The Effect of Feeding Processed Soy Protein on the Growth Performance and Apparent Ileal Digestibility in Weanling Pigs

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ABSTRACT : For Exp. 1, one hundred twenty Duroc×Yorkshire×Landrace pigs (6.34±0.70 kg average initial BW) were used in a 35 d growth assay. There were six pigs per pen and four pens per treatment. Dietary treatments included 1) NC (negative control; basal diet), 2) PC (positive control; added 5% HP 300®, HAMLET PROTEIN A/S, as protein source), 3) PSP 2.5 (added 2.5% Pepsoygen®, Genebiotech Co. Ltd., as protein source), 4) PSP 5.0 (added 5% Pepsoygen® as protein source), and 5) PSP 7.5 (added 7.5% Pepsoygen® as protein source). For d 21, ADFI was increased in pigs fed PSP diets compared with PC diet ($p<0.05$). ADG was tended to improve as concentration of PSP in the diets was increased. For d 21-35 and entire experimental period, pigs fed PSP diets had more feed intake than pigs fed NC or PC diets ($p<0.05$). For the whole period, ADG was improved in PSP treatments compared with NC treatment (Linear effect, $p=0.05$). On d 21 and d 35, digestibilities of DM and N were higher ($p<0.05$) for pigs fed PSP diets than pigs fed NC diet and PSP 2.5 treatment was the highest among the treatments. On d 21, digestibility of N was significantly improved in PSP treatments compared with PC treatment ($p<0.05$). For Exp. 2, five Duroc×Yorkshire×Landrace barrows (8.74±0.22 kg average initial BW) were surgically fitted with a simple T-cannulas approximately 15 cm prior to the ileo-cecal junction. The experimental designs were 5×5 latin squares with pigs and periods as blocking criteria. Dietary treatments were same as Exp.1. Generally, apparent ileal digestibilities of DM and N were higher for pigs fed PSP diets than pigs fed NC or PC diets ($p<0.05$) and PSP 5.0 and 2.5 treatments were the highest among the treatments, respectively. Apparent ileal digestibilities of the whole amino acids were increased in PSP treatments compared with NC treatment (Quadratic effect, $p\leq0.05$). Also, histidine, lysine and threonine digestibilities in essential amino acids and alanine, asparatic acid and glycine digestibilities in non essential amino acids were significantly higher for pigs fed PSP diets than pigs fed PC diets ($p\leq0.05$). In conclusion, feeding processed soy protein to weanling pigs increased growth performance, nutrient digestibility and apparent ileal digestibilities of DM, N and most amino acids. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 9 : 1271-1276)***

Key Words : Processed Soy Protein, Growth Performance, Ileal Digestibility, Pigs

INTRODUCTION

Milk or milk products were considered essential for growth and health of early-weaned pigs (Mahan, 1992). Although milk products are highly palatable and easily digested by young pigs and calves, competition from the human sector has increased costs and led to evaluate alternative protein sources. Blood products, such as blood meal and plasma protein have been used successfully in nursery diets, and have been used to induce feed consumption in early-weaned pigs (Hansen et al., 1993; Kats et al., 1994). Blood products, like milk products, are expensive and more likely to carry pathogens than refined protein products of plant origin. Alternatively, soybean meal is a vegetable source that is readily available and relatively inexpensive. Although the soybean meal contains high-quality proteins, it showed poor growth performance and low digestibility in weanling pigs because of antinutritional factors such as trypsin inhibitors, haemagglutinins, raffinose and stachyose (Anderson et al., 1979). Therefore, processed soy proteins has been developed and used, which were heat-treated (Osborne and Mendel, 1917; Hancock et al., 1990), extruded (Kim et al., 1999; Kim et al., 2000a; Kim et al., 2000b; Burnham et al., 2000; Shiyan et al., 2003), purified (Hancock et al., 1989) or defatted (Jones et al., 1989) for decrease level of antinutritional factors.

Proteins are broken down to peptides by protease in stomach that may have high absorption rate in intestine of pigs. Also, this efficacy was elevated when it was in small peptide form (Rerat et al., 1992; Lee et al., 1998). Therefore, this experiment was conducted to determine the effect of feeding processed soy protein which has a high proportion of small peptides and decrease antinutritional factors via a microbial fermentation on the growth performance and apparent ileal digestibility in weanling pigs.

