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Effects of Replacing Soy Protein Concentrate with Fermented Soy Protein in Starter Diet on Growth Performance and Ileal Amino Acid Digestibility in Weaned Pigs

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ABSTRACT : For Exp. 1, 120 ((Yorkshire×Landrace)×Duroc) weaned pigs (7.96±0.01 kg average initial BW, 21 days weaning) were used in a 28 d-growth assay to determine the effects of replacing soy protein concentrate (SPC) with fermented soy protein (FSP) in a starter diet (d 0 to 7) on the growth performance, apparent fecal amino acid digestibility and subsequent performance in weaned pigs. Dietary treatments included: i) FSP0 (basal diet; whey-skim milk powder-SPC based diet); ii) FSP5 (replacing SPC with 5% FSP); iii) FSP10 (replacing SPC with 10% FSP). Pigs were fed the phase I diet for 7 days, and then each group was fed a common commercial diet for 21 days to determine the effect of previous diet on subsequent performance. Average daily gain (ADG) from d 5 to 7 (linear effect, $p = 0.01$) and d 7 to 14 (linear effect, $p<0.001$) were increased as FSP level increased. The pigs fed with FSP was heavier than the pigs fed with SPC at d 5 to 7 and d 7 to 14 after weaning ($p<0.05$). In the entire period (d 0 to 28), there were no significant differences in weight gain and final weight between SPC and FSP diets ($p>0.05$). Average daily feed intake (ADFI) was higher in pigs fed with the 5% FSP diet than those fed with the other diets at d 0 to 2 post-weaning (quadratic effect, $p = 0.05$). Also, for the entire period of phase I (d 0 to 7), pigs consumed more 5% FSP diet compared to other treatments (quadratic effect, $p = 0.03$). Gain/feed (G/F) was not affected by dietary SPC or FSP in phase I and subsequent periods, but G/F from d 5 to 7 after weaning was improved linearly ($p = 0.04$) as dietary FSP level increased. Pigs fed with 10% FSP also improved G/F compared with those fed only SPC ($p<0.05$). At d 7, there were linear increments in fecal dry matter (DM) ($p<0.1$) and nitrogen (N) ($p<0.01$) digestibilities as the dietary FSP level increased. The digestibilities of fecal essential and total amino acids were increased as the FSP level increased (linear effect, $p<0.1$). For Exp. 2, three ((Yorkshire×Landrace)×Duroc) weaned barrows (average initial BW of 7.32 kg) were surgically fitted with a simple T-cannula approximately 15 cm prior to the ileo-cecal junction. The experimental designs were 3×3 latin squares with pigs and periods as blocking criteria. Dietary treatments and composition were the same as in Exp. 1. Apparent ileal N digestibility was increased as FSP level was increased (linear effect, $p<0.05$). The dietary treatments (SPC and FSP) did not affect apparent ileal DM digestibility ($p>0.05$). Among essential amino acids, apparent digestibility of ileal arginine (Arg), lysine (Lys), methionine (Met) and phenylalanine (Phe) were improved as the FSP level increased (linear effect, $p<0.1$). Also, apparent ileal total essential, non-essential and total amino acid digestibilities were increased linearly ($p<0.1$). In conclusion, replacing SPC with fermented soy protein appeared beneficial in growth performance, N and amino acid digestibility during the early 7 days after weaning, and an equivalent effect showed on growth performance in subsequent period of 7 to 28 days after weaning. (**Key Words** : Fermented Soy Protein, Starter Diet, Growth Performance, Ileal Amino Acids Digestibility, Weaned Pigs)

INTRODUCTION

Weaning is a period of major stress for piglets because of the transition from liquid milk to solid diet, removal from sow, mixing with several litters and so on. These factors can result in low feed intake and poor growth promoting for pigs after weaning. Also, Whittemore (1993) reported that voluntary feed intake may be limited by the digestibility of the diet. Therefore, the use of highly digestible ingredients is an essential component in a successful weaning period.

