The Effects of Chinese and Argentine Soybeans on Nutrient Digestibility and Organ Morphology in Landrace and Chinese Min Pigs

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ABSTRACT : Twenty Landrace and twenty Min piglets, with an average initial body weight of 22.4 kg, were randomly divided into 5 groups with 4 animals per group, within each of the breeds. The piglets were housed in individual concrete pens. Each group of the piglets was fed one of 5 diets. The diets contained either 20% raw Argentine soybeans, 20% processed Argentine soybeans (118°C for 7.5 min.), 20% raw Chinese soybeans, 20% processed Chinese soybeans (118°C for 7.5 min.) or no soybean products (control diet). Faecal samples were collected on days 6, 7 and 8 of the treatment period. Digestibilities of dietary nutrients were determined with AIA (acid insoluble ash) as a marker. After a 17 day treatment, three piglets were killed from each of the groups. Tissue samples of small and large intestine for light and electron microscopy examination were taken immediately after the opening of abdomen. Then, the weight or size of relevant organs was measured. The results show that the digestibilities of dry matter (DM), crude protein (CP) and fat were higher in Min piglets than in Landrace piglets ($p<0.05$). The diets containing processed soybeans had a significant higher CP digestibility than the control diet and the diets containing raw soybeans ($p<0.05$). Landrace piglets had heavier and longer small intestines, heavier kidneys and a lighter spleen than Min piglets ($p<0.05$). The pancreas of the animals fed the diets containing processed soybeans was heavier than that of the animals fed control diet ($p<0.05$) and the diets containing raw soybeans. But, the differences between raw and processed soybean diets were not significant. A significant interaction ($p<0.05$) between diet and pig breed was observed in weight of the small intestine. The Landrace piglets increased the weight in their small intestine when they were fed the diets containing soybeans. In the light micrographs and electron scanning micrographs, it was found that the villi of small intestinal epithelium of animals (especially Landrace piglets) fed the diets containing raw Chinese soybeans were seriously damaged. The transmission electron micrograph showed that a lot of vesicles were located between the small intestinal microvilli of these piglets. The histological examination also indicated that the proportion of goblet cells in villi and crypts in the piglets consuming the control diet was significantly lower ($p<0.01$ and $p<0.02$, respectively) than those of the animals consuming the diets containing raw or processed soybeans. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 4 : 555-564)***

Key Words : Full-Fat Soybean, Digestibility, Organ Morphology, Pig Breed

INTRODUCTION

Full-fat soybeans contain a high level of energy and protein. They are an ideal protein source in diets for farm animals. However, the nutritional value of soybeans is not consistent because of the variation in contents of antinutritional factors (ANFs) (Herkelman et al., 1992). The effects of feeding soybeans on animals depend not only on the properties (composition or ANF levels) of soybeans themselves, but also on the animals consuming them. Different species of animals respond differently to the ANFs in soybeans (Noland et al., 1976; Nitsan and Nir, 1986; Xian and Farrell, 1991) and also to ANFs in other legume seeds (Van der Poel et al., 1990a,b). Pigs are considered more sensitive to ANFs than chickens and rats (Huisman et al., 1990a,b).

The response of pigs to feeding raw or under-processed soybeans varies with their physiological state such as age, pregnancy etc., as reported by Herkelman and Cromwell (1990), Marty and Chavez (1993), Monari (1993) and Qin and Chen (1995). It is not clear whether there are also differences between different breeds or lines of pigs in their ability to tolerate soybean ANFs. Considerable variation in the morphology of the digestive organs and in digestibility of some dietary nutrients has been observed among different breeds or genotypes of pigs (Qin et al., 1995). If a significant difference in response to soybean ANFs exists between breeds or genotypes of pigs, then the optimal procedure for processing full-fat soybeans could be different for genetically different populations of pigs. This could be of great importance for applying full-fat soybeans for pig production.

In the present study, different breeds of pigs were fed diets containing raw or well-heated (Qin et al., 1996) soybeans of Argentine or Chinese origin. It is aimed to investigate the possible differences between the soybean origins in their antinutritive properties, and also the possible differences between pig breeds in their responses to soybean ANFs. Criteria of research were the digestibilities of nutrients as well as the weight of some organs, length of small and large intestines and the histological examination of the small and large intestine tissue.

