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Evaluation of FSP (Fermented Soy Protein) to Replace Soybean Meal in Weaned Pigs: Growth Performance, Blood Urea Nitrogen and Total Protein Concentrations in Serum and Nutrient Digestibility

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ABSTRACT : A total of one hundred and forty four weaned pigs with an average BW of 8.09±0.05 kg were used in a 28 day study to investigate the effects of fermented soy protein on growth performance, blood urea nitrogen and total protein concentrations in serum and nutrient digestibility in weaner pigs. Pigs were blocked by initial body weight and randomly allocated to one of four dietary treatments in a randomized complete block design. There were six replications per treatment. Dietary treatments included, SBM (corn-soybean meal basal diet), F 5, 10 and 15 (fermented soy product was used at 5, 10 and 15% to replace soybean meal in basal diet, respectively). ADG (average daily gain) and ADFI (average daily feed intake) were not affected ($p>0.05$) by dietary treatments during the entire 4-wk study period. There were linear increments in feed efficiency ($p<0.01$) as the dietary FSP level increased during the entire feeding period. No significant differences were observed for dry matter and nitrogen digestibility during the experimental period ($p>0.05$). Digestibilities of histidine, lysine and methionine were increased as the FSP level increased (linear effect, $p<0.05$, $p<0.01$). Among non-essential amino acids, alanine, glutamic acid, serine, tyrosine and total non essential amino acid digestibilities were increased linearly ($p<0.05$, $p<0.01$). There were quadratic effects in protein digestibility ($p<0.05$). Total amino acid digestibility of the F15 diet was improved compared with the F5 diet ($p<0.05$). There were no significant differences in fecal consistency score among the treatments ($p>0.05$). At the end of experiment, BUN (blood urea nitrogen) concentration was increased as the FSP level increased (linear effect, $p<0.01$) and total protein concentration was lowest ($p<0.05$) for pigs fed the SBM diet among treatments. In conclusion, the feeding of 10 or 15% FSP to nursery pigs improved feed efficiency, amino acid digestibility and blood urea nitrogen and total protein concentrations in blood. (**Key Words :** Fermented Soy Protein, Nutrient Digestibility, Weaned Pigs)

INTRODUCTION

Protein source is a very important factor for nursery pigs growth, because poor amino acid and protein nutrition have a profound effect on physiology health status and growth factor of pigs. As animal protein sources, milk, fish and blood products have been generally utilized for weaned pigs diets. On the other side, soybean meal is most widely used as protein source in swine diets and has high quality amino acids profile. However, soybean meal contains several antinutritional 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).

There were a number of studies that compared fermented soy protein (FSP) with conventional protein sources in early-weaned or nursery pigs (Kim et al., 2005; Yun et al., 2005). Specially, fermented soy protein (FSP) has a higher proportion of small peptide and lower anti-nutritional factors than soybean meal produced by microbial fermentation. Also, trypsin inhibitor was decreased after fermentation of soybean meal (Kim, 2004). Min et al. (2004) reported that FSP showed higher growth performance and nitrogen digestibility in weaned pigs than soybean meal. Kim et al. (2005) demonstrated that fermented soy protein can be used up to 10% in nursery pigs diet, successfully replacing the use of dried skim milk when the lactose content was matched. Min (2006) reported that pigs fed the FSP diet decreased backfat thickness and improved loin percentage, meat color and the protein and amino acid concentration in loin muscle.

Therefore, the objective of the present study was to

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Table 1. Diet composition (as-fed basis)

Ingredient (%)	SBM[1]	F5[1]	F10[1]	F15[1]
Expended corn	44.35	45.21	46.98	45.98
Soybean meal (Local)	30.00	24.50	18.10	14.90
FSP	-	5.00	10.00	15.00
Soy oil	4.10	3.80	3.45	3.10
Limestone	0.20	0.20	0.20	0.20
MCP	1.00	1.00	1.00	1.00
Salt (Flower salt)	0.27	0.27	0.27	0.27
Calprona P4	1.00	1.00	1.00	1.00
Saccharin	0.08	0.08	0.08	0.08
Fine sugar	3.00	3.00	3.00	3.00
Whey (Lactalis France)	13.75	13.75	13.70	13.70
Yeasture	0.50	0.50	0.50	0.50
DL-met	0.25	0.23	0.23	0.22
L-lysine·HCl	0.40	0.37	0.36	0.35
Threonine	0.16	0.15	0.14	0.14
Zinc oxide	0.30	0.30	0.30	0.30
Choline chl 50%	0.10	0.10	0.10	0.10
Perfactia	0.11	0.11	0.11	0.11
Neomycin sulfate	0.10	0.10	0.10	0.10
Vitamin premix[2]	0.10	0.10	0.10	0.10
Trace mineral premix[3]	0.18	0.18	0.18	0.18
Coliloc (org)	0.05	0.05	0.05	0.05
Chemical composition[4]				
NE (kcal/kg)	2,642	2,638	2,642	2,643
Crude protein (%)	20.24	20.51	20.50	20.51
Crude fat (%)	7.25	6.91	6.59	6.23
Lysine (%)	1.42	1.43	1.43	1.43
Methionine (%)	0.54	0.53	0.53	0.53
Met+cys (%)	0.87	0.87	0.87	0.88
Calcium (%)	0.75	0.75	0.75	0.75
Phosphorus (%)	0.74	0.75	0.75	0.75