Soybean meal is the most commonly used source of supplemental protein in the diet for non-ruminants because of its excellent amino acid profile and dependable supply. However, soybean meal contains several antinutritional

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factors, in particular, trypsin inhibitors and some of oligosaccharides which depress growth rate and decrease efficiency of nutrient utilization when fed to swine (Anderson et al., 1979). Therefore, many researchers have attempted to improve the utilization of soybean protein in postweaning pigs by nutrient substitution (Lennon et al., 1971; Wapnir et al., 1972) or improved processing (Wilson and Leibholz, 1981; Walker et al., 1986). Soy protein concentrate (SPC) and isolate soy protein (ISP) are the most widely used for replacing animal protein products to improve soy protein sources in weaning pig diet. Research by Sohn and Maxwell (1990) compared performances of pigs fed either dried skim milk, soybean meal, or one of three SPC. Average daily gain and feed efficiency were similar from d 0 to 14 for pigs fed dried skim milk and pigs fed one of the three SPC. Also, Dietz et al. (1988) and Geurin et al. (1988) identified SPC as a possible protein source for starter pig diets. Jones et al. (1990) reported the effect of partial or full replacement of dried skim milk with SPC.

Recently, there were a number of studies performed about fermented soy protein (FSP) (Kim et al., 2005; Yun et al., 2005) to compare it with conventional protein sources such as soybean meal, whey protein concentrate or dried skim milk (DSM) in weaned or early-weaned pigs. FSP, fermented by microbial, has a higher proportion of small peptide and lower anti-nutritional factors than soybean meal (Hong et al., 2004). It was found that protein improved absorption rate in a young animal's intestine in the form of small peptide. Guandalini and Rubino (1982) 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. Also, some research has suggested that animals and humans have a special transport mechanism for absorption of dipeptide by intestinal cells (Adibbi and Phillips, 1968; Matthews et al., 1974; Li et al., 1999). *In vivo* studies in pigs by Rerat et al. (1992) suggested that amino acids may have an advantage in absorption when presented to the mucosa in short-chain peptide bound form. In feeding trial, Kim et al. (2005) reported that FSP can be used up to 10% in a weaned pig's diet, successfully replacing the use of dried skim milk when the lactose content was matched. Min et al. (2004) also reported that FSP has shown a higher growth performance and nitrogen digestibility than in weaned pigs fed soybean meal diet. However, there was no study to show when influence of FSP appears on performance after weaning.

Therefore, these experiments were conducted to determine the effects of replacing SPC with fermented soy protein in a starter diet (d 0 to 7) on growth performance, ileal amino acids digestibility and subsequent performance in weaned pigs.

MATERIALS AND METHODS

Experiment 1

Fermented soy protein (FSP; Pepsoygen®, Genebiotech Co. Ltd.) was produced by fermentation of soybean meal which was inoculated *Aspergillus Oryzae* GB-107.

One hundred and twenty ((Yorkshire×Landrace) ×Duroc) weaned pigs (7.96±0.01 kg average initial BW, 21 days weaning) were used in a 28 d growth assay to determine the effects of replacing soy protein concentration (SPC) with fermented soy protein (FSP) in a starter diet (d 0 to 7) on growth performance, apparent fecal amino acids digestibility and subsequent performance in weaned pigs. This experiment was conducted by randomized complete block design (RBD) and pigs were assigned by body weight. There were 8 pens per treatment with 5 pigs per pen in an environmentally controlled building with slatted plastic floors.

Dietary treatments included: i) FSP0 (basal diet; whey-skim milk powder-SPC based diet); ii) FSP5 (replacing SPC with 5% FSP); and iii) FSP10 (replacing SPC with 10% FSP). Pigs were fed the phase I diet for 7 days, and then each group was fed the common commercial diet for 21 days to determine the effect of the previous diet on subsequent performance. Diets for d 0 to 7 (Table 1) were formulated to contain 3,860-3,912 kcal/kg of ME, 22.00% of CP and 1.60% 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 determination. Pigs were allowed to consume feed and water *ad libitum* from self-feeder and nipple waterer. The pigs and feeders were weighed on d 2, 5, 7, 14 and d 28 to determine average daily gain, average daily feed intake and G/F. Feces were collected to determine the apparent digestibilities of DM and N at 7, 24 and 28 days, and for apparent digestibility of amino acids at d 7.

Feed and feces were analyzed for DM and N concentrations (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. 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.

