Effects of Feeding Rice Protein Concentrate on Growth Performance and Ileal Digestibility in Early-weaned Pigs

J. H. Yun, J. S. Yong and B. J. Chae*
Division of Animal Resources, Kangwon National University, 192-1, Hyoja-2-dong, Chunchon 200-701, Korea

ABSTRACT : These experiments were conducted to evaluate the feeding value of rice protein concentrate (RPC) in weaning pigs. In expt. I, a 5-week feeding trial was conducted with 126 pigs (L×Y×D; 21 d-old; 5.32±0.34 kg). Treatments were spray-dried plasma protein (SDPP; control), soy protein concentrate (SPC) and RPC (phase 1), and dried porcine soluble (DPS; control), SPC and RPC (phase 2). An ileal digestibility trial was also conducted to compare digestibility of amino acids in the tested protein sources. In expt. II, 160 weaning pigs (L×Y×D; 21 d-old; 5.65±0.35 kg) were used in a 5-week feeding trial to determine the optimal inclusion level of RPC in the diet. Treatments were control (9% SPC), and three levels of RPC instead of SPC in the diets (3, 6 and 9%). During phase 1, pigs fed SDPP showed better ($p<0.05$) ADG and FCR compared with those fed SPC or RPC, while there was no difference in ADFI among treatments. During phase 2, however, pigs fed DPS showed lower ($p<0.05$) ADG than those fed SPC or RPC. During the total period, there were no significant differences in ADG, ADFI and FCR among treatments. The apparent ileal digestibilities of his, lys, phe, thr and met were not different among the tested protein sources. The apparent ileal digestibilities of arg, ile, leu and val were lower ($p<0.05$) in RPC than SDPP. The true ileal digestibilities of arg and leu were lower ($p<0.05$) in RPC than SDPP and SPC. However, that of met was higher ($p<0.05$) in RPC than SDPP. In expt. II, there were no significant differences in ADG and FCR when SPC was substituted with RPC up to 9% during the total period. In conclusion, based on our experimental results, RPC would replace SPC in the complex prestarter diet, which is somewhat cheaper than SPC. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 3 : 384-389)***

Key Words : Rice Protein Concentrate, Soy Protein Concentrate, Growth, Digestibility, Pig

INTRODUCTION

Soybean meal (SBM) is widely used as protein source in animal feeds throughout the world. However, young animals such as calves and piglets are sensitive to the antigenetic activity of SBM due to antinutritional factors (ANFs), so these animals suffer poor growth and digestive disorders when fed SBM (Lalles et al., 1993). Extruded full-fat soybeans were also tested as an alternative to soybean meal for use in weaned pig diets with some success (Qiao et al., 2003).

In fact, milk products such as dried skim milk and dried whey are typical feed ingredients in young pigs, due to their high palatability and digestibility, but these are somewhat expensive. Therefore, specially processed soy products such as soy protein concentrate (SPC) and soy protein isolate (SPI) is used in the starter diet. SPC is prepared from soybeans by removing most of the fat and water-soluble, non-protein constituents, and SPI is prepared by removing the majority of water-soluble, non-protein components from dehulled SBM (Kolar et al., 1985; Snyder and Kwon, 1988; Cromwell, 2001). It was reported that SPC and SPI provide equal or improved growth performance as compared with milk-based diets (Sohn et al., 1994).

Animal protein sources like spray dried plasma protein (SDPP) and dried porcine soluble (DPS) are also used in young pig diets. SDPP increases feed intake (Ermer et al., 1994; Kats et al., 1994; Chae et al., 1999) and immunity (Zimmerman, 1998; Kim et al., 2001), resulting in improved daily gain. However, it is highly expensive compared to other protein sources. Due to the high price of SDPP, efforts were made to replace SDPP with DPS in young pigs (Zimmerman, 1998; Kim et al., 2000; Kim et al., 2001).

Recently, rice protein concentrate (RPC) was introduced in the feed industry. It contains 75% crude protein and 4,381 kcal/kg ME in pigs. RPC is made from milled rice by extraction of fat and carbohydrates (Anonymous, 2003). However, the results of feeding RPC have not yet been reported for weaning pigs.

Therefore, these experiments were conducted to evaluate the feeding values of RPC (comparative growth performance with other protein sources, especially with SPC, optimal dietary level, and ileal digestibility of amino acids) in weaning pigs.