[1] SBM: corn-soybean meal basal diet; F 5, 10 and 15: fermented soy protein was used at 5, 10 and 15% in basal diet, respectively.
[2] 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.
[3] 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.
[4] Calculated value.

determine the effects of fermented soy protein to replace soybean meal on growth performance, blood urea nitrogen and total protein concentrations in serum and nutrient digestibility in weaning pigs.

MATERIALS AND METHODS

Experimental design, animals and diets

A total of one hundred and forty four weaned pigs with an average BW of 8.09±0.05 kg (21 days) were used in a 28 days study to investigate the effects of fermented soy protein on growth performance, blood urea nitrogen, nutrient digestibility and total protein concentrations in serum in weaning pigs. Pigs blocked by initial body weight and allocated to one of four dietary treatments in a randomized complete block design. There were six replications per treatment. Dietary treatments included: SBM (corn-soybean meal basal diet), F 5, 10 and 15 (fermented soy product was used by 5, 10 and 15% in basal diet, respectively). The experimental diets were formulated to meet or exceed the nutrient requirements recommended by NRC (1998). Pigs room temperature was maintained at 32°C for the first week, and then decreased by 1 to 2°C every week until 26°C was reached.

Producing fermented soy protein

Common soybean meal was fermented by inoculating *Aspergillus Oryzae* GB-107 under anaerobic conditions for 48 h. FSP was produced by solid fermentation techniques.

Sampling and measurements

Pigs were allowed to consume feed and water *ad libitum* from self-feeder and nipple waterer. Average daily gain (ADG) and average daily feed intake (ADFI) were measured on d 14 and 28 and gain/feed ratio was also calculated. Chromic oxide (Cr_2O_3) was added at 0.20% of

Table 2. Effects of fermented soy protein on growth performance in nursery pigs[1] (n = 6)

Items	SBM[2]	F5[2]	F10[2]	F15[2]	SE[3]
0-14days					
ADG (g)	203	209	213	216	13
ADFI (g)	269	290	284	279	14
Gain/feed	0.755	0.721	0.750	0.774	0.039
14-28days					
ADG (g)	569	589	604	611	24
ADFI (g)	858	889	839	828	27
Gain/feed[4]	0.663^{b}	0.663^{b}	0.720^{ab}	0.738^{a}	0.019
0-28days					
ADG (g)	386	399	409	414	14
ADFI (g)	564	590	562	554	17
Gain/feed[4]	0.684^{bc}	0.676^{c}	0.728^{ab}	0.747^{a}	0.014

[1] 144 pigs with initial average BW 8.09±0.05 kg.
[2] SBM: corn-soybean meal basal diet; F 5, 10 and 15: fermented soy protein was used at 5, 10 and 15% in basal diet, respectively.
[3] Pooled standard error. [4] Linear effect ($p<0.01$). a, b, c Means in the same row with different superscripts differ ($p<0.05$).

Table 3. Effects of fermented soy protein on dry matter and nitrogen digestibility in nursery pigs[1] (n = 12)

Items	SBM[2]	F5[2]	F10[2]	F15[2]	SE[3]
28 days					
DM	78.54	81.57	80.82	81.51	1.45
N	73.34	74.91	74.53	75.71	1.87

[1] 48 pigs with initial average BW 8.09±0.05 kg.
[2] SBM: corn-soybean meal basal diet); F 5, 10 and 15: fermented soy protein was used at 5, 10 and 15% in basal diet, respectively.
[3] Pooled standard error.

diets as a digestible marker on day-21 and at the end of experiment (d 28). fresh feces samples were collected by massaging the anus. Feed and feces samples were analyzed for DM and N concentrations (AOAC, 1995). Chromium was determined by UV absorption spectrophotometry (Shimadzu, UV-1201, Japan) and apparent digestibilities of DM and N were calculated using the indirect methods. 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 acids analyzer (Biochrom 20. Pharmacia Biotech. England). Sulfur-containing amino acids were analyzed after cold performic acid oxidation overnight and subsequent hydrolysis.

