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Effects of Fermented Soy Protein on Growth Performance and Blood Protein Contents in Nursery Pigs

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ABSTRACT : Fifty-four cross-bred ((Landrace×Yorkshire)×Duroc) pigs (13.47±0.03 kg average initial BW) were evaluated in a 42 d growth assay to determine the effects of the fermented soy product (FSP). The dietary treatments were: FSP 0 (corn-soybean basal diet), FSP 2.5 (FSP 0 amended with 2.5% FSP), and FSP 5 (FSP 0 amended with 5% FSP). The body weight at the end of the experiment increased linearly ($p = 0.05$) as the FSP levels in the diets increased. In addition, the ADG and G/F ratio also increased (linear effect, $p = 0.06$) as the levels of FSP increased. However, there was no effect of FSP on ADFI or DM digestibility ($p>0.05$). Furthermore, the N digestibility increased as the FSP levels increased (linear effect, $p = 0.003$), although the total protein concentration in the blood was not affected by FSP ($p>0.05$). Additionally, the albumin concentration was higher in pigs fed diets that contained 2.5% FSP than in pigs in the control group or the FSP 5 group (quadratic effect, $p = 0.07$). The creatinine concentrations were also evaluated at d 42 and found to be greater in pigs that received the FSP 2.5 diet (quadratic effect, $p = 0.09$). Moreover, the creatinine concentration increased linearly in response to FSP treatment ($p = 0.09$). Finally, although the BUN concentration on the final day of the experiment was greater in pigs that received the FSP 2.5 diet (quadratic effect, $p = 0.10$), there were no incremental differences in BUN concentrations among groups ($p>0.05$). Taken together, the results of this study indicate that feeding FSP to pigs during the late nursery phase improves growth performance and N digestibility. (**Key Words :** Fermented Soy Protein, Growth Performance, Blood Protein Contents, Nursery Pigs)

INTRODUCTION

Soybean meal (SBM), which is the most widely used protein source in swine diets, contains a high quality amino acids profile and easily digested nutrients compared to other plant protein sources. However, even though soybean meal is an excellent protein source, it has shown poor growth performance and low digestibility in weanling pigs due to the presence of anti-nutritional factors such as trypsin inhibitors, haemagglutinins, raffinose and stachyose (Anderson et al., 1979).

The inclusion of high quality protein sources in nursery diets is a common practice in the swine industry, and many novel protein products recently have been developed. As a matter of course, the performance of nursery pigs is maximized when their diets include animal protein sources such as milk or blood; however, due to the high cost of animal protein sources, plant protein sources that have been treated by heating, extraction or other unique processes are often used instead.

Conventionally, soy protein concentrate and isolated soy protein have been recognized as superior improved protein sources in the swine industry, and some studies have reported similar growth performance in pigs treated with these protein sources and those that were treated with dried skim milk (Dietz et al., 1988; Sohn and Maxwell, 1990; Burnham et al., 1995). Recently, the fermentation of soy with *Aspergillus oryzae* and *Bacillus sp.* has led to the development of a novel soybean protein source that has a lower level of anti-nutritional factors and a higher protein concentration. Furthermore, Kim (2004) observed that trypsin inhibitors were decreased in fermented soybean meal. Additionally, the results of feeding trials conducted by Min et al. (2004) revealed that weaned pigs provided with diets amended with fermented soy protein (FSP) had higher growth performance and nitrogen digestibility than those that were provided with untreated soybean meal diets. Moreover, Kim et al. (2005) reported that the diets of weaned pigs can contain up to 10% FSP, thereby allowing

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Table 1. Composition of experimental diets (as-fed basis)

Ingredients (%)	Level of FSP (%)		
	0	2.5	5
Corn	49.87	49.75	49.59
Soybean meal (Dehulled)	30.21	27.88	25.59
Whey	8.75	8.75	8.75
Bakery by-products	4.50	4.50	4.50
Fermented soy protein	0.00	2.50	5.00
Lard	2.50	2.50	2.50
Dicalcium phosphate	0.72	0.72	0.72
Organic acid	0.63	0.63	0.63
Limestone	0.50	0.50	0.50
L-lysine-HCL	0.30	0.28	0.25
Zinc oxide	0.30	0.30	0.30
DL-methionine	0.20	0.19	0.18
Yeast culture	0.20	0.20	0.20
Salt	0.20	0.20	0.20
Vitamin premix[1]	0.18	0.18	0.18
Mineral premix[2]	0.18	0.18	0.18
Flavoring	0.15	0.15	0.15
Choline chloride	0.10	0.10	0.10
Thiamulin	0.10	0.10	0.10
Chlortetracycline	0.10	0.10	0.10
Carbadox	0.10	0.10	0.10
Ivermectin	0.10	0.10	0.10
Threonine	0.08	0.07	0.05
Antioxidant	0.02	0.02	0.02
Yucca extract	0.01	0.01	0.01
Chemical composition[3]			
ME (kcal/kg)	3,463	3,467	3,472
NE (kcal/kg)	2,570	2,570	2,570
Crude protein (%)	20.00	20.22	20.45
Lysine (%)	1.32	1.32	1.32
Methionine+cystine (%)	0.83	0.83	0.83
Calcium (%)	0.66	0.66	0.66
Phosphorus (%)	0.53	0.53	0.54

[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.

replacement of the use of dried skim milk. However, few studies have been conducted to evaluate the effects of feeding diets containing FSP to late nursery pigs.