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Received October 8, 2003; Accepted May 12, 2004

MATERIALS AND METHODS

Experiment 1

One hundred twenty Duroc×Yorkshire×Landrace pigs (6.34±0.70 kg average initial BW) were used in a 35 d growth assay to determine the effect of feeding processed soy protein on the growth performance in weanling pigs. This experiment was conducted by randomized complete block (RCB) design and pigs were assigned by body weight.

Table 1. Diet composition (as-fed basis)

Ingredient, %	Phase I					Phase II				
	NC	PC	PSP			NC	PC	PSP		
			2.5	5.0	7.5			2.5	5.0	7.5
Extruded corn	33.57	35.96	34.34	35.11	35.84	48.22	50.60	49.00	49.75	50.51
Extruded soybean meal	39.42	32.75	36.28	33.13	30.02	35.07	28.40	31.91	28.78	25.63
Dried whey	10.00	10.00	10.00	10.00	10.00	-	-	-	-	-
Extruded oat	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Pepsoygen	-	-	2.50	5.00	7.50	-	-	2.50	5.00	7.50
HP300	-	5.00	-	-	-	-	5.00	-	-	-
Soybean oil	4.58	3.87	4.45	4.32	4.19	4.03	3.32	3.90	3.77	3.64
Fish meal	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Monocalcium phosphate	1.01	0.93	1.03	1.05	1.08	0.90	0.82	0.92	0.94	0.97
Organic acid	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Tricalcium phosphate	0.79	0.85	0.76	0.73	0.70	0.98	1.04	0.95	0.92	0.89
Yeast culture	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Zinc oxide	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	-	-	-	-	-	0.20	0.20	0.20	0.20	0.20
Vitamin premix[1]	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Mineral premix[2]	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
L-lysine·HCl	0.12	0.14	0.13	0.15	0.16	0.12	0.14	0.14	0.15	0.17
Apramycine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Oxytetracycline	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Antioxidant	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
DL-methionine	0.05	0.04	0.05	0.05	0.05	0.02	0.02	0.02	0.03	0.03
Chemical composition[3]										
ME, kcal/kg	3,336					3,336				
Crude protein, %	23.97					21.97				
Lysine, %	1.60					1.40				
Methionine, %	0.45					0.40				
Calcium, %	0.90					0.90				
Phosphorus, %	0.80					0.80				

[1] Provided per kg diet: 20,000 IU of vitamin A; 4,000 IU of vitamin D_3; 80 IU of vitamin E; 16 mg of vitamin K_3; 4 mg of thiamine; 20 mg of riboflavin; 6 mg of pyridoxine; 0.08 mg of vitamin B_{12}; 120 mg of niacin; 50 mg of Ca-pantothenate; 2 mg of folic acid and 0.08 mg of biotin.
[2] Provided per kg diet: 140 mg of Cu; 179 mg of Zn; 12.5 mg of Mn; 0.5 mg of I; 0.25 mg of Co and 0.4 mg of Se.
[3] Calculated value.

There were 4 pens per treatment with 6 pigs per pen in an environmentally controlled building with slatted concrete floors. Each pen size was 0.8 m×0.8 m.

Dietary treatments included 1) NC (negative control; basal diet), 2) PC (positive control; added 5% HP 300®, HAMLET PROTEIN A/S, as protein source), 3) PSP 2.5 (added 2.5% Pepsoygen®, Genebiotech Co. Ltd., as protein source), 4) PSP 5.0 (added 5% Pepsoygen® as protein source), and 5) PSP 7.5 (added 7.5% Pepsoygen® as protein source). Experimental diets were fed in two phases (d 0 to 21 and 21 to 35 postweaning). Diets for d 0 to 21 (Table 1) were formulated to contain 3,336 kcal/kg of ME, 23.97% of CP and 1.60% of lysine. Also, diets for d 21 to 35 (Table 1) were formulated to contain 3,336 kcal/kg of ME, 21.97% of CP and 1.40% of lysine. The diets were formulated to meet or exceed the nutrient requirements recommended by NRC (1998). Chromic oxide (Cr_2O_3) was added (0.2% in the diet) as an indigestible marker to allow digestibility determinations.

Pigs were allowed to consume feed and water *ad libitum* from self-feeder and nipple waterer. Average daily gain and average daily feed intake were measured on d 21 and 35 and gain/feed ratio was also calculated.

Feed and feces were analyzed for DM and N concentration (AOAC, 1994). Chromium was determined by UV absorption spectrophotometry (Shimadzu, UV-1201, Japan) and apparent digestibilities of DM and N were calculated using the indirect method.

