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Effects of Origins of Soybean Meal on Growth Performance, Nutrient Digestibility and Fecal Microflora of Growing Pigs

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ABSTRACT

This experiment was conducted to investigate the effects of soybean meal (SBM) of different origin (Korea, India or Brazil) on performance, fecal microflora and economics of grower pigs. A total of 144 grower pigs (initial BW, 10.4 kg) were randomly allotted to six treatments on the basis of BW. Pig's diets containing SBM were formulated based on the total amino acid (TAA) or true ileal digestible amino acid (TIDAA) levels. Pigs fed domestic SBM diets had greater ($p < 0.05$) overall ADG, ADFI and final body weight and apparent total tract digestibility (ATTD) of DM, GE and CP (phases I, II and III) than those fed diets containing SBM originated from India or Brazil. Moreover, greater (p < 0.05) ADG, ADFI, feed /gain (F/G), and ATTD of DM, GE and CP were observed in response to diets formulated on a TIDDA basis when compared with those formulated on a TAA basis. The fecal microflora was not affected ($p > 0.05$) by dietary treatments. The overall feed cost per kg body weight gain was less ($p < 0.05$) for diets formulated using domestic SBM than for those containing SBM from India, while the feed cost per kg body weight gain was less ($p < 0.05$) for diets formulated prepared on a TIDAA than a TAA basis. These results indicate that domestic SBM has better quality than SBM imported from Brazil or India and better performance was obtained when diets were formulated based on the true ileal digestible amino acid (TIDAA) content.

(**Key words :** Soybean meal, Growth performance, Nutrient digestibility, Fecal microflora, Growing pig)

INTRODUCTION

Soybean meal (SBM) is the most commonly used protein source in diets for pigs and poultry due to its relatively high concentration of protein (44 to 49%) and excellent amino acid profile (Kim et al., 1999; Cromwell, 2000). In a typical pig diet, about 50% of the protein and AA and 25% of the ME are supplied by SBM (ASA, 2010). The United States has been the leader in soybean (SB) production, supplying approximately 42% of the SB produced worldwide; however, SB production in other countries has increased in recent years. Currently, Brazil has the second highest SB production (24% of the world crop), followed by Argentina (16%), China (8%), and India (3%).

Studies have shown compositional differences in both SB (Grieshop and Fahey, 2001) and SBM (Baize, 1997; Grieshop et al., 2003; Wang et al., 2011) within and among geographic regions of the world. Park and Hurburgh (2002) found that SBM samples from the European Union and United States had the greatest content of protein and the least amount of fiber when compared with those from India, Brazil, Argentina, and China. Furthermore, Thakur and Hurburgh (2007) reported that the KOH solubility values were within the acceptable range of 80 to 85% for SBM samples from the EU, United States, and China. These differences in composition could potentially result in different amino acid digestibility of SBM; however, little research has been conducted to compare the digestibility of SBM produced throughout the world. This information is critical when determining the quality of SBM for the pigs. In the present study, SBM obtained from Korea, Brazil and India was evaluated for its effects on growth performance, nutrient digestibility, fecal microbial populations and economic analysis when fed to growing pigs. Additionally, comparisons were made between diets formulated based on total amino acid (TAA) and true ileal digestible amino acid (TIDAA).

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MATERIALS AND METHODS

This study was conducted in accordance with proper ethical standards and was approved by the Institutional Animal Care and Use Committee of Kangwon National University, Chuncheon, Republic of Korea.

1. Animals and diets

A total of 144 growing pigs (Landrace × Yorkshire × Duroc; average BW = 10.4 ± 0.12 kg 5 wk of age) were allotted to six treatments composed of four pens with six pigs in each pen. The main objective of this experiment was to compare the effects of the origin of SBM and investigate the

Table 1. Ingredients and chemical composition of experimental diets during phase I (wk 0~3; as-fed basis)