Therefore, this study was conducted to determine the effects of fermented soy protein on growth performance and blood protein contents in nursery pigs.

MATERIALS AND METHODS

Fifty four cross-bred ((Landrace×Yorkshire)×Duroc) pigs (13.47±0.03 kg average initial BW) were used in a 42 d growth assay. This experiment was conducted using a randomized complete block design with pigs being assigned to treatment groups by body weight. In this experiment, there were 6 pens per treatment with 3 pigs per pen. All experiments were conducted in an environmentally controlled building with slatted plastic floors.

The pigs were provided with one of the following dietary treatments: FSP 0 (corn-soybean meal basal diet), FSP 2.5 (FSP 0 amended with 2.5% FSP) and FSP 5 (FSP 0 amended with 5% FSP). Common soybean meal was fermented by inoculating *Aspergillus Oryzae* GB-107 under anaerobic condition for 48 h. FSP was produced by solid fermentation technique (Cho et al., 2007). The basal diet contained 3,463-3,472 kcal/kg of ME, 20.22-20.45% of CP and 1.32% of lysine, and all diets were formulated to meet or exceed the nutrient requirements recommended by the NRC (1998). In addition, 0.2% chromic oxide (Cr_2O_3) was added to the diet as an indigestible marker to allow evaluation of the digestibility. The pigs were allowed to consume feed and water *ad libitum* from a self-feeder, and the pigs and feeders were weighed on d 0 and d 42 to determine the average daily gain, the average daily feed intake and the G/F ratio.

In addition, feed and feces were analyzed for DM and N (AOAC, 1994). Furthermore, the chromium concentration was determined using visible absorption spectrophotometry (Optizen 1411V, Mecasys, Korea) and the apparent digestibilities of DM and N were calculated using the indirect method.

Blood samples were obtained by jugular venipuncture on d 0, 21 and 42 from one randomly selected pig in each pen. The samples were then evaluated using an automatic biochemistry analyzer (HITACHI747, Japan) to determine the total protein, albumin, creatinine and blood urea nitrogen (BUN) concentrations.

All data were analyzed using a randomized complete block design following the general linear model procedure of SAS (1996), with each pen as the experimental unit. Pigs in different dietary treatment groups were then compared using the polynomial regression method (Peterson, 1985) to determine the linear and quadratic effects of increased dietary FSP levels. Additionally, the means of the data corresponding to different treatment groups were compared using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Table 2 shows the effect of fermented soy protein on growth performance in nursery pigs. The body weight on the final day of the experiment was found to increase linearly ($p = 0.05$) as the FSP levels in the diets increased. Furthermore, the ADG and G/F also improved (linear effect, $p = 0.06$) as the FSP levels increased. However, FSP had no effect on ADFI ($p>0.05$). These findings contradict those of a feeding trial of weaned pigs conducted by Min et al.

Table 2. Effect of fermented soy protein on growth performance in nursery pigs

Item	Level of FSP (%)			SE[1]	Probability (p =)	
	0	2.5	5		Linear	Quadratic
IBW (kg)	13.46	13.46	13.50	0.03	0.38	0.70
FBW (kg)	37.61	38.16	39.04	0.45	0.05	0.81
ADG (kg)	0.575	0.588	0.608	0.011	0.06	0.83
ADFI (kg)	1.119	1.101	1.114	0.027	0.89	0.64
G/F	0.514	0.534	0.546	0.011	0.06	0.66

[1] Pooled standard error.

(2004), in which no effect on ADG and G/F was observed in pigs that were fed a diet amended with FSP for d 21 to 35 after weaning. However, their experiment was only allowed to run until a final weight of approximately 20 kg was attained. In addition, the duration of their experiments was quite different than ours. Conversely, Zhu et al. (1998) reported that the feed conversion ratio was affected by the addition of improved soy protein to the diets of weaning pigs that weighed between 12 kg and 18 kg (HP300; Denmark) for 3 to 4 weeks. In addition, Hancock et al. (1990) found that feeding pigs soy flaxes that had been subjected to ethanol extraction improved the ADG and feed efficiency of growing pigs. Additionally, they found that ethanol extraction improved the protein quality of soybean flakes provided to pigs. Moreover, Wolter et al. (1996) reported that pigs (BW 12-28 kg, approximately) that were fed a complex diet were heavier than those that were fed a simple diet. Although part of the soybean meal was replaced with fish meal in their trial, their findings could partially explain the effect of a high quality protein source on late nursery pigs.

