EFFECTS OF PROTEIN LEVEL AND EXTRUSION PROCESSING OF SOYBEAN MEAL ON THE PERFORMANCE OF GROWING PIGS

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Summary

A feeding trial was conducted to evaluate the effects of crude protein concentration (44% vs 48%) and extrusion processing of soybean meal (SBM) on the performance of weanling and growing pigs. One hundred and ninety two (96 pigs of each sex) 3 way crossed (Landrace × Hampshire × Duroc) weaned pigs were allotted to 12 pens each of 16 pigs (8 pigs of each sex). Three pens were assigned to each of the 4 treatment; T_1; 44% SBM diet, T_2; extruded 44% SBM diet, T_3; 48% SBM diet and T_4; extruded 48% SBM diet. The 44% SBM diet was formulated to have 18% CP for the starter phase (5-10 wk of age) and 15% CP for the grower phase (10-15 wk of age). The other treatments used equivalent amount of each SBM, replacing the 44% SBM. Chemical assay showed that extrusion processing generally decreased amino acid content especially total lysine and available lysine. Extrusion increased Hunterlab color +a value and decreased the urease activity index. The body weight gains for the T_3 and T_4 pigs were significantly ($p < 0.05$) greater than for those on T_1 and T_2 for the starter phase, but not the grower phase. Extrusion processing did not improve weight gain. Feed intake for the overall period was significantly ($p < 0.05$) different among treatments. The feed conversion ratios were not significantly different among treatments. An economic analysis showed that the high protein (48%) SBM diet was more cost effective than the low protein (44%) SBM diet, for the starter phase.

(**Key Words** : 44% SBM, 48% SBM, Dry Extrusion, Pigs)

Introduction

Soybean meal (SBM) is an excellent source of protein and amino acids for pigs. The availability of amino acids and energy of properly processed SBM is also higher than for other plant protein feedstuffs.

Simon and Melnick (1950) reported that heat treatment improves the quality of soybean because trypsin inhibitors are inactivated. Other anti-nutritional factors, such as, hemagglutinin, allergen, saponin and urease may also be affected by heat-treatment (Paik, 1990). Combs et al. (1967) reported that protein digestibility and weight gain of 8 wk old pigs were significantly improved by heat treatment of soybean in the diet. A digestion trial conducted by Vandergrift (1983) showed that the digestibility of DM, energy and amino acids of soyflake significantly improved when it was heated and fed to castrated pigs weighting 25-45 kg. However, excessive heat treatment reduces content and digestibility of amino acids, especially lysine (Chang et al., 1987) due to the Maillard reaction (Mauron, 1981). Hansen et al. (1987) reported that pigs fed excessively heated SBM showed poor growth rate and feed efficiency than those fed under, normal or over-heated SBM. The responses to heat-treatment were more evident for the weaner phase than the grower phase. The performances were not significantly different among under, normal and over heat-treatments in both phase, however. Friesen et al. (1993) reported that moist extruded SBM was better than dry extruded SBM and both extruded SBMs were better than non-extruded SBM in weight gain and feed efficiency, when they were included in starter pig diets.

The protein content of SBM available in Korea, locally produced or imported, has been approximately 44 %. Recently, high protein SBM (48%) became available. The present experiment was conducted to evaluate the effects of protein level (44% vs 48%) and extrusion processing of SBM on the performance of weaning and growing pigs.

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Materials and Methods

Experimental diet

The experimental diets were formulated to least cost based on NRC (1988) recommendations for starter and grower pigs (table 1). In each phase, there were 4 treatments (2 SBM sources × 2 heat-treatments). The source of SBM was either locally produced 44% SBM or 48% SBM imported from India. Heat-treatment was either non-treatment (as it is commercially available) or extrusion processing.

Extrusion processing was conducted with a dry extruder (Instapro Dry Extruder 2000R). Water was added at 6.5 GPH (galon per hr) which raises moisture content of SBM to 28-30%. Screw diameter was 130 mm, pitch of screw was 48 mm, screw speed was 500 RPM. Steam lock barrel temperature was 120℃ and retention time was 15-20 sec.