MATERIALS AND METHODS

Feeding and digestibility trial

In expt. I, a feeding trial was conducted with a total of 126 weaning pigs (Landrace×Yorkshire×Duroc; 21 d-old; 5.32±0.34 kg initial body weight) for 5 weeks to compare the effects of feeding RPC, animal protein and SPC at a commercial farm in Korea. For the feeding trial, piglets

* Corresponding Author: B. J. Chae. Tel: +82-33-253-2334, Fax: +82-33-244-2433, E-mail: bjchae@kangwon.ac.kr
Received April 9, 2004; Accepted November 19, 2004

Table 1. Formula and chemical composition of diets for a feeding trial

	Phase I			Phase II		
	SDPP	SPC	RPC	DPS	SPC	RPC
Ingredients (%)						
SDPP	8.00	4.00	4.00	-	-	-
DPS	-	-	-	5.00	-	-
SPC	-	4.00	-	-	5.00	-
RPC	-	-	4.00	-	-	5.00
Corn	39.41	38.81	39.99	38.04	40.00	41.70
SBM (48%)	12.20	12.96	11.61	21.77	19.55	17.80
Whey powder	35.00	35.00	35.00	30.00	30.00	30.00
Soy oil	2.36	2.00	2.00	2.00	2.18	2.00
Limestone	1.29	1.25	1.23	1.26	1.13	1.09
MCP	0.10	0.22	0.29	0.36	0.59	0.67
Salt	0.20	0.20	0.20	0.20	0.20	0.20
L-lysine HCL	0.36	0.46	0.60	0.34	0.35	0.52
DL-methionine (50%)	0.08	0.09	0.09	0.02	0.01	0.02
Vitamin premix[1]	0.30	0.30	0.30	0.30	0.30	0.30
Mineral premix[2]	0.20	0.20	0.20	0.20	0.20	0.20
Apramycin (100 g/kg)	0.15	0.15	0.15	0.15	0.15	0.15
Mecadox (50 g/kg)	0.10	0.10	0.10	0.10	0.10	0.10
ZnO	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00
Chemical composition (calculated, %)						
ME, kcal/kg	3,340	3,342	3,363	3,343	3,359	3,377
Crude protein	20.00	20.00	20.00	20.00	20.00	20.00
Ca	0.80	0.82	0.82	0.82	0.82	0.82
Av. P	0.42	0.40	0.40	0.40	0.40	0.40
Lys	1.60	1.60	1.60	1.45	1.45	1.45
Met+cys	0.79	0.76	0.75	0.68	0.65	0.65

[1] Supplied per kg diet: 9,600 IU vitamin A, 1,800 IU vitamin D_3, 24 mg vitamin E, 1.5 mg vitamin B_1, 12 mg vitamin B_2, 2.4 mg vitamin B_6, 0.045 mg vitamin B_{12}, 1.5 mg vitamin K_3, 24 mg Pantothenic acid, 45 mg Niacin, 0.09 mg Biotin, 0.39 mg Folic acid, 7.2 mg Ethoxyquin.

[2] Supplied per kg diet: 150 mg Fe, 96 mg Cu, 72 mg Zn, 46.49 mg Mn, 0.9 mg I, 0.9 mg Co, 0.336 mg Se.

were allotted to three treatments (3 replicates/treatment) on the basis of sex and body weight (gender ratio was 50:50).

During phase 1 (0-2 week post-weaning), as shown in Table 1, 8% SDPP was used for the control group, 4% SPC and 4% RPC were used, respectively, for treatment groups. During phase 2 (3-5 week post-weaning), however, DPS was included for the control group, while 5% of SPC and RPC were mixed in the test groups, respectively. Chromic oxide was added (0.25%) for the determination of apparent fecal nutrient digestibility.

The pigs were allowed *ad libitum* access to feed and water during the 35-d growth assay. Dietary lysine levels for phases 1 and 2 were 1.6% and 1.45%, respectively, and all diets were mash. The protein sources used in this study were SDPP (APC, USA), DPS 30 (Nutra-Flo, USA), SPC (Euroduna, German) and RPC (Jungjin Co. Ltd., Korea).

To study apparent fecal digestibility of nutrients in experimental diets, during the 3rd and 5th weeks of the feeding trials, fecal samples were taken from 4 pigs in each pen and pooled by pen (3 samples per treatment). Feces were dried in an air forced drying oven at 60°C for 3 days for chemical analysis.

