Soybean Checkoff-funded Research

Project Title: Broiler Feeding Trial to Compare Feeding Values of the Soybean Meals from Different Countries

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Summary of the Study

- Dehulled SBM from the U. S. appeared to have the highest level of crude protein (48%) followed by in the order of the SBMs from Brazil (46.3%), India (45.3%) and Argentine (44.4%). The dehulled SBM contained the lowest level of crude fiber (3.72%).

- The U. S. dehulled SBM, when expressed as % CP, contained higher levels of the most of amino acids, particularly lysine and total sulfur-containing amino acids, than the other SBMs.

- Amino Acid Score (or Chemical Score) of the U. S. dehulled SBM was slightly higher (55.2%) than those of the other SBMs.

- Pepsin digestibility and N solubility by KOH were higher in the Brazilian and the U. S. dehulled SBM, respectively, than those in the other SBMs. Urease activity values of the U. S. and Agentine SBMs (0.01- 0.02) were lower than those of the Brazilian and Indian SBMs (0.06-0.07).

- Broiler feeding trial in an animal room did not show significant differences in body weight gain, feed intake and F/G ratios among the four SBM dietary groups.

- No significant differences in PER and NPR values appeared among the four SBM groups, although the U. S. dehulled SBM tended to show higher PER and NPR values. NPUst value (60.7%) of the dehulled SBM was significantly ($P<0.05$) higher than that of the Indian (52.4%). No differences in NPUst appeared among the SBMs from Argentine, Brazil and India.

- Three SBMs from the U.S., Brazil and India were compared in a farm level broiler feeding trial. No significant differences in bird performances were observed between the SBMs from the U. S. and Brazil. The U. S. SBM produced better bird performances than the Indian SBM with a significance ($P<0.03$).

- When the return over production cost/kg bird was expressed as a percentage of the U. S. group (100), Brazil and Indian SBM groups appeared 100.3 and 83.6, respectively.

- When a single price, as an mean of the three SBMs, was applied to three SBMs, the final return over production cost/kg bird of the Brazil and India SBM groups appeared 99.1 and 84.6%, respectively, compared to 100% of the U. S. dehulled SBM group.

Study Background

In Korea, soybean meal has been one of the most popular and traditional protein sources of compound diets for poultry as well as for other livestock. Since local production of soybean and soy products has been limited, most of the soybean and soybean meals have been imported from the U. S., South America and India. Recently, public concern over the animal protein sources as feed ingredients has caused higher demand of the SMB in feed industries.
SBM as the dietary protein sources has many advantages such as high protein content, well-balanced essential amino acid compositions and excellent bioavailability (digestibility) of the amino acids over the other plant protein sources in animal nutrition. However, the availability of the amino acids, and the activity of the various protease inhibitors in the SBM could vary depending on the conditions (quality control) during the heat processing.

Dehulled soybean meal has been well known to have higher protein content, higher nutrient density, and better digestibility compared to non-dehulled SBM. Particularly, the low crude fiber content of the dehulled SBM plays a very important role in improving digestibility. Whether the merits of the dehulled SBM could be associated with better economical feasibility in Korean broiler diets need to be studied.

Objective of the Study

The objective of present study is to evaluate the feeding values of commercial loads of three SBMs originated from the U. S., South America, and India in broilers by chemical (in vitro) and in vivo assays, and feeding trials.

Chemical and in vitro measurement will include proximate and amino acid compositions, urease activity, and protein solubility tests. Feeding trials will include a lab scale feeding trial (in vivo assay) to compare protein quality, and a test-farm scale feeding trial to compare economic feasibility in broilers.

Study 1. Chemical compositions of the SBMs and in vitro evaluation of their protein quality

Materials and Methods

Soybean meals: Four commercial soybean meals locally obtained during a period from May to August, 2008.

(1) Dehulled soybean meal from the U. S.
(2) Non-dehulled soybean meal from Argentine
(3) Non-dehulled soybean meal from Brazil
(4)) Non-dehulled soybean meal from India

Analytical methods:

Proximate analyses - by AOAC(2002).