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MATERIALS AND METHODS

Soybean processing

Commercial soybeans (*Glycin max.*) from Argentine and Chinese origins were purchased from Schouten Industries (Giessen, The Netherlands) and Food and Oil Import and Export Company (Jilin province, China), respectively. Both the Argentine and Chinese soybeans were used in the experiment as either raw or steam-toasted at 118°C for 7.5 min. with a laboratory-scale steam toaster as described by Van der Poel et al. (1990a). The processing was carried out at the WageningenFeed Processing Centre, Wageningen, The Netherlands. The property of these soybeans and the processing procedure were the same as described by Qin et al. (1998). The processed soybeans were air-dried and sent to Changchun, Jilin province, P.R. China, for use in the experimental diets.

Diet formulation

Five diets, including one control and four treatment diets, were formulated according to the nutritional requirements of swine (NRC, 1988). The control diet did not contain soybeans or soybean products. The four treatment diets contained 20% of either raw or processed soybeans of Argentine or Chinese origin. The composition and nutrient contents of the diets are shown in tables 1 and 2.

Table 1. Composition of the control and experimental diets

	Control	Argentine soybeans		Chinese soybeans	
		Raw	Processed	Raw	Processed
Ingredients(%)					
Argentine raw soybeans	-	20.0	-	-	-
Argentine treated soybeans	-	-	20.0	-	-
Chinese raw soybeans	-	-	-	20.0	-
Chinese treated soybeans	-	-	-	-	20.0
Corn distillers' dried grain	19.72				
Corn meal	64.42	59.00	59.00	59.00	59.00
Wheat bran	8.39	13.59	13.59	13.59	13.59
Fish meal	5.00	5.00	5.00	5.00	5.00
Bone meal	1.06	0.58	0.58	0.58	0.58
Limestone meal	0.28	0.65	0.65	0.65	0.65
NaCl	0.18	0.18	0.18	0.18	0.18
L-lysine	0.40	-	-	-	-
Premix	1.00	1.00	1.00	1.00	1.00

Table 2. Nutrient contents of the control and experimental diets

	Control	Argentine soybeans		Chinese soybeans	
		Raw	Processed	Raw	Processed
Nutrient contents (%)					
Calculated					
Crude protein	17.5	176	17.6	17.6	17.6
DE (MJ/kg)	13.62	13.76	13.76	13.76	13.76
Lysine	0.95	0.95	0.95	0.95	0.95
Ca	0.7	0.7	0.7	0.7	0.7
P	0.6	0.6	0.6	0.6	0.6
TIA (%)	0.0	0.304	0.35	0.412	0.076
Analysed:					
Dry matter	90.7	90.6	90.4	90.6	90.6
Crude protein	16.9	16.8	16.8	16.7	16.9
Crude fat	4.5	6.3	5.0	5.1	7.2
Crude fibre	1.8	1.7	2.1	1.9	2.0
Crude ash	4.2	4.5	4.6	5.1	4.4
N-free extract	63.2	61.3	62.0	61.8	60.0
Acid insoluble ash (AIA)	1.5	1.2	1.1	1.4	1.2

Animals and management

Twenty Landrace and twenty Min (a native pig breed in the Northeast of China) male piglets, with an average initial body weight of 22.9 kg for Landrace and 22.0 kg for Min piglets, were randomly divided into 5 groups with 4 animals per group, within each of the breeds. The animals were housed in individual concrete pens for a period of 17 days. This period consisted of a 3 day's adaptation period and a 14-day's treatment period. Each group of the piglets were fed one of the 5 diets. The feed was provided 3 times daily at 08:00, 11:30 and 16:00 h as wet mash with a feed:water ratio of 1:1. Water was ad libitum available in the troughs. During the adaptation period, the feed allowance was adjusted to the appetite of each piglet and then this level of intake was maintained during the experimental period. The pens were cleaned twice a day to guarantee that only the diet and water was ingested by the animals.

Collection of faeces, organ and tissue samples

Faeces were collected from 06:00 to 18:00 h on day 6, 7 and 8 of the treatment period. After collection, the faeces were immediately stored in a plastic bag in a freezer (-20°C). After the collection period, the faeces of each individual animal were pooled and sampled for analyses.

On the day following the termination of the treatment period, three piglets were randomly taken from each of the groups. After the animals were weighed, they were killed by bleeding. The organs were removed quickly from the abdomen. The small and large intestines, pancreas, liver, spleen, stomach and kidney were weighed after sampling the tissue of the small and large intestine. The length of the small and large intestines were also measured.

Samples of small intestinal tissue were taken at 2 meters below the pyloric sphincter. For the large intestine, the tissue was sampled at the apex of the spiral coil of the colon. After being washed in saline, the samples were fixed in formalin for light microscopy, and in 2.5% glutaraldehyde solution for electronic microscopy.