Also, an ileal digestibility trial was conducted to compare the ileal digestibility of amino acids in the tested protein sources: SDPP, DPS, SPC and RPC. A total of 20 castrated piglets (Landrace×Yorkshire×Duroc; 21 d-old; 5.20±0.14 kg initial body weight) were used in a completely randomized design and housed in individual cages. Of the pigs, four were assigned to collect ileal digesta for endogenous amino acid excretions. After one day of fasting, pigs were fitted with a T-cannula in the terminal ileum according to the method suggested by Walker et al. (1986). Semi-purified, iso-nitrogenous (18% CP) diets were formulated with each protein sources to be tested, a N-free diet was also prepared, and each pig was fed a restricted amount of feed (5% of the body weight/day) three times daily. From the sixth day post-surgery, digesta was collected for 4 days. The collected samples were immediately frozen at -80°C, freeze dried (Samwon Inc., Korea), ground in a 1 mm-mesh Wiley Mill, and stored in a refrigerator until analysis.

In expt. II, a total of 160 weaning pigs (Landrace× Yorkshire×Duroc; 21 d-old; 5.65±0.35kg initial body weight) were used in a 5-week feeding trial to determine the

Table 2. Amino acid compositions (%) of protein sources used in this experiment

	SDPP[1]	DPS[2]	SPC[1]	RPC[2]
Crude protein	78.00	31.00	64.00	73.00
Essential amino acids				
Arg	4.55	1.50	5.79	5.83
His	2.55	0.65	1.80	1.84
Ile	2.71	1.20	3.30	2.96
Leu	7.61	2.20	5.30	6.22
Lys	6.84	2.05	4.20	2.60
Met+cys	3.38	1.55	1.90	4.52
Phe+tyr	7.95	2.25	5.90	7.64
Thr	4.72	1.25	2.80	2.74
Try	1.36	0.40	0.90	0.89
Val	4.94	1.55	3.40	3.84
Total	46.61	14.60	35.29	39.08
TEAA/CP (%)	59.76	47.10	55.14	53.53

[1] NRC (1998). [2] Manufacturer's data.

Table 3. The effect of different protein sources on the growth performance of weaning pigs

Item	SDPP/DPS	SPC	RPC	SEM[1]
Phase I (d 0-14)				
ADG (g)	308[a]	263[b]	266[b]	7.29
ADFI (g)	386	393	399	4.64
FCR	1.29[b]	1.49[a]	1.51[a]	0.05
Phase II (d 14-35)				
ADG (g)	350[b]	436[a]	434[a]	12.75
ADFI (g)	587	600	619	14.40
FCR	1.69[a]	1.38[b]	1.43[ab]	0.04
Overall (d 0-35)				
ADG (g)	333	366	367	5.58
ADFI (g)	506	517	531	12.24
FCR	1.57	1.41	1.44	0.02

[a, b] Values with different superscripts of the same row significantly differ ($p<0.05$).
[1] Standard error of means.

optimal inclusion level of RPC in the diet. Piglets were allotted to four treatments (4 replicates/treatment) on the basis of sex and body weight (gender ratio was 50:50). Treatments were control (9% SPC, 0% RPC), and three levels of RPC instead of SPC in the diet were formulated by replacing SPC on equal basis (3, 6 and 9 %), respectively. Iso-caloric and iso-nitrogenous diets (mash) were formulated to contain 1.65 and 1.45% lysine for phases 1 and 2, respectively.

Chemical and statistical analyses

Proximate analysis was conducted according to procedures detailed in AOAC (1990). Gross energy and chromium were measured with an adiabatic bomb calorimeter (Parr 1241, Molin, IL) and a spectrometer (Contron 942, Italy), respectively.

Following acid hydrolysis in 6 N HCl at 105°C for 24 h, amino acid concentrations were analyzed by using a HPLC (Waters 486, USA). Sulfur containing amino acids was analyzed after cold performic acid oxidation (Moore, 1963) overnight and by subsequent hydrolysis.

Statistical analysis was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), by using General Linear Model (GLM) procedure of SAS (1985) package program. Data were analyzed as a randomized complete block design. For expt. II a linear and quadratic effects were also measured. Pigs were blocked by initial weight with pen as the experimental unit. Individual piglets for an ileal digestibility trial were used as the experimental unit.