Item	Domestic		Imported			
			Brazil		India	
	TAA[1)]	TIDAA[2)]	TAA	TIDAA	TAA	TIDAA
Ingredient, %						
Corn	62.09	63.36	60.78	62.86	62.42	63.70
Soybean meal (44 %)	25.99	24.65	27.35	25.14	25.64	24.28
Fish meal	3.00	3.00	3.00	3.00	3.00	3.00
Soy protein concentrate	4.00	4.00	4.00	4.00	4.00	4.00
Soy oil	2.00	2.00	2.00	2.00	2.00	2.00
Choline chloride (50%)	0.05	0.05	0.05	0.05	0.05	0.05
Monocalcium phosphaste	1.10	1.10	1.09	1.10	1.10	1.11
Limestone	0.92	0.99	0.88	1.00	0.94	1.01
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Minerals premix[3)]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins premix[4)]	0.20	0.20	0.20	0.20	0.20	0.20
Tyrosine (10%)	0.10	0.10	0.10	0.10	0.10	0.10
Bambermycin (10%)	0.10	0.10	0.10	0.10	0.10	0.10
Chemical composition (%)						
ME, kcal/kg	3,330	3,330	3,330	3,330	3,330	3,330
CP	21.40	20.9	21.71	20.9	21.42	20.9
Ca	0.82	0.85	0.80	0.84	0.83	0.85
Available P	0.40	0.40	0.40	0.40	0.40	0.40
Lysine	1.18	1.15	1.19	1.14	1.17	1.13
Methionine	0.33	0.33	0.33	0.32	0.32	0.32
Methionine + cystine	0.68	0.66	0.67	0.65	0.65	0.64
Threonine	0.80	0.78	0.81	0.78	0.79	0.77
Tryptophan	0.21	0.20	0.21	0.20	0.21	0.21
Isoleucine	0.90	0.88	0.88	0.84	0.85	0.83
Leucine	1.85	1.81	1.85	1.79	1.83	1.79
Valine	1.06	1.03	1.03	0.99	1.0	0.97
Histidine	0.55	0.54	0.55	0.53	0.55	0.54
Arginine	1.38	1.35	1.37	1.31	1.39	1.35
Phenylalanine	1.07	1.04	1.06	1.02	1.04	1.02

1) TAA: total amino acids.

2) TIDAA: true ileal digestible amino acids.

3) Supplied per kilogram of diet: 90 mg Fe, 60 mg Cu, 30 mg Zn, 36 mg Mn, 0.72 mg I, 0.72 mg Co, 0.28 mg Se.

4) Supplied per kilogram of diet: 16,000 IU vitamin A, 3,000 IU vitamin D_3, 40 mg vitamin E, 2.5 mg vitamin B_1, 20.0 mg vitamin B_2, 4.0 mg vitamin B_6, 0.076 mg vitamin B_{12}, 2.5 mg vitamin K_3, 40 mg pantothenic acid, 75 mg niacin, 0.15 mg biotin, 0.65 mg folic acid, 12.0 mg thoxyquin.

influence of formulating diets based on TAA and TIDAA. Treatment diets containing domestic (Korean) and imported (Brazil and India) SBMs were formulated based on TAA and TIDAA. SBM from each country was purchased on the open market. Korean SBM was freshly prepared (one month before experimental feeding), while SBM imported from India and Brazil was prepared four months before the experimental feeding. The experimental diets were provided in three phases (phase I, 0 to 3 wk, phase II, 4 to 8 wk and phase III, 9 to 13 wk). Diets for phase I (Table 2), phase II (Table 3) and phase III (Table 4) were formulated to contain 3,330, 3,265 and 3,265 kcal ME/kg, and 21.0, 18.0 and 15.0% CP, respectively. All diets met or exceeded the nutrient requirements suggested by the National Research Council (NRC, 1998).

The experiment was conducted at the facility of Kangwon

Table 2. Ingredients and chemical composition of experimental diets during phase II (wk 4~8) of the feeding trial