Chemical analyses

The trypsin inhibitor activity of all soybean samples was determined according to the modified procedure of Kakade et al. (1974) as described by Van Oort et al. (1989). Acid insoluble ash (AIA) content of the diets and the faecal samples was determined according to the 4 N HCl insoluble method as described by Yang (1983). Nitrogen (N) was determined by the Kjeldahl method, and the crude protein (CP) content was calculated as N×6.25. Dry matter (DM), crude fibre (CF), ash (AS) and crude fat (EE) were determined, and N-free extract (NFE) was calculated according to conventional procedures (Yang, 1983).

Histological examination

For the light microscopy examination, the tissue samples of the intestines were cut into serial sections of 6 μm thickness. Successive sections were chosen and stained according to conventional H.E. (haematoxylin and eosin) and PAS (periodic acid-schiff) reaction procedures (Humason, 1967), respectively. General pathological examination and depth of colon enteradon (DCE) were conducted on the sections stained with the H.E method. The proportions of goblet cells in the epithelium (number of goblet cells/total number of cells counted) of villus (PGV) and of crypts (PGC) were measured on the sections stained with the PAS method.

Scanning electron microscopy and transmission electron microscopy were conducted with a HITACHI S570 and a HITACHI JEEM1-200, respectively, following the procedures as described by Li and Wen (1990).

Calculations and statistical analysis

The faecal digestibilities of dietary nutrients were calculated using the content of AIA (as an indigestible marker) and the corresponding nutrients in the diets and faecal samples by the following formula:

$$T(\%)=100-(b\times c)/(a\times d)\times 100$$

Where T: digestibility of a nutrient (%); a: the content of the nutrient in the diet (%); b: the content of the nutrient in the faecal sample (%); c: AIA content of the diet (%); d: AIA content of the faecal sample (%).

Analysis of variance was conducted for nutrient digestibilities, organ measurements and histological examination data using the following model:

$$Y_{ijk}=\mu+a_i+b_j+(a\times b)_{ij}+e_{ijk}$$

where Y_{ijk}: individual observation; μ: the expected mean; a_i: the effect of diet i; b_j: the effect of breed j; $(a\times b)_{ij}$: the interaction between a_i and b_j; e_{ijk}: the error term.

Linear correlation analysis was conducted between the relevant parameters. The software of SAS (1989) was used in the statistical analysis.

RESULTS AND DISCUSSION

Digestibility of dietary nutrients

For all groups of animals, except the Min piglets fed control diet, the daily feed intake was nearly the same (about 1,065 g/day.animal) (table 3). The diet nutrient digestibilities are presented in tables 4 and 5. In table 4, the digestibilities were compared between control diet and soybean-containing diet (pooled data of all soybean-containing diets). The digestibilities for dry matter (DM), fat (ether extract, EE), crude fibre (CF) and ash for the soybean-containing diet were significantly ($p<0.05$) higher than those for control diet. Crude protein (CP) digestibility of the soybean-containing diet was also higher then control diet, but not significant ($p<0.10$). The lower nutrient digestibilities of the control diet were probably caused by the inclusion of corn distillers' dried grains. Distillers' grains have a considerably lower digestibility. This is probably related to the distillation at high temperatures and the high concentration of ethyl alcohol. It's CP and gross energy digestibilities in pigs are only 60-70% (Qin, 1988; Sibrits, 1981). The ash digestibility of the control diet was extremely low, which can partially be explained by the relatively higher level of dietary acid insoluble ash (as shown in table 2).

DM, EE and CF digestibilities for Min piglets were significantly ($p<0.05$) higher than for Landrace piglets. A significant interaction in CF digestibility was observed between pig breed and diet. The digestibility of CF of the landrace piglets fed control diet was significantly ($p<0.05$) lower than that of the other treatments. This indicates that the source of dietary fibre may influence difference between pig breeds in CF digestibility. The higher digestibility values, especially the higher CF digestibility, of the Min pigs compared with the Landrace pigs observed in the present study agree with the results reported by Han et al. (1983).

Table 3. Daily feed intake (g/day/animal)*

Pig breed	Control	Argentine soybeans		Chinese soybeans	
		Raw	Processed	Raw	Processed
Landrace	1,064	1,067	1,065	1,064	1,067
Min	993	1,062	1,062	1,066	1,072

* SME:20.5.

Table 4. Effect of inclusion of full-fat soybeans on the digestibility of dietary nutrients

	DM	CP*	Ash	EE	CF	NFE
Means of diet						
Soya diet[1] (n=32)	81.2[a]	77.9	21.2[a]	62.3[a]	45.8[a]	84.9
Control diet (n=8)	78.2[b]	72.7	3.9[b]	47.7[b]	24.9[b]	87.2
Root SME	3.02	3.90	6.73	6.75	15.7	16.2

[1] Pooled data from the diets containing Argentine and Chinese, raw and heated soybeans.
* The significance of the difference between diets is "p<0.10".
[a,b] Means in the same column with different superscript differ significantly (p<0.05).