RESULTS

Amino-acid profiles of RPC

Crude protein and amino acid contents in tested protein sources are presented in Table 2. Crude protein contents of SDPP, DPS, SPC and RPC were 77.85, 31.00, 64.00 and 73.00%, respectively. The ratio of total essential amino acid (TEAA) to CP (%) was similar between SPC and RPC (55.14 vs. 53.53%). Among essential amino acids, RPC is low in lysine content but high in sulfa-amino-acid (methionine+cystine) content as compared with SPC.

Growth performance

The effects of feeding RPC on ADG, ADFI and FCR as compared with animal proteins and SPC are presented in Table 3. During phase 1, pigs fed SDPP showed better ($p<0.05$) ADG and FCR compared with those fed SPC or RPC, while there was no difference in ADFI among treatments. During phase 2, however, pigs fed DPS showed lower ($p<0.05$) ADG than those fed SPC or RPC. FCR was also poorer ($p<0.05$) in the DPS fed pigs than in the SPC fed group. During the total period, there were no significant differences in ADG, ADFI and FCR among treatments.

The growth performance of pigs fed diets containing graded levels of RPC is shown in Table 4. During phase 1, there were no significant differences in ADG, ADFI and FCR among treatments. During phase 2, ADFI was linearly ($p=0.037$) increased as dietary RPC level was increased, though no significant differences were detected in ADG and FCR among treatments. A similar trend was observed in growth performance during the total period.

Digestibility of nutrients

Apparent fecal digestibility of nutrients for the experimental diets used in expt. I is presented in Table 5. In the phase 1 diet, the digestibility of dry matter and crude protein was higher ($p<0.05$) in pigs fed diets containing SDPP than those fed SPC or RPC. However, pigs fed a diet with DPS showed lower ($p<0.05$) digestibility of dry matter and crude protein as compared with those fed SPC or RPC.

Table 4. Effect of dietary RPC level on growth performance of early weaning pigs

	Control	RPC content (%)			SEM[1]	Probability (P<)	
		3	6	9		Linear	Quadratic
Phase I (d 0-14)							
ADG	323	326	335	340	8.23	NS[2]	NS
ADFI	410	411	424	421	7.02	NS	NS
FCR	1.27	1.26	1.26	1.24	0.01	NS	NS
Phase II (d 15-35)							
ADG	481	487	492	496	6.25	NS	NS
ADFI	767[b]	789[ab]	812[ab]	823[a]	24.56	0.037	NS
FCR	1.60	1.62	1.65	1.66	0.03	NS	NS
Overall (d 0-35)							
ADG	412	417	423	427	6.65	NS	NS
ADFI	611[b]	624[ab]	642[ab]	647[a]	16.64	0.029	NS
FCR	1.48	1.50	1.52	1.52	0.02	NS	NS

[a, b] Values with different superscripts of the same row significantly differ (p<0.05).
[1] Standard error of means. [2] Not significant.

There were no significant differences in digestibility of DM, energy and protein between diets containing SPC and RPC.

The apparent and true ileal digestibility of amino acids for SDPP, DPS, SPC and RPC are presented in Table 6. The apparent ileal digestibilities of his, lys, phe, thr and met were not different among the tested protein sources. The ileal digestibilities of arg, ileu, leu and val were lower (p<0.05) in RPC than SDPP. The mean apparent digestibility of essential amino acids was higher (p<0.05) in SDPP than DPS and RPC, while there was no difference between SPC and RPC.

The true ileal digestibilities of arg and leu were lower (p<0.05) in RPC than SDPP and SPC. However, that of met was higher (p<0.05) in RPC than SDPP. The mean true digestibility of essential amino acids was lower (p<0.05) in RPC and DPS than SDPP, while there was no difference between SPC and RPC.

DISCUSSION

Rice itself is low in protein content (9.9±1.8%) (Grist, 1983), however, the crude protein content in RPC is very high. It is higher than in SPC (73 vs. 64%). The amino-acid profiles of RPC are also excellent, compared with SPC. Sulfur-containing amino acids (methionine+cystine) are substantially higher, compared with SPC (4.52 vs. 1.90%), while lysine content is low (2.6 vs. 4.2%). Other essential amino acid contents are very similar between RPC and SPC. As reported by several workers (Pecora and Hundley, 1951; Hoseney, 1994), lysine is the first limiting amino acid in RPC. Pecora and Hundley (1951) have shown that a diet containing 90% milled rice is markedly improved by the addition of lysine.