Item	Domestic		Imported			
			Brazil		India	
	TAA[1]	TIDAA[2]	TAA	TIDAA	TAA	TIDAA
Ingredient, %						
Corn	59.11	59.15	57.95	58.62	58.72	59.53
Soybean meal (44%)	26.78	26.74	27.98	27.28	27.21	26.34
Wheat bran	6.00	6.00	6.00	6.00	6.00	6.00
Animal fat	3.13	3.13	3.13	3.13	3.13	3.13
Molasses	2.00	2.00	2.00	2.00	2.00	2.00
Choline chloride (50%)	0.05	0.05	0.05	0.05	0.05	0.05
Tricalcium phosphate	1.56	1.56	1.55	1.55	1.55	1.56
Lime stone	0.62	0.62	0.59	0.62	0.59	0.64
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Minerals premix[3]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins premix[4]	0.20	0.20	0.20	0.20	0.20	0.20
Bambermycin (10%)	0.10	0.10	0.10	0.10	0.10	0.10
Chemical composition (%)						
ME, kcal/kg	3,265	3,265	3,265	3,265	3,265	3,265
CP	18.02	18.00	18.26	18.00	18.33	18.00
Ca	0.820	0.820	0.800	0.810	0.820	0.830
Available P	0.400	0.400	0.400	0.400	0.400	0.400
Lysine	0.950	0.949	0.950	0.933	0.950	0.928
Methionine	0.268	0.268	0.264	0.262	0.261	0.258
Methionine + cystine	0.574	0.573	0.562	0.556	0.553	0.546
Threonine	0.669	0.668	0.675	0.665	0.667	0.654
Tryptophan	0.171	0.171	0.171	0.168	0.176	0.172
Isoleucine	0.728	0.728	0.703	0.692	0.689	0.676
Leucine	1.560	1.559	1.548	1.532	1.554	1.533
Valine	0.870	0.870	0.836	0.825	0.818	0.804
Histidine	0.471	0.470	0.466	0.460	0.477	0.469
Arginine	1.137	1.135	1.118	1.099	1.162	1.137
Phenylalanine	0.903	0.902	0.892	0.879	0.892	0.875

1) TAA: total amino acids.

2) TIDAA: true ileal digestible amino acids.

3) Supplied per kilogram of diet: 70 mg Fe, 50 mg Cu, 25 mg Zn, 30 mg Mn, 0.7 mg I, 0.5 mg Co, 0.26 mg Se.

4) Supplied per kilogram of diet: 16,000 IU vitamin A, 3,000 IU vitamin D_3, 40 mg vitamin E, 2.5 mg vitamin B_1, 20.0 mg vitamin B_2, 4.0 mg vitamin B_6, 0.076 mg vitamin B_{12}, 2.5 mg vitamin K_3, 40 mg pantothenic acid, 75 mg niacin, 0.15 mg biotin, 0.65 mg folic acid, 12.0 mg ethoxyquin.

Table 3. Ingredients and chemical composition of experimental diets during phase III (wk 9~13) of the feeding trial

Item	Domestic		Imported			
			Brazil		India	
	TAA[1)]	TIDAA[2)]	TAA	TIDAA	TAA	TIDAA
Ingredient, %						
Corn	65.05	64.79	64.24	64.38	64.78	65.08
Soybean meal	16.95	18.75	17.71	19.14	17.22	19.15
Rapeseed meal	3.00	1.61	3.00	1.59	3.00	1.0
Wheat bran	6.00	6.00	6.00	6.00	6.00	6.00
Animal fat	3.13	2.98	3.16	2.99	3.14	2.90
Molasses	4.00	4.00	4.00	4.00	4.00	4.00
Choline chloride (50%)	0.05	0.05	0.05	0.05	0.05	0.05
Tricalcium phosphate	0.50	0.50	0.50	0.50	0.50	0.50
Limestone	0.57	0.57	0.59	0.60	0.56	0.57
Salt	0.25	0.25	0.25	0.25	0.25	0.25
Minerals premix[3)]	0.20	0.20	0.20	0.20	0.20	0.20
Vitamins premix[4)]	0.20	0.20	0.20	0.20	0.20	0.20
Bambermycin (10%)	0.10	0.10	0.10	0.10	0.10	0.10
Chemical composition (%)						
ME, kcal/kg	3,265	3,265	3,265	3,265	3,265	3,265
CP	15.20	15.50	15.35	15.50	15.40	15.60
Ca	0.500	0.500	0.500	0.500	0.500	0.500
Available P	0.190	0.190	0.190	0.190	0.190	0.190
Lysine	0.750	0.660	0.750	0.660	0.750	0.660
Methionine	0.244	0.205	0.242	0.199	0.240	0.200
Metheonine + cystine	0.525	0.410	0.518	0.396	0.512	0.390
Threonine	0.563	0.493	0.567	0.490	0.562	0.487
Tryptophan	0.413	0.126	0.143	0.122	0.146	0.127
Isoleucine	0.593	0.479	0.577	0.452	0.568	0.443
Leucine	1.361	1.139	1.353	1.118	1.357	1.112
Valine	0.732	0.579	0.710	0.547	0.699	0.535
Histidine	0.400	0.284	0.397	0.283	0.404	0.285
Arginine	0.911	0.797	0.900	0.773	0.928	0.804

1) TAA: total amino acids.