Table 5. Effect of soybean origin, processing and pig breed on the digestibility of dietary dry natter (DM), crude protein (CP), ash, fat (EE), crude fibre (CF) and nitrogen free extract (NFE)

	DM	CP	Ash	EE	CF	NFE
Means of treatment group (pig breed/diet, n=4)						
Landrace pigs:						
Argentine raw soybean diet	78.4	70.3	16.7	59.3	47.6	87.4
Argentine processed soybean diet	82.3	81.8	24.5	53.3	41.7	89.1
Chinese raw soybean diet	76.7	69.3	17.2	48.3	42.1	86.0
Chinese processed soybean diet	82.3	82.5	20.2	70.1	42.9	88.5
Min pigs						
Argentine raw soybean diet	81.5	76.4	23.4	66.4	46.5	88.7
Argentine processed soybean diet	84.1	84.2	28.4	68.5	54.4	84.7
Chinese raw soybean diet	78.6	72.5	18.8	53.6	45.7	87.7
Chinese processed soybean diet	84.1	86.1	20.4	78.8	46.0	88.9
Means of diets (n=8)						
Argentine raw soybean diet	79.9[ab]	73.4[b]	20.0	62.8[b]	47.0	88.1
Argentine processed soybean diet	83.2[a]	83.0[a]	26.4	60.9[bc]	48.0	86.9
Chinese raw soybean diet	77.7[b]	70.9[b]	18.0	50.9[cd]	43.9	86.8
Chinese processed soybean diet	83.2[a]	84.3[a]	20.3	74.4[a]	44.4	88.7
Means of pig breeds (n=16)						
Landrace pigs	79.4[b]	76.0[b]	19.6	57.7[b]	43.5	87.8
Min pigs	82.4[a]	79.8[a]	22.7	66.9[a]	48.1	82.1
Root SME	3.02	3.90	6.73	6.75	15.7	16.2

* Means in the same column and same block with different superscript differ significantly (p<0.05).

In table 5, nutrient digestibilities were compared between diets containing different soybeans. The results show that steam-heating significantly (p<0.05) improved the digestibilities of dietary DM, CP, EE and ash. The improvement of the digestibilities of these nutrients may be related to the inactivation of soybean ANFs, because the digestibilities DM and CP were highly and negatively correlated to the dietary TIA (table 8). This is in agreement with the results reported by Nitsan and Nir (1986), Qin et al. (1996), Vandergrift et al. (1983) and Visser and Tolman (1993).

Soybean origin had no significant (p<0.05) effect on the digestibilities of nutrients. But, there was a significant (p<0.05) interaction in EE digestibility between soybean origin and heat-processing (table 5). The EE digestibility of the diet containing raw Chinese soybeans was 23.5 percentage units higher than the diet containing processed Chinese soybeans. For Argentine soybeans, however, the heating did not improve the digestibility of EE. It is possible that properties and/or levels of ANFs relevant to EE digestion are different between Argentine and Chinese soybeans.

Organ measurements

Data for organ measurements were compared between pig breeds, between diets and between treatment groups (table 6). The small intestine of Landrace pigs was significantly (p<0.05) longer and heavier than that of Min pigs. For the large intestines, there are no significant differences in the length and weight between the two breeds. The diet did not have a statistically significant influence on the measurements of the intestines, but the small intestinal weight varied considerably among diets (p<0.25). The animals which consumed the Chinese raw soybean diet, for example, had a clearly heavier small intestine than those which consumed the other diets. A significant (p<0.05)

Table 6. Effect of soybean origin, processing and pig breed on pig's organ measurements* (cm or g/kg body weight)