Fecal consistency scoring was based on the following index used by Sherman et al. (1983): 0, nomal (feces firm and well formed); 1. soft consistency (feces soft and formed): 2, mild diarrhea (fluid feces, usually yellowish); and 3. severe diarrhea (feces watery and projectile).

Blood samples were obtained by jugular venipuncture on d 28 from two randomly selected pigs in each pen. samples were measured using the automatic biochemistry analyzer (HITACHI 747, Japan) for blood urea nitrogen (BUN), total protein concentrations.

Statistical analyses

In this experiment. all the datas were analyzed as a randomized complete block design using GLM procedures of SAS (1996). Dietary treatments were compared to each other by the polynomial regression (Peterson, 1985) method to determine linear and quadratic effects. Also, data was compared the means of treatments by the Duncan's multiple range test (Duncan. 1955).

RESULTS AND DISCUSSION

Growth performance

ADG and ADFI were not affected ($p>0.05$) by dietary treatments during the entire 4-wk study period (Table 2). There were linear increments in feed efficiency ($p<0.01$) as the dietary FSP level increased during entire feeding period. Kiers et al. (2003) demonstrated that piglets fed fermented soya beans (for *Rhizopus* and *Bacillus*) showed increased feed efficiency 3 and 8%. respectively. This 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 these fermentations (Steinkraus, 1996; Sarkar et al., 1997; Kiers et al., 2000). Also. Min (2006) demonstrated that FSP in his experiment had no effect on feed intake, therefore. it might lead to improving feed efficiency. This result is in agreement with our experimental results.

DM and N digestibilities

No significant differences were observed for dry matter and nitrogen digestibility during experimental period ($p>0.05$) (Table 3). DM and N digestibilities in FSP treatments were not affected compared to SBM treatment. Min (2006) reported that FSP did not affect DM

Table 4. Effects of fermented soy protein on amino acids digestibility in nursery pigs[1] (n = 12)

Items	SBM[2]	F5[2]	F10[2]	F15[2]	SE[3]
28 days					
Essential amino acid					
Arginine	85.54	84.43	86.70	87.10	0.88
Histidine[4]	68.13[b]	67.70[b]	73.92[a]	73.65[a]	1.79
Isoleucine	71.34	68.25	70.85	73.46	1.93
Leucine	73.75	71.94	75.42	76.83	1.54
Lysine[4]	77.75	77.72	81.62	81.68	1.39
Methionine[5]	70.98[b]	69.95[b]	74.61[ab]	76.24[a]	1.56
Phenylalanine	74.95	73.02	76.28	77.23	1.50
Threonine	70.51	69.45	73.11	74.51	1.70
Valine	70.89	67.69	71.00	72.88	1.97
Total essential amino acid	73.76	72.24	75.95	77.06	1.54
Non essential amino acid					
Alanine[4]	67.43[ab]	66.33[b]	71.04[ab]	72.66[a]	1.88
Aspartic acid	74.46	73.59	77.10	77.95	1.54
Cysteine	69.32	65.70	71.11	71.35	1.84
Glutamic acid[4]	77.52	76.90	80.20	81.03	1.30
Glycine	73.07	71.40	75.45	76.34	1.64
Proline[6]	78.80[ab]	75.42[b]	77.82[ab]	79.90[a]	1.21
Serine[4]	75.37[ab]	74.76[b]	78.87[ab]	79.21[a]	1.33
Tyrosine[5]	70.49[b]	70.14[b]	74.02[ab]	76.03[a]	1.54
Total non essential amino acid[4]	73.30[ab]	71.78[b]	75.70[ab]	76.81[a]	1.51
Total amino acid	73.54[ab]	72.02[b]	75.83[ab]	76.94[a]	1.52

[1] 48 pigs with initial average BW 8.09±0.05 kg.
[2] SBM: corn-soybean meal basal diet; F 5, 10 and 15: fermented soy protein was used at 5, 10 and 15% in basal diet, respectively.
[3] Pooled standard error. [4] Linear effect ($p<0.05$). [5] Linear effect ($p<0.01$). [6] Quadratic effect ($p<0.05$).
[a, b] Means in the same row with different superscripts differ ($p<0.05$).