All data were analyzed as a randomized complete block design using the general linear model procedure of SAS (1996), with pen as the experimental unit. Treatment differences were separated using the orthogonal contrast: 1) NC vs. others, and 2) PC vs. PSP. Also, NC diet was compared to PSP diets by the polynomial regression (Peterson, 1985) method to determine linear, quadratic and cubic effects.

Experiment 2

Five Duroc×Yorkshire×Landrace barrows (8.74±0.22 kg average initial BW) were surgically fitted with a simple T-

Table 2. Effect of processed soy protein (PSP) on growth performance in weanling pigs (Exp.1)[1]

Item	NC[2]	PC[2]	PSP[2]			SE[3]	Probability (P)				
							NC vs. others	PC vs. PSP	NC vs. PSP		
			2.5	5.0	7.5				Linear	Quadratic	Cubic
d 0-21											
ADG, kg	0.339	0.338	0.341	0.353	0.368	0.017	0.555	0.433	0.191	0.725	0.932
ADFI, kg	0.544	0.525	0.523	0.547	0.552	0.007	0.303	0.045	0.019	0.004	0.002
G/F	0.623	0.644	0.652	0.645	0.667	0.031	0.326	0.840	0.323	0.803	0.615
d 21-35											
ADG, kg	0.467	0.471	0.506	0.516	0.513	0.023	0.172	0.142	0.159	0.370	0.920
ADFI, kg	0.890	0.923	0.927	0.983	0.954	0.012	<0.0001	0.025	<0.0001	0.002	0.039
G/F	0.525	0.510	0.546	0.525	0.538	0.027	0.843	0.394	0.970	0.761	0.477
d 0-35											
ADG, kg	0.390	0.395	0.404	0.425	0.426	0.015	0.165	0.198	0.050	0.655	0.653
ADFI, kg	0.682	0.687	0.683	0.723	0.713	0.008	0.027	0.045	<0.0001	0.422	0.003
G/F	0.572	0.575	0.592	0.588	0.597	0.021	0.403	0.492	0.451	0.694	0.692

[1] One hundred twenty pigs with an average initial body weight of 6.34±0.70 kg (SD).
[2] Abbreviations: NC, negative control; PC, positive control included HP 300; PSP, Basal diet included 2.5%, 5.0% and 7.5% PEPSOYGEN.
[3] Pooled standard error.

Table 3. Effect of processed soy protein (PSP) on nutrient digestibility in weanling pigs (Exp. 1)[1]

Item	NC[2]	PC[2]	PSP[2]			SE[3]	Probability (P)				
							NC vs. others	PC vs. PSP	NC vs. PSP		
			2.5	5.0	7.5				Linear	Quadratic	Cubic
d 21											
DM	76.14	77.12	79.20	78.70	77.48	0.64	0.02	0.10	0.14	<0.002	0.23
N	73.20	73.56	76.75	76.51	74.43	0.66	0.02	0.01	0.19	<0.001	0.44
d 35											
DM	73.03	78.18	80.21	79.01	76.05	1.22	<.005	0.87	0.17	<0.002	0.24
N	68.68	75.56	78.42	76.86	73.16	1.35	<.001	0.71	0.09	<0.001	0.17

[1] One hundred twenty pigs with an average initial body weight of 6.34±0.70 kg (SD).
[2] Abbreviations: NC, negative control; PC, positive control included HP 300; PSP, Basal diet included 2.5%, 5.0% and 7.5% PEPSOYGEN.
[3] Pooled standard error.

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 Corporation, Korea). After surgery, the barrows were individually housed in stainless steel metabolism crates in a temperature controlled (28°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 was 4 d of adjustment to the experimental diets 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 allotment was offered as two meals at 12 h intervals (8:00 a.m. and 8:00 p.m.). Dietary treatments were same as Exp. 1. Experimental diets were formulated to contain 3,336 kcal/kg of ME, 23.97% of CP, 1.60% of lysine. The diets were 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.

Pigs were allowed to consume feed and water *ad libitum* from self-feeder and nipple waterer.

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 ileal digesta were analyzed for DM and N concentration (AOAC, 1994). Chromium was determined by UV absorption spectrophotometry (Shimadzu, UV-1201, Japan) and apparent ileal digestibilities of DM and N were calculated using the indirect 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). Treatment differences were separated using the orthogonal contrast: 1) NC vs. others, and 2) PC vs. PSP. Also, NC diet was compared to PSP diets by the polynomial regression (Peterson, 1985) method to determine linear, quadratic and cubic effects.