Experimental design, feeding and statistics

One hundred and ninety two 3 way crossed (Landrace × Hampshire × Duroc) weaned pigs weighing 9.70 kg in average were assigned to 4 treatments: T_1; 44% SBM treatment, T_2; extruded 44% SBM treatment, T_3; 48% SBM treatment, and T_4; extruded 48% SBM treatment. Each treatment had 3 replications (pens) each of 16 pigs (8 pigs of each sex) per replication.

Starter phase diets were given *ad libitum* from 5 wk (± 3 d) to 10 wk of age (5 weeks) and grower phase diets from 10 wk to 15 wk of age (5 weeks). The original experimental design was a 2 × 2 factorial design with 3 replications. Due to the limitation of litters, however, feeding of third replication started 10 days later than 1 and 2 nd replication. Therefore, analysis of variance was conducted based on a randomized block design. Significant differences between treatment means were tested with Duncan's Multiple Range Test (Steel and Torrie, 1980).

Chemical analysis

Proximate and mineral analysis of SBMs were conducted by the method of AOAC (1990). Amino acids assay was conducted with an Automatic Amino Acid Analyzer (Model 3A29, Carlo Erba, Italy). In order to cross check total lysine content more accurately. SBM samples were hydrolyzed with 6N HCl for 24 h at 110℃ and derived using OPA (o-phtaldialdehyde). The derivatives were separated with a Supelcosil LC-18 column using HPLC and measured by flourescence detector (Supelco, 1992). The available lysine content of the samples was determined by the FDNB (1-fluoro-2, 4-dinitrobenzene) method (Booth, 1971) using a spectrophotometer. Hunterlab color values were determined with a Hunterlab Color Quest (Model SN-C5340) (McNaughton et al., 1981). Urease activity was determined by the AOCS (1970) method.

TABLE 1. FORMULA AND COMPOSITION OF PIG DIETS DURING THE EXPERIMENTAL PERIODS

Items	Starter	Grower
Ingredients (%)		
Corn	34.95	46.98
Wheat	30.00	30.00
Soybean meal (44% or 48%)	26.87	17.77
Animal fat	3.96	2.13
Calcium phosphate (18%)	1.56	1.13
Limestone	1.36	1.09
Mineral premix[1,2]	0.40	0.20
Salt	0.29	0.31
Vitamin premix[3,4]	0.27	0.15
Lysine-HCl (78%)	0.11	0.15
Linsmycin premix	0.10	–
Carbadox premix	0.05	–
Ethoxyquin	0.05	0.05
Pig flavor	0.03	–
Zn-Bacitracin	–	0.04
Total	100.00	100.00
Composition[5]		
ME (kcal/kg)	3,200.57	3,199.81
CP (%)	18.00	15.00
Lysine (%)	1.05	0.85
Met + Cys (%)	0.60	0.57
Ca (%)	0.90	0.70
P-available (%)	0.45	0.35
P-total (%)	0.72	0.60

[1] Provides per kg of starter diet: I, 0.16 mg; Zn, 100 mg; Mn, 12 mg; Fe, 92 mg; Cu, 152 mg; Co, 0.52 mg; Se, 0.32 mg.

[2] Provides per kg of grower diet: I, 0.14 mg; Zn, 60 mg; Mn, 10 mg; Fe, 90 mg; Cu, 10 mg; Co, 0.50 mg; Se, 0.20 mg.

[3] Provides per kg of starter diet: vitamin A, 16,000 IU; vitamin D_3 3,200 IU; vitamin E, 30 IU; vitamin K_3, 4 mg; vitamin B_1, 1 mg; vitamin B_2 4 mg; vitamin B_6, 2 mg; vitamin B_{12}, 20 μg; niacin, 25 mg; pantothenic acid, 15 mg; folic acid, 1 mg; choline, 250 mg; ethoxyquin, 125 mg;

[4] Provides per kg of grower diet: vitamin A, 12,000 IU; vitamin D_3, 2,400 IU; vitamin E, 30 IU; vitamin K_3, 4 mg; vitamin B_1, 1 mg; vitamin B_2, 4 mg; vitamin B_6, 2 mg; vitamin B_{12}, 20 μg; niacin, 25 mg; pantothenic acid, 15 mg; folic acid, 1 mg; choline, 75 mg; ethoxyquin, 125 mg;

[5] Calculated values using 44% SBM data.