	SIL	LIL	PANW	SIW	LIW	LIVW	SPLW	STOMW	KIDW
Means of treatment groups (pig breed/diet, n=3)									
Lan/ArR	0.68	0.14	1.57	40.12[abc]	18.86	22.11	1.45	10.97	4.55
Lan/ArP	0.67	0.12	1.56	45.85[ab]	18.31	22.43	1.45	8.89	4.67
Lan/ChR	0.72	0.15	1.36	50.29[a]	20.64	27.03	1.32	9.47	5.12
Lan/ChP	0.67	0.13	1.74	44.27[abc]	19.72	24.19	1.52	9.19	5.52
Lan/Cont.	0.68	0.13	1.12	37.91[bc]	23.26	21.27	1.57	9.53	4.73
Min/ArR	0.64	0.13	1.53	39.25[abc]	20.14	24.50	1.74	10.92	3.95
Min/ArP	0.52	0.13	1.79	32.85[c]	20.31	23.79	2.61	9.82	3.94
Min/ChR	0.58	0.11	1.36	36.95[bc]	18.50	20.80	2.13	10.17	3.69
Min/ChP	0.52	0.12	1.58	35.12[bc]	17.95	24.56	1.61	9.78	4.31
Min/Cont.	0.65	0.13	1.35	38.74[abc]	20.60	24.91	2.00	9.20	4.36
Means of diets: (n=6)									
ArR	0.66	0.13	1.55[ab]	39.69	19.50	23.31	1.60	10.95[a]	4.25[b]
ArP	0.60	0.12	1.68[a]	39.35	19.31	23.11	2.03	9.36[b]	4.30[ab]
ChR	0.65	0.13	1.36[ab]	43.62	19.57	23.92	1.72	9.82[ab]	4.41[ab]
ChP	0.59	0.12	1.66[a]	39.70	18.84	24.38	1.57	9.49[ab]	4.92[a]
Cont.	0.66	0.13	1.24[b]	38.32	21.93	23.09	1.79	9.36[b]	4.55[ab]
Means of pig breeds (n=15)									
Landrace	0.68[a]	0.13	1.47	43.69[a]	20.16	23.41	1.46[b]	9.61	4.92[a]
Min	0.58[b]	0.12	1.52	36.58[b]	19.50	23.71	2.02[a]	9.98	4.05[b]
Root SME	0.07	0.02	0.24	4.03	3.03	2.59	0.50	0.89	0.38

* SIL: small intestinal length; LIL: large intestinal length; PANW: pancreas weight; SIW: small intestinal weight; LIW: large intestinal weight; LIVW: liver weight; SPLW: spleen weight; STOMW: stomach weight; KIDW: kidney weight.

[a,b,c] Means in the same column and same block with different superscript differ significantly ($p<0.05$).

interaction was observed between pig breed and diet for the small intestine weight. The small intestine of the Landrace pigs fed the diets containing various soybeans were, in general, heavier than those of the Min pigs which consumed the same diets. For the animals fed the control diet, however, the results were contradictory. No significant interactions between pig breed and diet were found for length and weight of large intestine and for length of the small intestine.

Similar results to those of the present study have been reported previously in the literature. Enlargement of the small intestine of chicks, geese or rats was caused by feeding raw soybeans (Nitsan and Nir, 1986), purified soybean lectin (Grant et al., 1987 and 1988) or kidney bean (*Phaseolus vulgaris*) lectin (De Oliviera et al., 1988). Huisman et al. (1990a) reported that the weight of the small intestine of piglets was increased by feeding raw kidney beans (*Phaseolus vulgaris*) compared to feeding heated beans. According to Grant et al. (1988) the enlargement or increased weight of the small intestine is mainly due to the cellular proliferation caused by ingesting lectin. In the present study, the heaviest small intestine was found in the animals fed the diet containing raw Chinese soybeans, indicating that raw Chinese soybeans may contain a higher level of lectin. Moreover, Landrace piglets were more sensitive to feeding diets containing both raw and processed soybeans. This can be seen in the increased small intestine weight of the Landrace piglets consuming various soybeans.

Normally, Chinese native pig breeds have heavier intestines, especially the large intestine, compared with Landrace (Zhao, 1989) and Large white pigs (Fevrier et al., 1988). The results of the present study, however, do not agree with these previous observations. This is possibly caused by the higher sensitivity of the Landrace piglet to the ANFs of soybeans, because the small intestine of Landrace piglets were heavier than that of Min piglets when fed the diets containing soybeans, but the opposite was observed when the control diet was fed. The high and negative correlation coefficients of small intestine weight and/or length to crude protein and crude fat digestibilities (table 8) indicates that animals with heavier small intestines did not digest or absorb dietary nutrients as good as those with lighter small intestines. This is an evidence that the heavier small intestine of Landrace piglets may result from a pathological effect caused by soybean ANFs.

The relative weight of the intestines may be associated with age and body weight of Animals (Duan, 1984). The large intestine may develop in later time of life. The great genetic potential for large intestinal development of Min pigs has not been realized when these animals were killed at the body weight of less than 30 kg in the present experiment. This is another explanation for the difference in intestinal weights found in the present study compared with previous reports (Zhao, 1989).