All data was analyzed as a randomized complete block design using the general linear model procedure of SAS (1996), with pen as the experimental unit. Dietary treatments were compared to each other by the polynomial

Table 1. Experimental diets composition for d 0-7 (as-fed basis)

Ingredients (%)	Level of FSP (%)		
	0	5	10
Whey	17.10	17.23	17.41
Skim milk powder	10.00	10.00	10.00
Sugar	10.00	10.00	10.00
Lactose	10.00	10.00	10.00
Whey protein concentrate	10.00	11.25	11.25
Soy protein concentrate	8.00	3.35	-
Fermented soy protein	-	5.00	10.00
Expanded corn	5.00	5.00	5.00
Soybean meal (dehulled)	5.00	5.00	5.00
Rice protein concentrate	5.00	5.00	5.00
Fish meal	3.00	3.00	2.27
Coconut oil	3.67	2.64	2.69
Soybean oil	3.00	3.31	3.43
Glucose	2.50	1.54	0.28
Yeast culture	2.00	2.00	2.00
Monocalcium phosphate	1.50	1.50	1.50
Organic acid	1.08	1.04	1.02
Lecithin	0.50	0.50	0.50
Limestone	0.40	0.40	0.40
Mineral/vitamin premix[1]	0.40	0.40	0.40
Antibiotics	0.35	0.35	0.35
L-lysine-HCl	0.34	0.32	0.33
Zinc oxide	0.30	0.30	0.30
DL-methionine	0.29	0.28	0.29
Salt	0.20	0.20	0.20
Threonine	0.15	0.15	0.15
Saccharin	0.10	0.10	0.10
Choline chloride	0.10	0.10	0.10
Antioxidant	0.03	0.03	0.03
Chemical composition[2]			
ME (kcal/kg)	3,912	3,880	3,860
Crude protein (%)	22.00	22.00	22.00
Lysine (%)	1.60	1.60	1.60
Methionine+cystine (%)	1.03	1.03	1.04
Threonine (%)	1.07	1.07	1.07
Lactose (%)	29.75	30.48	30.61
Calcium (%)	0.88	0.88	0.88
Phosphorus (%)	0.77	0.78	0.79

[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; 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.

[2] Calculated value.

regression (Peterson, 1985) method to determine linear and quadratic effects. Also, the means of treatments were compared by the Duncan's multiple range test (Duncan, 1955).

Experiment 2

Three ((Yorkshire×Landrace)×Duroc) weaned barrows (average initial BW of 7.32 kg) were surgically fitted with 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 Corporation, Korea). After the surgery, the barrows were individually housed in the stainless steel metabolism crates in a temperature controlled (28°C) room. The pigs were allowed 10 d of recovery before initiation of the experiment.

The experimental design was 3×3 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 and composition were the same as in Exp. 1. Chromic oxide was added (0.2% in the diet) as an indigestible marker to allow digestibility determinations.

Ileal digesta were collected during the 12 h period between the morning (8:00 a.m.) and evening (8:00 p.m.) 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.

DM, N, chromium concentrations of feed and ileal digesta and apparent ileal DM, N and AA digestibility were obtained by the same methods with experiment 1.

The data was analyzed as latin squares using the ANOVA of SAS (1996). Dietary treatments were compared to each other by the same methods with experiment 1.

Table 2. Amino acids composition of fermented soy protein (as-fed basis)

Item	%
Crude protein	54.25
Essential amino acids	
Arginine	4.23
Histidine	1.54
Isoleucine	2.63
Leucine	4.40
Lysine	3.54
Methionine	0.80
Phenylalanine	2.91
Threonine	2.23
Valine	2.74
Total essential amino acids	25.02
TEAA/CP	46.12

[1] Total essential amino acid.

RESULTS AND DISCUSSION

Experiment 1

Amino acids profile of fermented soy protein is presented at Table 2. Contents of CP, Lys and Met were

54.25, 3.54 and 0.80%, respectively. These analyzed values were similar with results of Yang et al. (2007) who reported the values were 53.0, 3.52 and 0.75%, respectively. The ratios of TEAA/CP were also similar with result of Yang et al. (2007) by 46 and 44%, respectively.