Table 5. Effects of fermented soy protein on fecal scores in nursery pigs[1] (n = 36)

Items	SBM[2]	F5[2]	F10[2]	F15[2]
No. of pigs	36	36	36	36
2 days	2 (0.9)	2 (0.9)	3 (0.9)	1 (0.8)
4 days	2 (0.7)	2 (0.8)	1 (0.6)	2 (0.5)
8 days	1 (0.5)	1 (0.6)	1 (0.4)	1 (0.4)
14 days	0 (0.3)	0 (0.2)	0 (0.2)	0 (0.2)

[1] 144 pigs with initial average BW 8.09±0.05 kg.
[2] SBM: corn-soybean meal basal diet; F 5, 10 and 15: fermented soy protein was used at 5, 10 and 15% in basal diet, respectively.

digestibility, however, N digestibility was higher as FSP levels was increased. Also, there were no significant differences in DM and N digestibilities between the adding of FSP in simple diet and non adding FSP in the complex diet (Min, 2006). In the other side, fermentation of soybean meal using *Aspergillus oryzae* decreased trypsin inhibitor about 84% (Hong et al., 2004) and the researchers demonstrated that FSP diet had higher DM and N digestibilities than the SBM diet (Min et al., 2004; Yun et al., 2005). Because FSP has a high proportion of small peptide and low anti-nutritional (trypsin inhibitor, oilgosaccharides level) factors by microbial fermentation (*Aspergillus oryzae and Bacillus* sp.), we looked forward to improving nutrition digestibility. However, our study did not identify FSP effect on DM and N digestibilities for young pigs.

Amino acid digestibility

The essential and nonessential amino acid digestibilities are presented in Table 4. Digestibilities of Histidine, Lysine and Methionine were increased as the FSP level increased (linear effect, $p<0.05$, $p<0.01$). Among non-essential amino acids, Alanine, Glutamic acid, Serine, Tyrosine and total non essential amino acid digestibilities were increased linearly ($p<0.05$, $p<0.01$). There were quadratic effect in Pro digestibility ($p<0.05$). Total amino acids digestibility of F15 diet was improved compared with F5 diet ($p<0.05$). Min (2006) reported that individual essential amino acids digestibility of FSP diet was improved compared with SBM diet because FSP had a high amount of small peptide by microbial fermentation (Kim, 2004) that presented to the mucosa in short-chain peptide bound form (Rerat et al., 1992). Also, researchers demonstrated that young pigs fed FSP were similar to pigs fed other protein sources (whey

Table 6. Effects of fermented soy protein on BUN and total protein concentrations of blood in nursery pigs[1] (n = 12)

Items	SBM[2]	F5[2]	F10[2]	F15[2]	SE[3]
28days					
BUN[4]	10.87[b]	13.65[a]	13.77[a]	14.55[a]	0.49
Total protein	5.10[b]	5.17[ab]	5.58[a]	5.32[ab]	0.15

[1] 48 pigs with initial average BW 8.09±0.05 kg.
[2] SBM: corn-soybean meal basal diet; F 5, 10 and 15: fermented soy protein was used at 5, 10 and 15% in basal diet, respectively.
[3] Pooled standard error. [4] Linear effect ($p<0.01$).
[a, b] Means in the same row with different superscripts differ ($p<0.05$).

protein, fish meal, SPC, ISP and DSM) on the apparent amino acids digestibility (Shon et al., 1994; Yun et al., 2005). These datas partially agreed with our research on non-essential amino acids digestibility.

Fecal consistency score

Fecal consistency score of pigs fed experimental diet is presented in Table 5. There was no significant difference in fecal consistency score among the treatments ($p>0.05$). Fecal consistency score was lowed in all treatments because our nursery room has all-in all-out system to control disease. Kim et al. (2007) reported that the villous height, crypt depth and villous height to crypt depth ratio were not affected by fermented soy protein. Also, Kelly et al. (1991) and Vente-Spreeuwenberg et al. (2004) reported that villous height and crypt depth were positively related to feed intake. Although diarrhea is highly affected by various factors, intestinal morphology is considered as a primary factor to diarrhea.

Blood profiles

At the end of experiment, BUN concentration was increased as the FSP level increased (linear effect, $p<0.01$) and total protein concentration was lowest ($p<0.05$) for pigs fed SBM diet among treatments (Table 6). These results showed that total protein and BUN concentrations were affected by FSP diet. Min (2006) reported that total protein concentration in blood was not affected by the FSP level in diets, however, BUN concentration on the final day of experiment was greater in FSP 2.5% diet. This result is inconsistent with our result on total protein concentration. Plasma protein is affected by protein intake and many researchers (Eggum, 1970; Orok and Bowland, 1975; Bassily et al., 1982) demonstrated that BUN is connected with protein type, intake and quality. Because of high utility value of FSP, we can detect the effect of FSP on plasma protein concentration in nursery pigs.

In conclusion, the feeding of 10 or 15% FSP to nursery pigs diet improved feed efficiency, amino acids digestibility and blood urea nitrogen and total protein concentrations in blood. Therefore, it is suggested that FSP (fermented soy protein) can be used to replace soybean meal in diets for weaned pigs.

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