The effect of fermented soy protein on DM and N digestibilities is presented in Table 3. DM digestibility was not affected by treatment with fermented soy protein ($p>0.05$). However, N digestibility increased as the FSP level increased (linear effect, $p = 0.003$). Min et al. (2004) reported that providing weaned pigs with diets that contained FSP or HP300 during the phase 2 period increased the DM and N digestibilities. In addition, Zhu et al. (1998) observed that the net availability and biological value of protein was improved when HP300 was added to the diets of pigs. These consistent results can be attributed to the improved quality of treated soybean meal. Both types of improved soy proteins (FSP and HP300) are produced using a similar process. These findings are also supported by those of a study conducted by Hancock et al. (1990), in

Table 3. Effect of fermented soy protein on DM and N digestibility in nursery pigs

Item (%)	Level of FSP (%)			SE[1]	Probability (p =)	
	0	2.5	5		Linear	Quadratic
DM	70.85	72.60	73.80	1.27	0.13	0.86
N	63.41^{b}	67.89^{a}	70.36^{a}	1.34	0.003	0.55

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

Table 4. Effect of fermented soy protein on blood protein contents in nursery pigs

Item	Level of FSP (%)			SE[1]	Probability (p =)	
	0	2.5	5		Linear	Quadratic
Total protein (g/dl)						
Initial	5.17	5.33	5.08	0.13	0.66	0.22
Final	6.70	6.63	6.53	0.12	0.34	0.91
Difference	1.53	1.30	1.45	0.17	0.74	0.38
Albumin (g/dl)						
Initial	3.27	3.37	3.30	0.10	0.83	0.53
Final	3.45	3.75	3.58	0.10	0.35	0.07
Difference	0.18	0.38	0.28	0.17	0.69	0.50
Creatinine (g/dl)						
Initial	1.13	0.98	0.95	0.08	0.14	0.57
Final	1.27	1.40	1.30	0.05	0.65	0.09
Difference	0.13^{b}	0.42^{a}	0.35^{ab}	0.08	0.09	0.11
BUN (g/dl)						
Initial	10.62	10.98	10.68	1.26	0.97	0.83
Final	18.08	21.20	18.28	1.38	0.92	0.10
Difference	7.47	10.22	7.60	1.89	0.96	0.27

[1] Pooled standard error.

which growing pigs provided with soybean flakes that had been heated and extracted with ethanol were found to have greater apparent N retention, N digestibility and biological value than pigs that were provided with soybean flakes that were heated but not extracted. Even though we did not evaluate the trypsin inhibitor contents of the FSP used in our experiment, Kim (2004) stated that trypsin inhibitors were decreased following the fermentation of soybean meal, and that this decrease might be correlated with improved N digestibility, increased ADG and increased G/F.

As shown in Table 4, the total protein concentration in blood was not affected by the FSP level in the diets ($p>0.05$). However, the albumin concentration was higher in pigs provided with a diet that contained 2.5% FSP than in pigs provided with the other diets (quadratic effect, $p = 0.07$). Furthermore, at d 42, the creatinine concentration was increased in pigs that were fed a diet that contained 2.5% FSP (quadratic effect, $p = 0.09$). Moreover, the creatinine concentration increased linearly as the concentration of FSP increased ($p = 0.09$). Additionally, the BUN concentration on the final day of the experiment was greater in pigs that received the FSP 2.5 diets (quadratic effect, $p = 0.10$). However, there was no difference on the increment of BUN ($p>0.05$). Plasma protein that contains albumin, fibrin, globulin and prothrombin is produced by the liver; therefore, if protein intake is insufficient in an animal, the plasma protein concentration will be reduced. In addition, an animal's metabolic system always tries to maintain balance between the plasma proteins, amino acids and tissue proteins (Yang, 2004). No differences were observed in the concentration of total proteins in the blood of animals evaluated in our experiment. This may have been because all of the pigs were provided with sufficient amounts of protein, regardless of the experimental diets they received. However, there was no evidence of an increase in albumin concentration in pigs fed the 2.5% FSP diets. Creatinine, which is a type of non-protein nitrogen, is produced by the synthesis of arginine, glycine and methionine in the liver. In this experiment, the creatinine levels were found to be higher in pigs that were fed the FSP 2.5 diets.

When the BUN concentration was evaluated, the results were found to be inconsistent with those of other studies. The BUN concentration is directly related to protein intake and inversely related to protein quality (Eggum, 1970; Orok and Bowland, 1975; Bassily et al., 1982). However, in this study, no relationship between BUN concentration and the G/F ratio was observed. Therefore, further studies should be conducted to evaluate the relationship between the BUN concentration and the G/F ratio in the growing phase.

In conclusion, providing pigs with a diet that contained FSP during the late nursery phase appears to improve growth performance and N digestibility.

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