Table 3 presents the effect of replacement with fermented soy protein on the growth performance. The pigs lost weight during 2 days post-weaning regardless of the treatments (p>0.05). ADG for d 5 to 7 (linear effect, p = 0.01) and d 7 to 14 (linear effect, p<0.001) were increased as FSP level increased. Besides, the pigs fed with FSP was heavier than those pigs fed with SPC in d 5 to 7 and d 7 to 14 after weaning (p<0.05). Also, ADG for d 0 to 14 was increased linearly (p = 0.05) as FSP level increased. In entire period (d 0-28), there were no significant differences on weight gain and final weight between SPC and FSP diets (p>0.05). ADFI was higher in pigs fed with 5% FSP diet than pigs fed others in d 0 to 2 post-weaning (quadratic effect, p = 0.05). Also, in the entire period of phase I (d 0 to 7), pigs fed with 5% FSP diet consumed more than other treatments (quadratic effect, p = 0.03). However, FSP did not affect on the feed intake during the divided period within phase I (d 2 to 5 and 5 to 7) and subsequent period. G/F was not affected by dietary SPC or FSP in phase I and subsequent periods, but G/F of d 5 to 7 after weaning was improved linearly (p = 0.04) as dietary FSP level increased. Pigs fed with 10% FSP diet also improved G/F compared with those fed only SPC diet (p<0.05).

The transition of piglets at weaning from a liquid milk diet to a solid feed is a major stress which can lead to obstruct voluntary feed intake. It is well known that most of weaned pigs do not eat for 24-48 h because of these stresses.

Table 3. Effect of fermented soy protein on growth performance in weaned pigs (Exp. 1)

Item	Level of FSP (%)			SE[1]	Probability (p =)	
	0	5	10		Linear	Quadratic
Body weight (kg)						
d 0	7.96	7.96	7.96	0.01	0.78	0.87
d 28	21.49	21.94	21.60	0.25	0.75	0.22
ADG (g)						
d 0-2	-78	-26	-80	33	0.97	0.21
d 2-5	384	380	373	22	0.71	0.95
d 5-7	332[b]	382[a]	372[a]	10	0.01	0.03
d 7-14	489[b]	513[a]	525[a]	6	<.001	0.42
d 7-28	565	577	569	10	0.82	0.42
d 14-28	603	609	590	13	0.50	0.45
d 0-5	199	218	192	17	0.76	0.31
d 0-7	237	265	243	12	0.74	0.13
d 0-14	363[b]	389[a]	384[ab]	7	0.05	0.10
d 0-28	483	499	487	9	0.76	0.24
ADFI (g)						
d 0-2	99	142	95	17	0.86	0.05
d 2-5	423	446	401	18	0.41	0.15
d 5-7	354	340	364	12	0.58	0.07
d 7-14	601	631	626	19	0.37	0.47
d 7-28	822	811	808	13	0.45	0.80
d 14-28	933	901	900	14	0.10	0.38
d 0-5	294	324	279	15	0.50	0.06
d 0-7	311[ab]	343[a]	303[b]	12	0.64	0.03
d 0-14	456	487	465	12	0.62	0.09
d 0-28	695	694	682	10	0.38	0.63
G/F						
d 0-2	-1.78	-0.28	-1.46	0.68	0.75	0.13
d 2-5	0.91	0.86	0.93	0.05	0.72	0.33
d 5-7	0.94[b]	0.98[ab]	1.03[a]	0.03	0.04	0.88
d 7-14	0.82	0.82	0.84	0.02	0.42	0.61
d 7-28	0.69	0.71	0.70	0.01	0.30	0.19
d 14-28	0.65	0.68	0.66	0.01	0.62	0.13
d 0-5	0.67	0.67	0.68	0.04	0.97	0.98
d 0-7	0.76	0.77	0.80	0.03	0.33	0.81
d 0-14	0.80	0.80	0.83	0.01	0.14	0.46
d 0-28	0.70	0.72	0.71	0.01	0.20	0.22

[1] Pooled standard error. [a, b] Means in the same row with different superscript differ (p<0.05).

Table 4. Effect of fermented soy protein on DM and N digestibilities in weaned pigs (Exp.1)

Item (%)	Level of FSP (%)			SE[1]	Probability (p =)	
	0	5	10		Linear	Quadratic
d 7						
DM	79.63	80.59	82.38	1.05	0.09	0.75
N	67.53[b]	70.66[ab]	73.06[a]	1.36	0.01	0.83
d 14						
DM	72.50	73.63	73.17	0.92	0.61	0.49
N	72.34	73.00	72.45	0.99	0.94	0.63
d 28						
DM	71.06	71.03	71.94	1.42	0.67	0.79
N	71.78	70.22	71.35	1.24	0.81	0.39

[1] Pooled standard error. [a, b] Means in the same row with different superscript differ ($p<0.05$).