Results and Discussion

Chemical and physical analysis of SBM

Proximate and mineral (Ca and P) composition of SBMs are shown in table 2. Crude protein content of local 44% SBM was 45.74% and that of imported 48% SBM was 48.08%. Crude fat content of 48% SBM was 1.27% which was lower than that of the 44% SBM. The contents of crude fiber and ash were higher and calcium was lower in 48% SBMs than in 44% SBMs.

TABLE 2. PROXIMATE AND MINERAL COMPOSITION OF SOYBEAN MEAL (%)

Item	44% SBM	Extruded 44% SBM	48% SBM	Extruded 48% SBM
Crude protein	45.74	45.19	48.08	47.74
Crude fat	2.25	2.10	1.27	1.26
Crude fiber	3.43	2.89	3.75	3.36
Crude ash	6.14	6.15	7.51	7.52
Calcium	0.32	0.30	0.28	0.29
Phosphorus	0.65	0.63	0.64	0.62

Amino acid compositions, Hunterlab color values and urease activity index of SBM are shown in table 3. Amino acid profiles showed that extruded SBM was generally lower in amino acids content than regular SBM, both in the 44% and 48% SBM. Basic amino aicds, that is, arginine and lysine were the most affected by extrusion. Extrusion of SBM decreased both total lysine and available lysine values but the latter was slightly more affected. Hunterlab color L (lightness) was decreased and Hunterlab color +a (redness) was increased by extrusion in both 44% and 48% SBM. Urease activity index was decreased by extrusion in both 44% and 48% SBM. According to Chang et al. (1987), SBM heat-treated under normal condition showed Hunterlab color +a 3.2 and urease activity 0.11. Hansen et al. (1987), however, reported that performance of starting and growing pigs were not significantly different when they were fed SBMs having Hunterlab color +a in the range of 2.9-7.3 and urease activity index in the range of 0.01-0.19. The values of SBMs used in this experiment were within the range of values reported by Hansen et al. (1987).

Weight gain, feed intake and feed conversion

The results of the feeding trial are shown in table 4. Factorial analysis of variance showed no significant treatment effects or interactions in all items studied. However, linear analysis of randomized block design showed that weight gain of 48% SBM treatment (T_3) and extruded 48% SBM treatment (T_4) were significantly ($p < 0.05$) greater than 44% SBM treatment (T_1) or extruded 44 % SBM treatment (T_2) during starter phase. Weight gains during grower phase and overall period (starter and grower phase) were not significantly different among treatments although 48% SBM treatments (T_3 and T_4) showed slightly greater weight gain than 44% SBM treatments (T_1 and T_2). Normal SBM treatment (T_1 and T_3)

TABLE 3. AMINO ACID COMPOSITIONS, HUNTERLAB COLOR VALUES AND UREASE ACTIVITY INDEX OF SOYBEAN MEAL

Item	44% SBM	Extruded 44% SBM	48% SBM	Extruded 48% SBM
Amino aicds (%)				
Aspartic acid	4.91	4.85	5.29	5.18
Threonine	1.74	1.61	1.77	1.76
Serine	2.28	2.14	2.39	2.34
Glutamic acid	9.86	9.12	10.45	9.80
Glycine	1.89	1.73	1.95	1.82
Alanine	1.98	1.86	2.09	1.94
Valine	2.08	1.94	2.11	1.94
Isoleucine	2.07	2.01	2.13	2.01
Leucine	3.39	3.20	3.42	3.25
Tyrosine	1.61	1.37	1.75	1.56
Phenylalanine	2.22	2.08	2.41	2.21
Histidine	1.52	1.86	1.58	1.55
Arginine	3.25	2.68	3.65	2.83
Cystine	0.69	0.65	0.63	0.51
Methionine	0.87	0.88	0.85	0.92
Lysine	3.05	2.85	2.89	2.59
Total lysine[1] (%)	2.89	2.80	3.09	2.90
Available lysine[2] (%)	2.50	2.15	2.37	2.17
Hunterlab color value[3]				
L	72.27	68.18	71.06	65.88
+a	3.22	4.36	3.89	4.57
b	20.09	20.01	19.71	18.17
Urease activity (ΔpH)	0.09	0.01	0.16	0.02

[1] Lysine values obtained from OPA assay method (Supelco, 1992).
[2] Determined by FDNB method (Booth et al., 1971)
[3] L : lightness (100 for white to 0 for black)
+a: redness (100 for red to −70 for green).
b: yellowness (70 for yellow to −80 for blue).