Table 7. Proportions (%) of goblet cells in villi (PGV) and crypts (PGC) of small intestine and depth of colon enteraden (DCE)

	PGV (%)	PGC (%)	DCE (μm)
Means of treatment groups (pig breed/diet, n=3)			
Landrace/ArR	8.23	23.47	403.78
Landrace/ArP	10.20	25.07	433.16
Landrace/ChR	8.53	23.83	429.73
Landrace/ChP	10.05	28.03	452.41
Landrace/Control	7.13	21.77	389.52
Min/ArR	11.37	24.10	353.78
Min/ArP	9.25	23.80	372.34
Min/ChR	10.03	21.47	328.18
Min/ChP	8.07	25.13	343.81
Min/Control	6.33	14.67	384.71
Means of Diets (n=6)			
ArR	9.80	23.78	378.78
ArP	9.82	24.56	402.75
ChR	9.28	22.65	378.95
ChP	8.86	26.58	398.11
Control	6.73	18.22	387.11
Means of pig breeds (n=15)			
Landrace	8.74	24.43	421.72[a]
Min	8.99	21.69	356.56[b]
Root SME	2.13	5.04	36.01

Means in the same column and same block with different superscript differ significantly (p<0.05).

Table 8. Correlation coefficients between relevant parameters

	Correlation coefficient	Probability (P<)
D-DM vs TIA	-0.991	0.01
D-CP vs TIA	-0.981	0.01
D-CP vs SIL	-0.593	0.01
D-CP vs PANW	0.495	0.01
D-CP vs STOMW	-0.372	0.05
D-CP Vs SIW	-0.332	0.10
D-CF vs PGC	-0.493	0.01
D-CF vs LIL	0.498	0.01
D-EE vs SIL	-0.576	0.01
D-EE vs PANW	0.415	0.01
D-EE vs SIW	-0.480	0.01
D-ash vs PGC	-0.569	0.01
TIA vs PANW	-0.952	0.01
SIL vs PANW	-0.360	0.05
SIL vs SPLW	-0.567	0.01
SIL vs KIDW	0.506	0.01
SIL vs DCE	0.485	0.01
LIL vs PGV	-0.397	0.05
LIL vs PGC	-0.417	0.05
SIW vs SPLW	-0.588	0.01
SIW vs KIDW	0.759	0.01
SIW vs DCE	0.545	0.01

* TIA: trypsin inhibitor activity; SIL: small intestinal length; PANW: pancreas weight; STOMW: stomach weight; PGC: proportion of goblet cell in crypts of small intestine; LIL: large intestinal length; SIW: small intestinal weight; SPLW: spleen weight; KIDW: kidney weight; DCE: depth of colon enteraden; PGV: proportion of goblet cell in villi of small intestine; D-DM, D-CP, D-CF, D-EE and D-ash are the digestibility coefficient of dietary DM, CP, CF, EE and ash.

The pancreas weight of piglets was significantly (p<0.05) influenced by diet. The animals fed the processed soybean-diets had heavier (p<0.05) pancreas than those fed the control and raw soybean-diets. Feeding raw soybeans, under-processed soybean products, or other legume seeds such as Vicia faba, Pisum sativum and *Phaseolus vulgaris* beans causes enlargement of the pancreas in rats, chicks, mice and geese due to the presence of trypsin inhibitors in these ingredients (Liener et al., 1985; Nitsan and Nir, 1986; Huisman et al., 1990a,b). For pigs, as well as for some other animals, whose relative pancreatic weight is normally below 0.3% of the body weight ingesting soybean trypsin inhibitors may not cause pancreatic hypertrophy (Yen et al., 1974). When the effect of feeding raw compared with heat processed *Phaseolus vulgaris* beans, it was found that the relative pancreatic weight of the piglets fed the diets containing raw beans was lower (Huisman et al., 1990a; Van der Poel et al., 1990a) or the same as that of the piglets fed the diets containing processed beans (Huisman et al., 1990b). The heavier pancreas of the animals consuming the diets containing treated soybeans in the present study agrees with that reported in above mentioned literature. Pancreatic hypertrophy may be a adaptive mechanism to overcome the depressive effects of trypsin inhibitors. The animals which can develop pancreatic hypertrophy may adapt more easily to dietary protease inhibitors than those who cannot develop this mechanism (Nitsan and Nir, 1986). Inability to develop pancreatic hypertrophy may be one of the explanations for the higher sensitivity of piglets than rats of and chicks to legume ANFs. In the present study, the high and positive correlations between pancreas weight and protein (p<0.01) or crude fat (p<0.01) digestibilities, and high and negative correlation between pancreas weight and dietary TIA (p<0.01) were observed (table 8). This indicates that the decreased nutrient digestibilities of the diets containing raw soybeans result from both the inhibition of digestive enzymes and from the inability of compensative enzyme production by the pancreas.