Inconsistently, pigs fed a small amount of feed for d 0 to 2 in this experiment, nevertheless pigs lost weight for the same period. This might be due to that only several pigs approached feeder before 2 days after weaning. Although it is hard to be convinced all pig fed with experimental diet for d 0 to 2, significantly higher in 5% FSP diet may be able to explain that replacement of SPC with FSP by 5% can increase palatability in newly weaned pigs. It was found that protein improved absorption rate in young animal's intestine in the form of small peptide (Guandalini and Rubino, 1982). Also, the FSP in this experiment had been known for included higher amount of small size of peptides than soybean meal by Hong et al. (2004). Therefore, we hypothesized that pigs could be influenced intensively in the early period when fed FSP. Indeed, ADG was affected by dietary FSP from d 5 to 7 in this study. Although there was no effect in d 0 to 5, it might be due to the fact that some pigs could not adopt unfamiliar solid diets and circumstance for 2 days after weaning. Also, during the subsequent period of d 7-14, FSP increased the pig's gain ($p<0.001$), so that led to an increase in ADG for d 0 to 14 ($p<0.05$). Even though ADFI was decreased in pigs fed with 10% FSP diet for d 0 to 7, increased ADG compensated for the lower feed intake resulting in a similar feed efficiency. In total the subsequent period (d 7-28) and the total feeding period (d 0-28), there were no differences by replacing SPC with FSP on ADG, ADFI and G/F ($p>0.05$). Kiers et al. (2003) also reported significantly improved feed utilization of *Bacillus subtilis* fermented soybean compared to toasted soybean in *E. coli* inoculated pigs after weaning. They supposed the result was likely because of the extensive hydrolysis of protein resulting in readily available free amino acids and peptides which is a major characteristic of *B. subtilis* fermentation (Steinkraus, 1996; Sarkar et al., 1997; Kiers et al., 2000). Improved soy protein for replacing animal protein sources in pigs diets has been studied by many researchers. Sohn and Maxwell (1990) conducted an experiment to characterize the influence of replacing dried skim milk with soy isolate. Average daily gain tended to increase during d 0 to 14 post-weaning. Also, Sohn et al. (1994) reported that ADG and feed efficiency were greater for pigs fed with the DSM diet, ISP diet, or SPC diet during the first 2-wk period than for pigs fed with the SBM diet. In an experiment about purified soybean via a proprietary microbial process (HP300; Hamlet protein, Denmark) by Zhu et al. (1998), replacement of dried whey, fish meal, full fat extruded soybeans and a part of the soybean meal with HP300 in piglet diets, improved average daily gain and feed conversion ratio. Also, Kim (2005) reported that the FSP can be used up to 6% in a weaned pig's diet replacing to dried skim milk without reduction of growth rate. Few studies were conducted to compare conventional processed soybean with fermented soy protein. Yang et al. (2007) reported higher growth performance in pigs fed with SPC diet than in fed SBM, HP300 and FSP diet. However, according to present growth trial, FSP appeared to have the effect of partially or fully replacing SPC in weaned pig's diet.

Apparent digestibilies of fecal DM and N are shown in Table 4. At d 7, there were linear increments in DM ($p<0.1$) and N ($p<0.01$) digestibilities as the dietary FSP level increased. Also, there were no differences among treatments in the subsequent periods (at d 14 and 28). This data is consistent with present growth data which ADG and G/F were increased in pigs fed FSP diets for d 5 to 7. Research by Min et al. (2004) partially agrees with present result who reported that the fermented soy protein has higher digestibilities of DM and N than HP300 at 21 days after weaning. Yang et al. (2007) also reported statistically equivalent DM and CP digestibilities at d 14 between SPC and FSP which was included 8% in weaned pig's diet. The higher DM and N digestibilities when pigs are fed FSP diets may be due to the low trypsin inhibitor, oilgosaccharides level and high proportion of small size peptide in soybean meal via fermentation by *Aspergillus oryzae* and *Bacillus spp.* Hong et al. (2004) reported that the trypsin inhibitor of soybean meal was decreased about 84% throughout the *Aspergillus oryzae* fermentation. Also, according to earlier report by Kiers et al. (2000), fermentation of soybean using several *Bacillus spp.* resulted in major biochemical changes