2) TIDAA: true ileal digestible amino acids.

3) Supplied per kilogram of diet: 70 mg Fe, 50 mg Cu, 25 mg Zn, 30 mg Mn, 0.7 mg I, 0.5 mg Co, 0.26 mg Se.

4) Supplied per kilogram of diet: 16,000 IU vitamin A, 3,000 IU vitamin D_3, 40 mg vitamin E, 2.5 mg vitamin B_1, 20.0 mg vitamin B_2, 4.0 mg vitamin B_6, 0.076 mg vitamin B_{12}, 2.5 mg vitamin K_3, 40 mg pantothenic acid, 75 mg niacin, 0.15 mg biotin, 0.65 mg folic acid, 12.0 mg ethoxyquin.

National University farm, and growing pigs (Landrace × Yorkshire × Duroc) were housed in concrete floor pens with a size of 2.0 × 3.0 m. All pens were equipped with a self-feeder and a nipple drinker to allow ad libitum access to feed and water.

2. Experimental procedures, measurements and analyses

Pigs were weighed individually, and feed consumption was measured at the end of each phase to calculate ADG, ADFI, and F/G. To evaluate the effects of dietary treatments on the ATTD of energy and nutrients, 0.25% chromic oxide was added to each diet as an inert, indigestible indicator. The pigs were then fed diet containing chromium during the last 7 d of each phase, and fecal samples were collected from

Table 4. Effects of origin of soybean meal on growth performance of pigs[1)]

Item	Domestic		Imported[2)]				SEM[3)]	P-value[4)]			
			BRA		IND						
	TAA	TIDAA	TAA	TIDAA	TAA	TIDAA		D vs. I	D vs. BRA	D vs. IND	TAA vs. TIDAA
Phase I (wk 0~3)											
ADG, g	417	427	405	411	400	407	2.11	0.001	0.002	0.001	0.067
ADFI, g	633	646	630	640	627	635	1.64	0.068	0.253	0.033	0.001
F/G	1.52	1.51	1.56	1.56	1.57	1.56	0.01	0.001	0.001	0.001	0.725
Phase II (wk 4~8)											
ADG, g	801	838	776	810	762	796	5.17	0.002	0.016	0.001	0.001
ADFI, g	1,682	1,725	1,664	1,712	1,642	1,704	6.24	0.060	0.251	0.065	0.001
F/G	2.10	2.06	2.15	2.11	2.16	2.14	0.01	0.001	0.001	0.001	0.027
Phase III (wk 9~13)											
ADG, g	1,074	1,135	1,016	1,097	942	1,012	13.42	0.001	0.033	0.001	0.005
ADFI, g	2,569	2,620	2,551	2,604	2,465	2,524	11.72	0.010	0.402	0.001	0.017
F/G	2.39	2.31	2.51	2.37	2.62	2.49	0.02	0.001	0.010	0.001	0.005
Overall (wk 0~13)											
ADG, g	817	858	784	830	749	790	7.33	0.001	0.021	0.001	0.002
ADFI, g	1,781	1,820	1,767	1,808	1,724	1,773	6.73	0.011	0.270	0.001	0.001
F/G	2.18	2.12	2.25	2.18	2.30	2.24	0.01	0.001	0.003	0.001	0.007
Final body weight (kg/pig)											
	84.82	88.43	81.69	85.88	78.59	82.31	0.67	0.001	0.018	0.001	0.002

1) Data represent means based on four replicates per treatment.
2) BRA = Brazil; IND = India.
3) Standard error of means.
4) D vs. I = Domestic vs. Imported; D vs. BRA = Domestic vs. Brazil; D vs. IND = Domestic vs. India; TAA vs. TIDAA = Total amino acid vs. True ileal digestible amino acid.

the floor of each pen during the last 4 d of each phase to determine the nutrient digestibility. The fecal samples were pooled within the pen and dried in a forced air drying oven at 60°C for 72 h, after which they were ground in a Wiley mill (ThomasModel 4 Wiley Mill, Thomas Scientific, Swedesboro, NJ) using a 1-mm screen and used for chemical analysis. Additionally, feces samples were collected from each pen on the last day of each phase for analysis of fecal microflora. The samples collected for microflora analysis were immediately placed on ice until analyses were conducted later on the same day.