RESULTS

Experiment 1

Growth performance of pigs fed experimental diet is presented in Table 2. For d 0-21, ADFI was increased in pigs fed PSP diets compared with PC diet ($p<0.05$). ADG was tended to improve as concentration of PSP in the diets was increased. For d 21-35 and entire experimental period, pigs fed PSP diets had more feed intake than pigs fed NC or PC diets ($p<0.05$). For the whole period, ADG in pigs fed the NC diet was 390 g, compared with 404, 425, 426 g for those fed the PSP 2.5, 5.0 and 7.5 diets, respectively (Linear effect, $p=0.05$). The effects of processed soy protein on nutrient digestibility of weanling pigs are summarized in Table 3. On d 21-35, digestibilities of DM and N were higher ($p<0.05$) for pigs fed PSP diets than pigs fed NC diet and PSP 2.5 treatment was the highest among the treatments. On d 21, digestibility of N was significantly improved in PSP treatments compared with PC treatment ($p<0.05$).

Experiment 2

Apparent ileal digestibility of DM and N in weanling pigs fed experimental diet is presented in Table 4. Generally, apparent ileal digestibilities of DM and N were higher for pigs fed PSP diets than pigs fed NC or PC diets ($p<0.05$) and PSP 5.0 and 2.5 treatments were the highest among the treatments. As shown in Table 5, Apparent ileal digestibilities of the whole amino acids were increased in PSP treatments compared with NC treatment (Quadratic effect, $p\leq0.05$). Also, histidine, lysine and threonine digestibilities in essential amino acids and alanine, asparatic acid and glycine digestibilities in non essential amino acids were significantly higher for pigs fed PSP diets than pigs fed PC diets ($p\leq0.05$).

In conclusion, feeding processed soy protein use to weanling pigs had increased apparent ileal digestibilities of DM, N and most amino acids.

DISCUSSION

In present study, during the overall period, pigs fed PSP

Table 4. Effect of processed soy protein (PSP) on apparent ileal digestibility of DM and N in weanling pigs (Exp. 2)[1]

Item	NC[2]	PC[2]	PSP[2]			SE[3]	Probability (P)				
							NC vs. others	PC vs. PSP	NC vs. PSP		
			2.5	5.0	7.5				Linear	Quadratic	Cubic
DM	70.04	66.87	75.90	77.26	71.20	1.13	0.06	<0.0003	0.42	<0.004	0.62
N	71.88	77.44	87.38	85.53	82.78	1.18	<0.0001	<0.0004	<0.002	<0.0003	0.03

[1] Five barrows pigs with an average body weight of 8.74±0.22 kg (SD) were used as 5×5 latin square design.
[2] Abbreviations: NC, negative control; PC, positive control included HP 300; PSP, Basal diet included 2.5%, 5.0% and 7.5% PEPSOYGEN.
[3] Pooled standard error.

Table 5. Effect of processed soy protein (PSP) on apparent ileal digestibility of amino acids in weanling pigs (Exp. 2)[1]

Item, %	NC[2]	PC[2]	PSP[2]			SE[3]	Probability(P)				
							NC vs. others	PC vs. PSP	NC vs. PSP		
			2.5	5.0	7.5				Linear	Quadratic	Cubic
Essential amino acids											
Arginine	80.85	85.09	86.51	88.72	84.30	1.01	<0.002	0.26	0.01	<0.001	0.42
Histidine	50.74	66.02	72.81	77.06	70.93	1.88	<0.001	0.01	<0.003	<0.002	0.95
Isoleucine	65.68	69.33	74.51	78.51	71.70	2.23	0.01	0.06	0.01	<0.002	0.38
Leucine	64.28	69.05	73.39	78.39	69.81	2.34	0.01	0.11	0.02	<0.002	0.22
Lysine	73.94	75.82	80.16	83.42	78.10	1.16	<0.004	0.01	0.01	<0.001	0.22
Methionine	74.42	77.33	82.16	84.89	77.63	1.87	0.02	0.09	0.16	0.05	0.54
Phenylalanine	70.05	76.91	76.75	82.74	71.46	2.04	0.02	0.98	0.20	<0.002	0.06
Threonine	69.23	73.14	78.77	83.77	75.39	1.96	0.01	0.03	0.01	<0.001	0.20
Valine	60.82	66.42	70.21	76.15	69.40	2.33	0.01	0.08	0.01	0.01	0.31
Non essential amino acids											
Alanine	60.77	64.43	71.90	78.28	68.82	3.16	0.02	0.05	0.04	0.01	0.38
Asparatic acid	69.95	74.08	78.30	82.22	76.18	1.77	<0.005	0.05	<0.001	<0.0001	0.18
Cystine	58.74	69.61	70.60	77.64	66.31	2.84	0.01	0.58	0.07	0.01	0.36
Glutamic acid	70.83	76.44	78.48	82.63	77.38	1.86	0.01	0.19	0.01	0.01	0.43
Glycine	57.04	62.10	68.87	73.47	65.48	2.35	<0.005	0.03	0.01	<0.003	0.56
Proline	64.73	69.08	68.43	77.84	69.68	2.45	0.04	0.34	0.01	0.01	0.02
Serine	67.37	69.64	74.50	78.40	71.83	2.04	0.03	0.06	0.02	<0.002	0.25
Tyrosine	70.68	74.66	76.20	80.14	74.00	1.89	0.03	0.36	0.08	0.01	0.24