Table 5. Effect of fermented soy protein on apparent fecal amino acids digestibility in weaned pigs (Exp.1)

Item (%)	Level of FSP (%)			SE[1]	Probability (p =)	
	0	5	10		Linear	Quadratic
Essential amino acids						
Arginine	75.93	77.28	77.51	0.93	0.30	0.65
Histidine	39.00[b]	47.70[ab]	51.34[a]	2.98	0.04	0.53
Isoleucine	74.05	73.14	74.23	1.67	0.71	0.49
Leucine	72.99	72.95	57.76	1.01	0.10	0.31
Lysine	77.54	78.98	80.86	0.94	0.05	0.85
Methionine	75.56	71.81	77.84	2.45	0.55	0.18
Phenylalanine	71.24	70.74	74.15	1.28	0.18	0.28
Threonine	72.28	73.62	74.61	1.06	0.20	0.90
Valine	71.67	70.46	71.91	1.11	0.79	0.38
Total essential amino acids	70.03	70.74	73.14	1.10	0.10	0.60
Non essential amino acids						
Alainine	59.24	61.41	63.18	1.72	0.18	0.93
Asparatic acid	72.81	74.05	75.45	1.27	0.22	0.96
Cystine	48.72	49.25	50.82	4.42	0.75	0.93
Glutamic acid	74.44	75.62	77.45	0.87	0.11	0.78
Glycine	60.81	62.05	65.80	1.80	0.09	0.60
Proline	73.99[b]	76.78[ab]	77.98[a]	0.83	0.03	0.48
Serine	64.61	67.14	70.34	1.66	0.07	0.88
Tyrosine	68.73	67.20	71.37	1.39	0.25	0.17
Total non essential amino acids	65.42	66.69	69.05	1.54	0.17	0.79
Total amino acids	67.72	68.71	71.09	1.17	0.09	0.70

[1] Pooled standard error. [a, b] Means in the same row with different superscript differ (p<0.05).

Table 6. Effect of fermented soy protein on apparent ileal DM and N digestibilities in weaned pigs (Exp.2)

Item (%)	Level of FSP (%)			SE[1]	Probability (p =)	
	0	5	10		Linear	Quadratic
DM	71.49	72.78	72.84	1.34	0.49	0.71
N	70.11	73.07	73.70	1.33	0.05	0.48

[1] Pooled standard error.

in the substrate leading to an increase in solubility and *in vitro* digestibility.

Digestibilities of apparent fecal amino acids at d 7 are presented in Table 5. Digestibilities of histidine (His), leucine (Leu), Lys and total essential amino acids were increased as the FSP level increased (linear effect, p<0.1). Among non-essential amino acids, glycine (Gly), proline (Pro) and serine (Ser) digestibilities were increased linearly (p<0.1). Also, total amino acids digestibility was improved as the dietary FSP level increased (linear effect, p<0.1). Recent researches agree with this result (Yun et al., 2005; Cho et al., 2007). Yun et al. (2005) reported that the mean digestibility of essential amino and non-essential amino acids were comparable with FSP and whey protein concentration or fish meal. Also, Sohn et al. (1994) found that the apparent essential amino acids digestibility on d 7 and 14 was similar in pigs fed with the SPC, ISP or DSM diets. Even though the dietary treatments were different with present experiments, these researches observed an equivalent amino acids digestibility between improved soy protein (SPC and FSP) and animal protein source. Also, there was consistency between N and total amino acids digestibility which were analyzed at d 7 in present data. This result suggests that FSP was more effectively absorbed in the early period after weaning.