Landrace piglets had significant (p<0.05) heavier kidney and lighter spleen than Min piglets. The weights of liver and stomach were not significantly different between the pig breeds (table 6). However, diet treatment had a significant (p<0.05) influence on stomach and kidney weights, but not on liver and spleen weights. The stomachs of the animals fed the diets containing raw soybeans were heavier than those of the animals fed the diets containing processed soybeans. The correlation coefficient showed that stomach weight was negatively correlated to the digestibility of CP ($p<0.05$). This means that the increased stomach weight was associated with soybean ANFs. It is remained to be studied whether the increased stomach weight was due to a increased secretion caused by ANFs or by other means of the actions of the ANFs.

The processing and origin of soybeans did not evidently influence the kidney weight. However, higher correlations between kidney weight and small intestinal length ($p<0.01$) or weight ($p<0.01$) were observed. This indicates that the enlargement of the small intestine may be accompanied by an enlargement of the kidneys. It is possible that the animals with heavier and/or longer small intestine may be different from other animals in composition (such as nitrogen) or amount of their urine, which subsequently influence their kidney weight.

Histological observations

The status of small intestinal epithelial mucosa of the piglets varied among the treatment groups from normal in the animals fed the control diet to most seriously damaged in the animals fed the diet containing raw Chinese soybeans. In the light micrographs (figure 1) and electron scanning micrographs (figure 2), it can be seen that the upper part of the villi of the piglets fed the diet containing raw Chinese soybeans were damaged seriously. The cells at the top of the villi are sloughed off in these animals. The sloughing off is more serious in Landrace piglets than in Min piglets (see figures 1 and 2) when they were fed raw Chinese soybean diet. The damage of the villi is possibly associated with lectin in the soybeans. It was reported that soybean lectin mainly bind to the mature cells on the upper part of the villi and may lead to extensive damage of the cells (Pusztai, 1988). In the transmission electron micrographs of small intestine epithelial cells of the animals fed the diet containing raw Chinese soybeans, a lot of vesicles were observed between the microvilli. No vesicles were found in that of the animals fed the control diet (figure 3). It has been reported that higher numbers of microvillus vesicles are formed in the explants of the pig small intestine mucosa cultured in the presence of air classified common bean (*Phaseolus vulgaris* L.) fraction (Van der Poel et al., 1990) or cultured in the presence of purified *Phaseolus vulgaris* lectin than in that of control animals (Kik et al., 1991). Similar vesicles were also observed in epithelial cells of rats (King et al., 1982) and Caco-2 cells of humans (Hendriks et al., 1991) after exposure to lectin. The presence of these vesicles probably reflects an increased turnover of the microvillus membrane according to Hendriks et al. (1991). The mechanism involved in the development of the vesicles is not clear.

The proportion of goblet cells in villi (PGV) and crypts (PGC) did not significantly differ between pig breeds, but the PGC of Min piglets tended to be higher than of Landrace piglets ($p<0.16$). The PGV and PGC of the piglets on the control diet was clearly lower than those of the animals on both the diets with raw and with processed soybeans ($p<0.12$ and $p<0.10$, respectively). Interaction between pig breed and diet was not significant for PGV and PGC (table 7). The increased PGV and PGC in the piglets fed the soybean diets might be associated with the production of more mucus on the intestinal mucosal surface (Kik et al., 1988), which is a possible response of the animals to soybean diets. The negative correlation coefficients of PGV and PGC with large intestinal length, and of PGC with digestibilities of crude fibre and ash (table 8) suggest that increased PGC and PGV, by secreting more mucous, probably shortens the residence time of the digesta inside the digestive tract, especially in the hind gut because the digestion of fibre and absorbtion of minerals occurs mainly in the large intestine. The increased secretion of mucous and the rapid passage of digesta may be part of the mechanism of diarrhoea caused by feeding soya products to piglets. The similarity in PGV and PGC between the animals consuming raw and processed soybean diets indicates that the increased amount of goblet cells in intestinal epithelium may result from some heat-stable factors in soybeans.

Landrace piglets had significantly ($p<0.05$) deeper colon enteraden (DCE) than Min piglets. There were no evident differences between diets in the DCE. The data of various treatment groups showed that when animals were fed the control diet there was almost no difference between pig breeds in DCE, although Landrace piglets fed any soybean diet showed deeper colon enteraden than Min piglets. The interaction between pig breed and diet for DCE ($p<0.13$) showed that Landrace piglets were more sensitive to soybean diets in DCE than Min piglets. It was also found that the animals with longer and/or heavier small intestines had deeper colon enteraden. The correlation coefficients between DCE and length or weight of small intestines are shown in table 8.