TABLE 4. WEIGHT GAIN, FEED INTAKE AND FEED CONVERSION RATIO OF PIGS DURING STARTER (5-10 WK) AND GROWER (10-15 WK) PHASE

Item	Treatment				SEM
	T_1	T_2	T_3	T_4	
Weight gain (kg)					
Starter	15.34[a]	15.21[a]	16.44[b]	16.16[b]	0.25
Grower	18.52	18.02	18.13	17.79	0.59
Starter-Grower	33.86	33.23	34.57	33.95	0.62
Feed intake (kg)					
Starter	27.81	28.73	30.39	30.36	0.63
Grower	50.09	50.93	52.03	51.76	0.46
Starter-Grower	77.90[a]	79.66[ab]	82.42[c]	82.12[bc]	0.74
Feed/Gain					
Starter	1.81	1.89	1.85	1.88	0.04
Grower	2.70	2.84	2.92	2.91	0.07
Starter-Grower	2.30	2.40	2.38	2.42	0.04

T_1; 44% SBM, T_2; Extruded 44% SBM, T_3; 48% SBM.
T_4; Extruded 48% SBM.
a–c: Means in same row with different superscripts are significantly different at $p < 0.05$.
SEM: Standard error of means.

showed greater weight gain than extruded SBM treatments (T_2 and T_4) but they were not statistically different.

Feed intakes of overall period (starter and grower phase) were significantly different ($p < 0.05$) among treatments. T_3 was greatest and significantly different from T_1 and T_2, and T_4 was greater than T_1 in feed intake. The 48% SBM treatments tended to be greater in feed intake than the 44% SBM treatments. Feed/gain ratios were not significantly different among treatments.

The results indicate that extra protein and amino acids supplied by 48% SBM over 44% SBM can significantly improve weight gain during starter phase (18% CP diet) but not during grower phase (15% CP diet). Extrusion processing did not improve weight gain in either phase although Friesen et al. (1993) had shown improved performance of starting pigs fed extruded SBM diets. It was expected that extrusion processing would further inactivate or destroy antinutritional factors in tested SBM, such as, trypsin inhibitor, allergens and so on. Extrusion processing decreased urease activity index and increased Hunterlab color +a, but further improvement in the quality of SBM might not have been achieved because 44 % SBM and 48% SBM were already properly heat-treated on the basis of urease activity index and Hunterlab color values (Chang et al., 1987; Hansen et al., 1987). On the other hand, contents of total lysine and available lysine, the first limiting amino acid in pigs, were decreased by extrusion processing, which resulted in a slight decrease in weight gain. Greater feed intake of 48% SBM treatments may be the result of faster growth and complementary intake due to low fat, in other words, low energy content of 48% SBM compared to 44% SBM.

TABLE 5. ECONOMIC ANALYSIS DURING STARTER PHASE (5-10 WK OF AGE)

Item	44%-SBM (T_1)	48%-SBM (T_3)	Difference (T_3-T_1)
Price of SBM (won/kg)	230	235	5
Price of feed[1] (won/kg)	164.13	165.47	1.34
Consumption of feed (kg/head)	27.81	30.39	2.58
Cost of feed (won/head)	4,564.45	5,068.63	464.18
Weight gain (kg/head)	15.34	16.44	1.10
Pig price (× 1,500 won/kg live wt)	23,010	24,660	1,650

[1] Price of feed accounts only ingredient cost as of January, 1993.

Economic analysis

Since the starter phase alone showed significant differences in weight gain, economic analysis was conducted for starter phase only (table 5). Also, treatments of extruded SBMs were not included because extrusion did not improve the performance of pigs. Analysis results showed that pigs fed 48% SBM diet costed 464.18 won more for feed and gained 1,650 won more for pig price than those fed 44% SBM diet, resulting in 1,185.82 won (1,650-464.18 won) of benefit per pig during starter phase.

It was concluded that extrusion of regular SBMs during starter and grower phase had no beneficial effects on pig performance. High protein (48%) SBM diet returned more benefit than low protein (44%) SBM diet during starter (5-10 wk of age) phase.

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