Experiment 2

As shown in Table 6, apparent ileal N digestibility was increased as FSP level was increased (linear effect, p<0.05). This agreed with apparent fecal N digestibility in Exp. 1. The dietary treatments (SPC and FSP) did not affect the apparent ileal DM digestibility (p>0.05) conflictingly with fecal DM digestibility. This discrepancy may be result from microbial digestion in large intestine. As discussed in Exp. 1., FSP has a low trypsin inhibitor, oilgosaccharides level and a high proportion of small size peptide via fermentation by *Aspergillus oryzae* and *Bacillus spp.*. Kim (2004) also reported that the trypsin inhibitor level of soybean meal was decreased from 2.70 to 0.42 mg/g after *Aspergillus oryzae* fermentation, whereas crude protein and crude fat levels were increased. Also, in feeding trial, Min et al. (2004) observed that apparent ileal digestibility of N was higher for pigs fed FSP diets than pigs fed SBM and HP300 diets. The improved N digestibility in the data showed a similar trend

Table 7. Effect of fermented soy protein on apparent ileal amino acids digestibility in weaned pigs (Exp.2)

Item (%)	Level of FSP (%)			SE[1]	Probability (p =)	
	0	5	10		Linear	Quadratic
Essential amino acids						
Arginine	76.47	76.69	78.83	0.54	0.07	0.33
Histidine	70.61	71.71	76.12	1.87	0.11	0.51
Isoleucine	76.27	76.51	78.22	0.78	0.15	0.49
Leucine	76.11	76.57	78.26	0.75	0.11	0.54
Lysine	76.64	76.91	78.49	0.58	0.09	0.40
Methionine	77.14	77.41	78.83	0.57	0.10	0.45
Phenylalanine	75.89	76.40	78.10	0.74	0.10	0.55
Threonine	76.07	76.48	78.12	0.71	0.11	0.52
Valine	75.61	75.79	78.02	0.88	0.13	0.48
Total essential amino acids	75.65	76.07	78.06	0.82	0.10	0.48
Non essential amino acids						
Alainine	73.88	74.70	77.34	1.24	0.12	0.58
Asparatic acid	76.36	76.74	78.20	0.60	0.10	0.51
Cystine	73.14	73.60	76.06	1.15	0.15	0.52
Glutamic acid	76.41	77.06	78.45	0.65	0.09	0.66
Glycine	73.89	74.61	77.36	1.28	0.13	0.55
Proline	76.51^{b}	76.95^{ab}	78.54^{a}	0.49	0.04	0.39
Serine	75.08	75.74	77.99	0.88	0.08	0.50
Tyrosine	76.53	76.56	78.30	0.62	0.11	0.32
Total non essential amino acids	75.22	75.74	77.78	0.85	0.10	0.51
Total amino acids	75.43	75.91	77.92	0.83	0.10	0.49

[1] Pooled standard error. [a, b] Means in the same row with different superscript differ ($p<0.05$).

to the further analyzed apparent ileal amino acids digestibility.

As shown in Table 7, among essential amino acids, apparent ileal Arg, Lys, Met and Phe digestibilities were improved as the FSP level increased (linear effect, $p<0.1$). Also, the total essential, non-essential and total amino acids digestibility were increased linearly ($p<0.1$). Especially, improved digestibilities of Lys, Pro and Ser had a similar trend to the apparent fecal Lys, Pro and Ser digestibilities in Exp. 1. Some research suggests that animals and humans have a special transport mechanism for the absorption of dipeptide by intestinal cells (Adibbi and Phillips, 1968; Matthews et al., 1974; Li et al., 1999). *In vivo* studies in pigs by Rerat et al. (1992) suggest that amino acids may have an advantage in absorption when presented to the mucosa in the short-chain peptide bound form. The result was convinced by Kim (2004)'s research who reported that fermented soy protein has a higher proportion of the small peptide size (<20 kD) than in soybean meal. Also, in the feeding trial, conducted by Min et al. (2004), the apparent ileal essential amino acids digestibility was higher in pigs fed with FSP diets than in those fed with HP 300 diet and soybean meal diets. They also observed that improved Lys and Met digestibilities in FSP diets compared to HP300 diets. However, Yang et al. (2007) observed similar apparent ileal digestibilities of total essential, non essential amino acids between FSP and SPC diets. These inconsistencies are may be due to disagree with FSP concentration in present experimental diet and experimental design. SPC was replaced with 5 and 10% of FSP in present experimental diets, whereas they provided 8% FSP, SBM, SPC and HP300 respectively as an experimental protein source to compare each others.

In conclusion, replacing SPC with fermented soy protein appeared beneficial in growth performance, N and amino acid digestibilities during the early 7 days after weaning, and equivalent effect showed on growth performance in subsequent period of 7-28 days after weaning.

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