3. Chemical and microbial analyses

Experimental diets and excreta samples were analyzed in triplicate for DM (Method 930.15), CP (Method 990.03), ash (Method 942.05), Ca and P (Method 985.01) according to the AOAC (2007) methods. Gross energy of diets and excreta were measured using a bomb calorimeter (Model 1261, Parr Instrument Co., Molin, IL), while chromium concentrations were determined with an automated spectrophotometer (Jasco V-650, Jasco Corp., Tokyo, Japan) according to the procedure described by Fenton and Fenton (1979).

The microbiological assay of fecal samples was carried out using the procedure suggested by Choi et al. (2011). The microbial groups analyzed were as follows: *Clostridium* spp. (tryptose sulphite cycloserine agar), *Bifidobacterium* spp. (MRS agar + 0.02% NaN_3 + 0.05% L-cystine hydrochloride monohydrate), *Lactobacillus* (MRS agar + 0.02% NaN_3 + 0.05 % L-cystine hydrochloride monohydrate) and coliforms (violet red bile agar). The tryptic soy agar (No. 236950), MRS agar (No. 288130), violet red bile agar (No. 216695), plate count agar (No. 247940), and potato dextrose agar (No. 213400) used were purchased from Difco Laboratories (Detroit, MI), while TSC agar (CM0589) was purchased from Oxoid (Hampshire, UK).

4. Economic analysis

The feed cost (FC) was calculated based on the price of ingredients used and then employed to calculate the feed cost per kg body weight gain (FCG) as follows:

FCG = TFI × FC/TWG

where, TFI = total feed intake and TWG = total weight gain per pig (kg).

5. Statistical analysis

Statistical analysis was conducted using the GLM procedure of the SAS software (1996). The treatments were the main effects. Pens were used as the experimental unit for the analysis of growth, feed intake and nutrient digestibility. An independent t-test was used to compare SBMs of domestic and imported origin, domestic and Brazilian origin, and domestic and Indian origin, while additional comparisons were of diets formulated on the basis of TAA and TIDAA were made. To enhance the interpretation of the results, the mean separations were analyzed using the Student-Newman-Keuls multiple range test. Probability values of ≤ 0.05 were considered significant in both experiments.

RESULTS AND DISCUSSION

1. Growth performance

The growth performance of pigs fed diets containing SBM from different origins is presented in Table 4. The ADG and F/G were better ($p < 0.05$) in pigs fed Korean (domestic) SBM diets during phases I, II, III and the overall study period than in pigs fed SBM from Brazil or India. Greater ($p < 0.05$) ADFI was observed in pigs fed domestic SBM than in those fed Indian SBM during phases I, III and the overall study period, while pigs fed domestic SBM diets had greater ($p < 0.05$) ADFI during phase III and the overall study period than pigs fed imported (Brazil + India) SBM diets. In comparison with TAA, pigs fed diets formulated on a TIDAA basis had greater ($p < 0.05$) ADFI during phase I, and improved ($p < 0.05$) ADG, ADFI and F/G during phases II, III and the overall study period. Pigs fed domestic SBM diets had greater ($p < 0.05$) final body weight than those fed diets containing SBM imported from Brazil or India. Moreover, pigs fed diets formulated on a TIDAA basis had greater ($p < 0.05$) final body weight than those fed diets formulated on a TAA basis. Variations in the performance of pigs fed diets containing SBM of different origin might have been be due to variations in the nutrient compositions of SBM. Previous studies have reported that variations in nutrient compositions of SBM among geographic regions are due to differences in environmental conditions, genetic variations and processing conditions (Baiz, 1997; Grieshop and Fahey, 2001). Park and Hurburgh (2002) found that SBM samples from the European Union (EU) and United States had the greatest content of protein and the least amount of fiber when compared with SBM from India, Brazil, Argentina, and China. Similar to the results of the present study, Wang et al. (2011) reported that growing pigs fed diets containing SBM from the United States had greater growth performance than those fed Indian or Brazilian SBM.