Between the SPC and RPC groups, there was no difference in growth performance, such as ADG, ADFI and FCR (expt. I). There were little differences in growth performance in pigs when SPC was replaced by RPC up to 9% in the complex starter diet (expt. II). During phase II and overall study in experiment II, the ADFI was significantly higher (p=0.037 and p=0.029, respectively) in 9% RPC added diet than SPC in control diet. A linear trend was noticed with respect to ADFI during these phases of study. Also, apparent and true ileal digestibilities of amino acids in young pigs were quite similar between the two plant protein sources. True ileal digestibility of limiting amino acids (lys, met and thr) in pigs was also similar. The digestibility of rice protein is high. It was reported that rice protein is almost 100 percent digestible in growing rats (Eggum and Juliano, 1975), even though cereal proteins are less digestible than animal proteins such as egg and milk protein (WHO, 1985).

Digestibility of protein is associated with ANFs in the feedstuffs. Rice grain also contains ANFs such as phytate, trypsin inhibitor, and haemagglutinins. However, these ANFs are concentrated in the bran fraction (Juliano, 1985). It is known that there is no ANFs in RPC, because it is extracted from milled rice (Anonymous, 2003).

Specially processed soy products such as SPC and ISP are established protein sources in weaning pigs diet (Giesting et al., 1985; Sohn et al., 1994; Chae et al., 1999). They reported that pigs fed SPC or ISP has equal or better growth performance than those fed dried skim milk. The ability to utilize the soybean protein from the soy products could be a means of reducing the inclusion rate of expensive animal proteins (like milk proteins) in young pig diets. Feeding processed soy protein to weanling pigs increased growth performance, nutrient digestibility and apparent ileal digestibilities of DM, N and most amino acids were also reported by Min et al. (2004).

As mentioned, our data indicate that SDPP is an excellent protein source in the prestarter diet. Pigs fed a diet containing SDPP showed better ADG and FCR than those fed SPC or RPC. This result is well consistent with previous reports (Gatnau and Zimmerman, 1991; Ermer et al., 1994;

Table 5. The effect of different protein sources on fecal digestibility of experimental diet in weaned pigs

Item	SDPP/DPS	SPC	RPC	SEM[1]
Phase I diet				
Dry matter	86.99[a]	85.37[b]	85.21[b]	0.29
Gross energy	85.72	84.61	83.60	0.37
Crude protein	78.77[a]	75.99[b]	75.71[b]	0.53
Phase II diet				
Dry matter	81.38[b]	83.94[a]	84.21[a]	0.46
Gross energy	79.55[b]	82.94[a]	81.88[ab]	0.55
Crude protein	74.75[b]	77.37[a]	77.19[a]	0.45

[a, b] Values with different superscripts of the same row significantly differ ($p<0.05$).
[1] Standard error of means.
[2] Phase I : SDPP 8%, SPC 4%, RPC 4%.
[3] Phase II : DPS 5%, SPC 5%, RPC 5%.

Kats et al., 1994; Chae et al., 1999). In their study, feed intake was mostly improved when SDPP was included in the phase 1 diet, resulting in improved ADG. However, in this study feed intake was not increased in pigs fed the SDPP diet.

The reason of better growth performance in pigs fed SDPP than in those fed RPC or SPC remained obscure, although feed intake was not affected by protein sources. It is probably assumed that ADG was improved in pigs fed SDPP due to increased nutrient digestibility. As shown in Table 5, digestibility of dry matter and crude protein was higher in the SDPP diet than in the SPC or RPC diets. A similar trend was found in the ileal digestibility of amino acids in the tested protein sources (Table 6).

In addition to the digestibility of nutrients, evidence from research with SDPP (Zimmerman, 1998; Kim et al., 2001) suggests that immunoglobulins in plasma protein were responsible for the positive effect on ADG. Gatnau et al. (1995) and Pierce et al. (1995) also conducted experiments with three fractions of SDPP to evaluate the mode of action of SDPP in weaned pigs. Both groups concluded that the beneficial effects from SDPP appeared to be associated with the IgG fraction containing growth-stimulating factors.

