine	78.65[a]	70.81[b]	72.41[b]	70.52[b]	59.44[c]	1.91
Total essential amino acids	79.87 [a]	74.48 [ab]	75.93 [ab]	74.00 [ab]	63.80 [b]	1.85
Non essential amino acids						
Alanine	66.16[a]	65.59[a]	65.14[a]	63.24[a]	51.61[b]	2.53
Asparatic acid	69.83[a]	73.27[a]	75.69[a]	73.53[a]	51.51[b]	2.27
Cystine	67.29[a]	69.17[a]	72.11[a]	70.26[a]	47.42[b]	2.14
Glutamic acid	76.93[a]	80.82[a]	78.30[a]	79.48[a]	71.30[b]	1.29
Glycine	48.03	56.27	54.21	54.38	44.73	3.59
Proline	81.80[a]	69.07[b]	72.73[ab]	72.38[ab]	57.57[c]	3.81
Serine	71.11[a]	70.90[a]	72.53[a]	69.49[a]	56.17[b]	2.28
Tyrosine	88.99[a]	76.44[b]	76.67[b]	72.70[b]	71.05[b]	1.89
Total non essential amino acids	71.27[a]	70.19 [a]	70.92 [a]	69.43 [a]	56.42 [b]	2.48

[1] Five barrows with an average BW of 58.6 kg. [2] Abbreviated KSBM, Korean soybean meal; CSBM, Chinese soybean meal; ASBM, Argentine soybean meal; RSM, Rapeseed meal; CNM, Coconut meal. [3] Pooled standard error. [abc] Means in the same row with different superscripts differ ($p<0.05$).

Table 4. Apparent digestibility of DM, N and digestible energy of the corn starch-based diets containing soybean meal, rapeseed meal and coconut meal as the vegetable protein source in finishing pigs[1]

Item, %	KSBM[2]	CSBM[2]	ASBM[2]	RSM[2]	CNM[2]	SE[3]
DM digestibility						
Small intestine	73.04	67.70	68.68	66.77	65.60	2.80
Total tract	82.01[a]	76.14[bc]	77.21[b]	73.33[bc]	71.89[c]	1.56
N digestibility						
Small intestine	76.57[a]	70.34[ab]	71.30[ab]	66.34[bc]	60.26[c]	2.30
Total tract	80.66[a]	75.81[ab]	75.53[ab]	69.70[bc]	63.37[c]	2.60
Digestible energy	83.44[a]	78.17[ab]	77.77[ab]	70.99[bc]	67.35[c]	2.75

[1] Five barrows with an average BW of 58.6 kg. [2] Abbreviated KSBM, Korean soybean meal; CSBM, Chinese soybean meal; ASBM, Argentine soybean meal; RSM, Rapeseed meal; CNM, Coconut meal. [3] Pooled standard error. [abc] Means in the same row with different superscripts differ ($p<0.05$).

SBM than in RSM; the difference in crude protein digestibilities was about 17%, with value higher than our results (10%, KSBM vs. RSM). Lower digestibility values of canola meal were demonstrated by Sauer et al. (1982). The authors suggested that lower digestibility values of canola meal than SBM may be attributed to its higher fiber content (7.20%, Li et al., 2000), as a result of a large proportion of hulls and protein associated with hulls, which are poorly digestible (Li and Sauer, 1994). Furthermore, oil extraction and toasting procedures, particularly treatment duration with high temperature, may affect amino acid digestibility of RSM, especially lysine (Grala et al., 1994). Apparent ileal digestibility of arginine was relatively high, which those of glycine and threonine were relatively low as compared with other amino acids (Table 4). The improved digestibility of arginine may result from specificity of digestive proteolytic enzymes hydrolyzing peptide bonds with this amino acid (Low, 1980).

Our data indicated that dietary CNM decreased apparent ileal digestibilities of amino acids, DM, N and DE in finishing pigs. Similar results were reported by Noblet and Perez (1993) who observed that a high level of fiber in the diet resulted in some of the organic matter, protein and energy in the diet becoming unavailable. Coconut meal had more crude fiber compared with SBM. Flipot et al. (1971) implicated crude fiber as a factor depressing utilizability of amino acids. The results indicated that proper use of CNM by poultry could be achieved by combining it with other protein sources to provide better amino acid balance.

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