In the present study, SBM from Korea was freshly prepared, whereas SBM imported from India and Brazil was stored for a long duration, which might have affected the quality of the SBM. The discrepancy in growth performance of pigs fed diets containing SBM of different origin might also be due to variations in the quality of SBM due to variations in soybean processing conditions, such as moisture, drying time and drying temperature. Over and under processing due to improper heating conditions can result in the production of poor quality SBM (Araba and Dale, 1990). Over processing of SBM results in a portion of the lysine being rendered unavailable for pigs due to the Maillard reaction, whereas under processed SBM contains a high concentration of antinutritional factors such as trypsin inhibitors and saponins, which decease the quality of SBM (Araba and Dale, 1990).

2. Nutrient Digestibility

The apparent nutrient digestibility of pigs fed diets containing SBM of different origin is presented in Table 5. During phases I, II and III, the apparent digestibility of DM, GE and CP was greater ($p < 0.05$) in pigs fed domestic SBM than in those fed SBM from Brazil or India. Additionally, pigs fed diets formulated on a TIDAA basis had greater ($p < 0.05$) CP digestibility during phase I, and higher ($p < 0.05$) digestibility of DM, GE and CP during phase II and phase III than pigs fed diets formulated on a TAA basis. Additionally, pigs fed domestic SBM diet formulated on a TIADD basis had the highest ($p < 0.05$) digestibility of DM,

Table 5. Effects of origin of soybean meal on apparent fecal nutrients digestibility of pigs[1)]

Item	Domestic		Imported[2)]				SEM[3)]	P-value[4)]			
			BRA		IND						
	TAA	TIDAA	TAA	TIDAA	TAA	TIDAA		D vs. I	D vs. BRA	D vs. IND	TAA vs. TIDAA
Phase I (wk 0~3)											
DM	85.28	85.42	84.96	85.24	84.67	84.99	0.07	0.002	0.048	0.002	0.068
GE	87.09	87.37	86.55	86.91	86.91	86.53	0.12	<0.001	0.003	0.003	0.098
CP	79.07	79.66	77.75	78.73	78.73	78.05	0.18	<0.001	0.004	<0.001	0.046
Phase II (wk 4~8)											
DM	71.72	72.33	71.48	71.91	71.40	71.59	0.07	0.018	0.077	0.006	0.005
GE	74.79	75.47	74.43	74.82	74.29	74.56	0.10	0.008	0.023	0.006	0.022
CP	65.22	66.14	64.99	65.41	63.52	64.80	0.22	0.024	0.301	0.004	0.044
Phase III (wk 9~13)											
DM	75.15	76.32	74.91	75.46	73.86	74.88	0.16	0.006	0.080	0.001	0.002
GE	78.56	79.99	78.07	78.83	77.32	78.02	0.21	0.004	0.029	0.004	0.018
CP	65.58	67.13	65.21	65.90	64.53	65.35	0.18	0.010	0.050	0.003	0.002

1) Data represent means based on four replicates per treatment.
2) BRA = Brazil; IND = India.
3) Standard error of means.
4) D vs. I = Domestic vs. Imported; D vs. BRA = Domestic vs. Brazil; D vs. IND = Domestic vs. India; TAA vs. TIDAA = Total amino acid vs. True ileal digestible amino acid.

GE and CP during phases I, II and III.