On the other hand, pigs fed DPS showed poorer ADG than those fed SPC or RPC during the phase 2 period. This was due to decreased feed intake as compared with SPC or RPC. In young pigs, though SDPP can be partially substituted with DPS (Zimmerman, 1998), the feeding value of DPS is lower than SDPP when it is included separately in the diet (Kim et al., 2000; Kim et al., 2001). In this study, pigs fed a diet containing DPS showed lower feed intake as compared with those fed diets containing SPC or RPC. It is assumed that reduced feed intake in pigs fed DPS during phase 2 was due to abrupt changes in a diet from SDPP to DPS, resulting in lower ADG. Also, digestibilities such as dry matter, crude protein and amino acids were lower in the diet containing DPS than SPC or RPC.

Based on our experimental results, RPC would replace SPC in the complex prestarter diets. RPC is somewhat cheaper than SPC in the formulation of weaner diets.

Table 6. Apparent and true ileal digestibility of amino acids in various protein sources used in this experiments

	SDPP	DPS	SPC	RPC	SEM[1]
Apparent[2]					
Arg	73.21[ab]	72.26[b]	74.54[a]	72.75[b]	0.98
His	76.64	77.00	78.56	78.63	1.03
Ile	76.91[a]	74.00[ab]	74.54[ab]	72.91[b]	1.69
Leu	77.37[a]	74.94[ab]	74.43[b]	72.32[b]	2.08
Lys	77.58	75.11	74.89	73.84	1.59
Phe	74.95	71.68	72.20	72.01	1.51
Thr	71.44	71.63	71.18	72.72	0.68
Val	71.88[a]	69.29[b]	68.79[b]	68.39[b]	1.57
Met	72.02	72.04	71.24	71.67	0.37
Mean	74.67[a]	73.11[b]	73.38[ab]	72.80[b]	0.82
True[2]					
Arg	86.63[a]	83.01[b]	87.29[a]	84.00[b]	2.05
His	87.77	87.44	90.74	91.57	2.08
Ile	87.82[a]	80.81[c]	84.72[ab]	81.52[bc]	3.22
Leu	87.31[a]	82.96[ab]	85.09[a]	80.52[b]	2.91
Lys	87.73[a]	82.78[c]	84.62[bc]	86.04[ab]	2.10
Phe	86.21[a]	83.01[ab]	84.81[ab]	82.58[b]	1.68
Thr	83.50[a]	80.72[b]	81.88[ab]	83.91[a]	1.48
Val	83.94[a]	78.65[b]	81.20[ab]	81.16[ab]	2.16
Met	82.18[b]	81.48[b]	84.04[a]	84.53[a]	1.46
Mean	85.90[a]	82.32[c]	84.93[ab]	83.98[b]	1.53

[a, b, c] Values with different superscripts of the same row significantly differ ($p<0.05$).
[1] Standard error of means. [2] Tryptophan was not analyzed.

REFERENCES

Anonymous. 2003. A bulletin for rice protein concentrate. Jungjin Co. Ltd., Seoul Korea. pp. 2-7.

AOAC. 1990. Official method of analysis (15th ed). Association of Offical Analytical Chemists. Arlington, VA.

Chae, B. J., In K. Han, J. H. Kim, C. J. Yang, J. D. Hancock, I. H. Kim and D. A. Anderson. 1999. Effects of dietary protein sources on ileal digestibility and growth performance for earlly-weaned pigs. Livest. Prod. Sci. 58:45-54.

Cromwell, G. L. 2001. Utilization of soy products in swine diets. In: Soy in animal nutrition (J. K. Drackley). Federation of Anim. Sci. Soc. Savoy, IL. pp. 258-287.

Duncan, D. B. 1955. Multiple range and multiple F test. Biometrics. 11:1-42.

Eggum, B. O. and B. O. Juliano. 1975. Higher protein content from nitrogen fertilizer application and nutritive value of milled rice protein. J. Sci. Food Agric. 26:425-427.

Ermer, P. M., P. S. Miller and A. J. Lewis. 1994. Diet preference and meal patterns of weaning pigs offered diets containing either SDPP or dried skim milk. J. Anim. Sci. 72:1548-1554.

Gatanau, R. and D. R. Zimmerman. 1991. Spray-dried porcine plasma (SDPP) as a source of protein for weanling pigs in two environments. J. Anim. Scil. 69 (suppl.1):103 (Abstr).

Gatnau, R., C. Cain, M. Drew and D. R. Zimmerman. 1995. Mode of action of spray-dried porcine plasma in weanling pigs. J. Anim. Sci. 73 (Suppl. 1):82 (Abstr.).