CONCLUSION

The results of the present study show that the digestibilities of dietary dry matter, crude protein, crude fat, crude fibre, ash and N-free extract are generally higher in Min piglets than in Landrace piglets at a body weight of about 30 kg. Landrace piglets have a longer and heavier small intestine, heavier kidneys, deeper colon enteraden and a smaller spleen than Min piglets when fed the same diet containing full-fat soybeans. The significant differences in

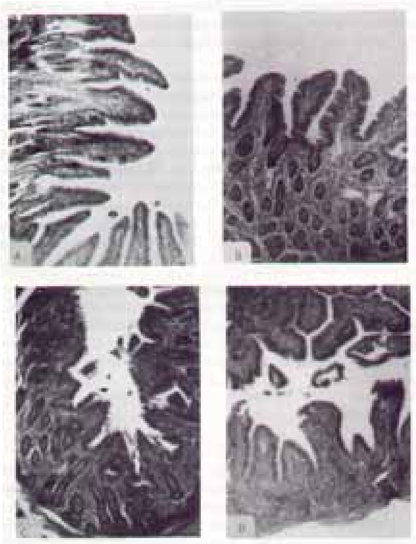

Figure 1. Light microphotograph (X32) of Small intestinal epithelial mucosa of piglets

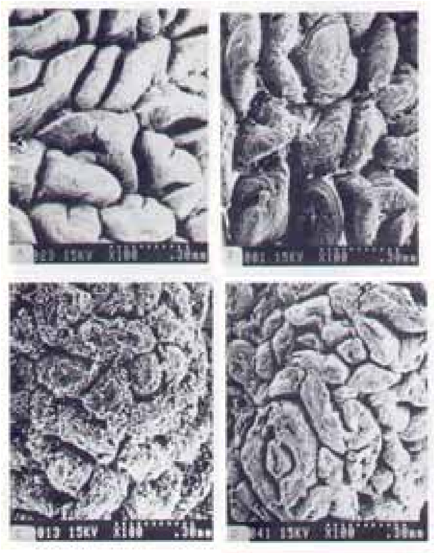

Figure 2. Scanning electron microphotograph of small intestinal epithelial mucosa of piglet

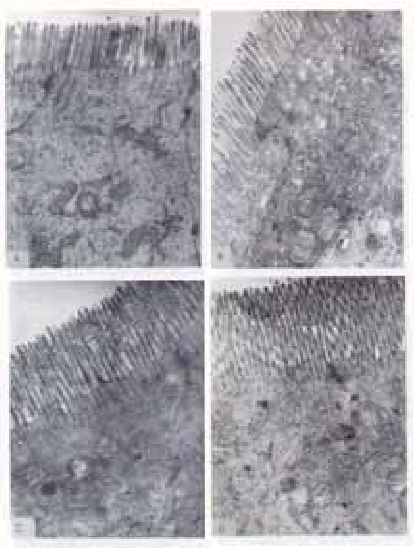

Figure 3. Transmission electron microphotograph (X12000) of small intestinal epithelial cell of piglet

#A: LP/CD B: MP/CD C:LP/RC D: MP/RC #A: LP/CD B: MP/CD C: LP/RC D: MP/RC #A: LP/CD B: MP/CD C: LP/RC D: MP/RC#
LP/CD: Landrace piglet/Control diet MP/CD: Min piglet/Control diet LP/RC: Landrace piglet/Raw Chinese soybean diet MP/RC: Min piglet/Raw Chinese soybean diet.

nutrient digestibilities and in organ measurements between animals fed different diets show that steam-heating can effectively improve the feeding value of the full-fat soybeans. Furthermore, raw Chinese soybeans may have more deleterious effects on nutrient digestibilities and animal health than raw Argentine soybeans. The interaction between the pig breed and dietary composition on organ measurements and histological examinations demonstrates that Landrace piglets are more sensitive than Min piglets to raw soybean diets. The proper processing of full-fat soybeans is more necessary for feeding Landrace pigs than for Min pigs.

The digestibilities of dietary dry matter and crude protein, and pancreas weight are highly and negatively correlated to the dietary TIA level. Ingesting a raw soybean diet may cause a decrease in pancreas weight and an increase in length and weight of the small intestine. Based on the correlation analysis, crude protein and fat digestibility reduction is accompanied by a decrease in pancreas weight and an increase in length and weight of the small intestine.

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