The results of the present study are in good agreement with those reported by Wang et al. (2011), who observed lower digestibility of DM and N in pigs fed diets containing Indian and Brazilian SBM than in pigs fed diets containing SMB originating from the United States. Similarly, Karr-Lilienthal et al. (2004) reported that pigs fed diets containing SBM from India had lower CP digestibility. It has been reported that different growing conditions and the use of various soybean genotypes in different regions can affect nutrient composition, including contents of oligosaccharides, protease inhibitors and fiber (Kumar et al., 2010; Baker and Stein, 2009). As a result, nutrient digestibility in different batches of SBM fed to pigs may differ (Karr-Lilienthal et al., 2005). Moreover, regional variations in processing conditions of the soybeans may also affect the nutrient digestibility of SBM (Sauer and Ozimek, 1986). For example, thermal treatment during SBM processing is frequently applied to inactivate residual contents of trypsin inhibitors in SBM (Qin et al., 1998). However, under processing of SBM may result in incomplete removal of some anti-nutritional factors (Araba and Dale, 1990) which, in turn, may decrease nutrient digestibility in these SBM.

In the present study, the performance and digestibility of nutrients in pigs fed diets formulated on the basis of true ileal digestible amino acid (TIDAA) was greater than that of pigs fed diets formulated on the basis of total amino acid (TAA). This might have been due to the greater availability of digestible amino acids in diets formulated on a TIDAA basis than a TAA basis. Greater digestibility of amino acids and CP may result in more AA reaching the organ systems of the pigs, leading to improved growth performance.

3. Fecal microflora

Dietary treatments had no effect on the number of total aerobic bacteria, *Clostridium* spp., *Bifidobacterium* spp., *Lactobacillus* spp. and coliforms in the feces during phases I, II and III (Table 6). It has been reported that dietary sources of protein and fermentable carbohydrates affect the host animal by improving its intestinal balance (Fuller, 1989) and creating gut micro-ecological conditions that suppress harmful microorganisms such as *Clostridium* and coliforms (Line et al., 1998; Pascual et al., 1999; Shim et al., 2010),

Table 6. Effects of origin of soybean meal on fecal microbial populations of pigs (Log10 CFU/g)[1)]

Item	Domestic		Imported[2)]				SEM[3)]	P-value[4)]			
			BRA		IND			D vs. I	D vs. BRA	D vs. IND	TAA vs. TDAA
	TAA	TIDAA	TAA	TIDAA	TAA	TIDAA					
Phase I (wk 0~3)											
Clostridium spp.	7.83	7.82	7.82	7.85	7.87	7.84	0.010	0.267	0.533	0.290	0.784
Bifidobacterium	9.24	9.23	9.19	9.22	9.20	9.21	0.008	0.070	0.125	0.127	0.555
Lactobacillus	9.01	9.04	8.97	8.96	8.98	9.01	0.017	0.182	0.156	0.422	0.678
Coliforms	7.10	7.17	7.20	7.16	7.29	7.28	0.038	0.215	0.656	0.103	0.939
Phase II (wk 4~8)											
Clostridium spp.	7.91	7.90	7.93	7.93	7.95	7.92	0.009	0.117	0.213	0.209	0.640
Bifidobacterium	9.26	9.24	9.23	9.22	9.21	9.21	0.010	0.119	0.308	0.110	0.801
Lactobacillus	8.97	8.99	8.93	8.92	8.93	8.95	0.018	0.204	0.211	0.380	0.768
Coliforms	7.28	7.30	7.32	7.34	7.35	7.37	0.025	0.290	0.548	0.256	0.657
Phase III (wk 9~13)											
Clostridium spp.	7.92	7.90	7.91	7.94	7.93	7.92	0.012	0.658	0.611	0.672	0.870
Bifidobacterium	9.27	9.26	9.24	9.22	9.22	9.23	0.010	0.056	0.728	0.101	0.873
Lactobacillus	9.02	9.03	9.00	9.01	8.98	9.00	0.017	0.416	0.145	0.411	0.684
Coliforms	7.41	7.45	7.51	7.45	7.52	7.52	0.019	0.091	0.265	0.094	0.819

1) Data represent means based on four replicates per treatment.
2) BRA = Brazil; IND = India.
3) Standard error of means.
4) D vs. I = Domestic vs. Imported; D vs. BRA = Domestic vs. Brazil; D vs. IND = Domestic vs. India; TAA vs. TIDAA = Total amino acid vs. True ileal digestible amino acid.

as well as by favoring beneficial microorganisms like *Lactobacillus* and *Bifidobacterium.* In the present experiment, there were no differences in microflora populations among pigs fed diets containing SBM of different origin. Moreover, formulation of the diet on a TIDAA or TAA basis had no effects on fecal microbial populations. These findings indicate that the origin of SBM has no effect on the fermentation pattern and intestinal microflora of pigs, indicating that improved growth performance in pigs fed diets containing Korean SBM is due to greater nutrient digestibility rather than improved microbial balance.