Giesting, D. W., R. A. Easter and B. A. Roe. 1985. A comparison of protein and carbohydrate sources of milk and plant origin for starter pigs. J. Anim. Sci. 61 (Suppl. 1):299 (Abstr.).

Grist, D. H. 1983. Nutritional value of rice. In: Rice (5th ed). Longman Inc. New York, NY. pp. 449-471.

Hoseney, R. C. 1994. Principles of cereal science and technology (2nd ed). American Assoc. Cereal Chem. St. Paul, MN. p. 77.

Juliano, B. O. 1985. Rice: Chemistry and technology (2nd ed). American Assoc. Cereal Chem. St. Paul, MN. p. 774.

Kats, L. J., J. L. Nelssen, M. D. Tokach, R. D. Goodband, J. A. Hansen and J. L. Laurin. 1994. The effect of SDPP on growth performance in early-weaned pigs. J. Anim. Sci. 72:2075-2081.

Kim, J. D., Y. Hyun, K. S. Sohn, T. J. Kim, H. J. Woo and In K. Han. 2001. Optimal dietary ratio of SDPP and DPS in improving growth performance and immune status in pigs weaned at 21 days of age. Asian-Aust. J. Anim. Sci. 14(3):338-345.

Kim, J. H., B. J. Chae and Y. G. Kim. 2000. Effects of replacing SDPP with DPS on ileal digestibility and growth performance in early-weaned pigs. Asian-Aust. J. Anim. Sci. 13(12):1738-1742.

Kolar, C. V., S. H. Richert, C. D. Decker, F. H. Steinke and R. J. Vander Zanden. 1985. 3. Isolated soy protein. New Protein Foods. 5:261.

Lalles, J. P. 1993. Soy products as protein sources for preruminants and young pigs. In: Soy in animal Nutrition (J. K. Drackley). Fed. Anim. Sci. Soc. Savoy, IL. pp. 106-125.

Min, B. J., J. W. Hong, O. S. Kwon, W. B. Lee, Y. C. Kim, I. H. Kim, W. T. Cho and J. H. Kim. 2004. The effect of feeding processed soy protein on the growth performance and apparent ileal digestibility in weaning pigs. Asian-Aust. J. Anim. Sci. 17(9):1271-1276.

Moore, S. 1963. On the determination of cystine as cysteric acid. J. Biol. Sci. 238:235-237.

NRC. 1998. Nutrinent requirements of swine (9th ed). National Academy Press. Washington, DC.

Pecora, L. T. and J. M. Hundley. 1951. Nutritional improvement of white polished rice by the addition of lysine and threonine. J. Nutr. 44:101.

Pierce, J. L., G. L. Cromwell, M. D. Lindeman and R. D. Coffey. 1995. Assesment of three fraactions of spray-dried porcine plasma on performance of early weaned pigs. J. Anim. Sci. 73 (Suppl. 1):81 (Abstr.).

Qiao Shiyan, Defa Li, Jianyang Jiang, Hongjie Zhou, Jingsu Li and P. A. Thacker. 2003. Effects of moist extruded full-fat soybeans on gut morphology and mucosal cell turnover time of weanling pigs. Asian-Aust. J. Anim. Sci. 16(1):63-69.

SAS. 1985. SAS. User's Guide: Statistics, SAS Inst. Inc. Cary. Nc.

Snyder, H. E. and T. W. Kwon. 1988. Soybean Utilization. p. 132.

Sohn, K. S., C. V. Maxwell, D. S. Buchanan and L. L. Southern. 1994. Improved soybean protein sources for early-weaned pigs. 1. Effects on performance and total track amino acid digestibility. J. Anim. Sci. 72:622-630.

Walker, W. R., G. L. Morgan and C. V. Maxwell. 1986. Ileal cannulation in baby pigs with a simple T-cannula. J. Anim. Sci. 63:505-512.

WHO. 1985. Energy and protein requirements. Report of a joint FAO/WHO/UNU expert consultation WHO Tech. Rep. Ser. 724. Geneva WHO. p. 206.

Zimmerman, D. R. 1998. Nutritive value of some newly developed protein sources for the early-weaned pig. Proc. Preconference Symposia. The 8th World Conference on Animal Production. June 28-July 4. Seoul National University, Seoul Korea. pp. 101-109.