[1] Five barrows pigs with an average body weight of 8.74±0.22 kg (SD) were used as 5×5 latin square design.
[2] Abbreviations: NC, negative control; PC, positive control included HP 300; PSP, Basal diet included 2.5%, 5.0% and 7.5% PEPSOYGEN.
[3] Pooled standard error.

diet had improved (Linear effect, p=0.05) ADG compared with NC treatment. These results agree with Zhu et al. (1998) who reported that replacement of various protein sources with HP300 in piglet diets improved ADG. Feeding processed soy protein (both PC and PSP) to weanling pigs had higher ($p<0.05$) apparent fecal DM and N digestibilities, ileal DM, N and amino acid digestibilities and feed intake than only feeding soybean meal (NC). Similarly, Zhu et al. (1998) reported that there was a trend toward improved DM, crude protein and amino acid ileal digestibilities with the use of HP 300 in pig diets. Sohn et al. (1994a; 1994b) observed that increased total tract DM and N digestibilities and ileal amino acid digestibility in pigs fed ISP (Isolate Soy Protein) and SPC (Soy Protein Concentrates) diets compared with those fed a SBM diet. These results may be due to decreased antinutritional factors in soybean meal which was through the process such as purifying and extracting. Also, Kim et al. (1996) supported that as the complexity of the processing method increased, nutritional value for the soy products tended to improve.

Processed soy protein used in this experiment has a high proportion of small peptide that was acted upon by protease which was produced through microbial fermentation. For experimental d 21, digestibility of N was higher ($p<0.05$) in pigs fed PSP diets compared with pigs fed PC diets (Exp. 1). This indicated that small peptide is more efficiently utilized by young pig. This has also proved by Guandalini and Rubino (1982) who determined absorption rate of glycine and glycine peptide from the intestine of rabbits. They reported that the uptake of the dipeptide was considerably greater than that of free glycine, especially in the immature animal. Results more definitely showed that the apparent ileal digestibility of DM and N in Exp. 2 was higher ($p<0.0005$) in PSP treatment than PC treatment. This supported other studies that amino acid or peptide transporter only exists in small intestine (Chen et al., 1999; Winckler et al., 1999). Apparent ileal digestibility of amino acids was increased in pigs fed PC or PSP diet compared with fed NC diet. The lower digestibilities of amino acids in pigs fed NC diet may be due to the presence of indigestible carbohydrate complexes (Walker et al., 1986). The presence of indigestible proteins such as glycinin and β-conglycinin (Li et al., 1990) or the presence of proteolytic enzyme inhibitor (Bowman, 1944) have also been associated with lower digestibility. It was found in some other studies that feeding processed soy protein such as SPC (Soy Protein Concentrates) and ISP (Isolate Soy Protein) in swine diet improved digestibility of amino acids compared with feeding SBM (Walker et al., 1986; Sohn et al., 1994b). Although SPC or ISP were some different soy protein from this study, those anitinutritional factors such as trypsin inhibitor, stachyose and rafiinose were lower than soybean meal. Also, in Exp. 2., digestibility of histidine, lysine, threonine, alanine, asparatic acid, glycine ($p<0.05$) and methionine ($p<0.09$) were higher in PSP treatment than in PC treatment. *In vivo* studies in pig suggested that amino acids may have advantage in absorption when presented to the mucosa in short-chain peptide bound form (Rerat et al., 1992).

IMPLICATIONS

Using processed soy protein in pig's diet improved nutrient digestibility. Also, small peptide form as protein sources seem to have more improved digestibility of N at early age in pigs.

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