4. Economic analysis

Economic analysis of diets containing SBM from different origins is presented in Table 7. When compared with pigs fed SBM imported from Brazil and India, pigs fed domestic SBM diets had lower feed cost per kg gain during phases I and III, as well as for the overall experimental period. Additionally, formulating diets on a TIDAA basis resulted in lower feed cost per kg gain during phases II and III and for the overall experimental period. The improved cost effectiveness in response to domestic SBM diets might be due to the greater nutrient digestibility and overall performance of pigs fed diets containing SBM that originated from Korea.

CONCLUSIONS

Domestic SBM was more efficient than Brazilian and Indian SBM for the production of pigs. These findings indicate that domestic SBM has better quality than SBM imported from Brazil and India, which contributes to the improved performance and nutrient utilization in pigs. Overall, the results of this experiment suggest that use of domestic SBM with excellent protein quality and amino acid digestibility will make it useful for economic production of pigs.

Table 7. Production cost of pigs as affected by soybean meal origin[1)]

Item	Domestic		Imported[2)]				SEM[3)]	P-value[4)]			
			BRA		IND			D vs. I	D vs. BRA	D vs. IND	TAA vs. TDAA
	TAA	TIDAA	TAA	TIDAA	TAA	TIDAA					
Phase I (wk 0~3)											
Feed cost (₩/kg)	647.2	644.3	637.8	633.93	634.9	632.5					
Total weight gain (kg/pig)	8.76	8.97	8.51	8.63	8.40	8.55	0.04	0.001	0.002	0.001	0.067
Total feed intake (kg/pig)	13.30	13.58	13.24	13.44	13.17	13.35	0.03	0.068	0.253	0.033	0.001
Feed cost (₩/kg wt. gain)	983.1	975.2	992.9	987.3	996.3	987.8	2.32	0.024	0.050	0.036	0.122
Phase II (wk 4~8)											
Feed cost (₩/kg)	488.7	488.5	478.6	477.3	477.3	475.7					
Total weight gain (kg/pig)	28.02	29.35	27.15	28.33	26.66	27.84	0.18	0.002	0.016	0.001	0.001
Total feed intake (kg/pig)	58.87	60.36	58.25	59.93	57.45	59.64	0.21	0.060	0.251	0.065	0.001
Feed cost (₩/kg wt. gain)	1,026.8	1,004.8	1,026.7	1,009.5	1,028.7	1,019.0	1.93	0.216	0.674	0.104	0.001
Phase III (wk 9~13)											
Feed cost (₩/kg)	456.4	462.9	449.9	455.1	449.3	456.4					
Total weight gain (kg/pig)	37.58	39.72	35.55	38.40	32.98	35.40	0.47	<0.001	0.033	<0.001	0.005
Total feed intake (kg/pig)	89.92	91.71	89.30	91.13	86.27	88.33	0.41	0.010	0.402	<0.001	0.017
Feed cost (₩/kg wt. gain)	1,092.0	1,068.7	1,130.4	1,079.8	1,175.0	1,138.7	7.84	0.001	0.036	<0.001	0.016
Overall (wk 0~13)											
Total weight gain (kg/pig)	74.36	78.04	71.20	75.37	68.04	71.79	0.67	<0.001	0.016	<0.001	0.002
Total feed intake (kg/pig)	162.08	165.65	160.79	164.49	156.89	161.32	0.60	0.011	0.270	0.001	<0.001
Feed cost (₩/kg wt. gain)	1,054.6	1,033.9	1,074.4	1,042.7	1,095.6	1,074.3	4.42	<0.001	0.068	<0.001	0.003

1) Data represent means based on four replicates per treatment.
2) BRA = Brazil; IND = India.
3) Standard error of means.
4) D vs. I = Domestic vs. Imported; D vs. BRA = Domestic vs. Brazil; D vs. IND = Domestic vs. India; TAA vs. TIDAA = Total amino acid vs. True ileal digestible amino acid.

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