Amino acids analysis - acid hydrolysis with 6N HCl followed by ninhydrin reaction. Methionine and cystine were separately hydrolyzed with performic acid. Tryptophan was not analyzed. Auto amino acid analyzer (Hitachi L-8500) was used.

Pepsin digestibility – % nitrogen digested in 0.002% pepsin-HCl solution was measured (AOAC, 2002).

N solubility by KOH solution – % nitrogen solublized in 0.2% potassium hydroxide solution was measured (Parsons et al., 1991).

Urease activity - by phenol red indicator method (Caskey et at., 1944).

Amino Acid Score (Chemical Score) estimation:-

AAS was calculated as suggested by Block and Mitchell (1946) by dividing essential amino acid contents of the four SBM expressed as % crude protein by the essential amino acid requirement (Table 2) of the ROSS 308 Nutrition (Aviagen, 2008).

The amount of each essential amino acid required was estimated based on 22% crude protein content for the young broiler chicks. The lowest ratio value was selected as the Amino Acid Score of the specific SBM.

Results

Results of proximate analyses and amino acid contents of the four soybean meal samples are as show in Table 1. As expected, the U. S. dehulled SBM showed the highest level of crude protein (48%) followed by in the order of the SBMs from Brazil (46.3%), India (45.3%) and Argentine (44.4%). The dehulled SBM contained the lowest level of crude fiber (3.72%).

The amino acid contents in Table 1 were simply expressed as air-dry weight basis. Meanwhile, the amino acid contents in Table 2 were expressed as % crude protein, and these values were used to estimate Amino Acid Score (Chemical Score) of each SBM.

The U. S. dehulled SBM, when expressed as % CP, contained the most of amino acid with higher values (emphasized in bold), particularly lysine and total sulfur-containing amino acids, than the other SBMs. Amino Acid Score (or Chemical Score) of the dehulled SBM was slightly higher (55.2%) than those of the other SBMs (Table 2).

Pepsin digestibility, N solubility by KOH and urease activity of the SBMs are as shown in Table 3. The SBM from Brazil had higher value in pepsin digestibility, and KOH solubility was higher in the U. S. dehulled SBM, respectively, compared to those in the other SBMs. Urease activity values of the SBMs from the U. S. and Argentine (0.01- 0.02) were lower than those of the Brazil and Indian (0.06-0.07) SBMs.

Conclusion

Dehulled SBM from the U. S. contained the highest level of crude protein (48%) followed by the SBMs from Brazil, India and Argentine. The dehulled SBM contained the lowest level of crude fiber as expected.

Dehulled SBM, when expressed as % CP, appeared to have higher levels for most of amino acid, particularly lysine and total sulfur-containing amino acids, than the other SBMs. Amino Acid Score (Chemical Score) of the dehulled SBM was slightly higher (55.2%) than those of the other SBMs, which means the dehulled SBM was marginally higher in first limiting amino acid (TSAA) content.

Pepsin digestibility and N solubility by KOH were higher in the SBMs from Brazil and the U.S., respectively, compared to those in the other SBMs. The urease activity values of the SBMs from the U. S. and Argentine were lower than those of the Brazil and India.

It seems reasonable to conclude from the overall data that the dehulled SBM from the U. S. has the better protein quality than the SBMs from the other sources.

Table 1. Chemical composition of soybean meals from different countries (Study 1)

	Origins of soybean meals			
Nutrients	U. S.[1]	Argentine	Brazil	India
	--------- % air-dry basis ---------			
Moisture	10.42	10.65	10.09	10.29
Crude protein	48.01	44.44	46.25	45.29
Crude fat	1.42	1.53	1.95	1.40
Crude ash	6.58	6.46	6.16	7.73
Crude fiber	3.72	4.14	5.65	6.06
Amino acids				
Aspartic acid	5.37	5.00	5.21	5.03
Serine	2.26	2.19	2.30	2.21
Glutamic acid	9.02	8.42	8.66	8.36
Glycine	2.03	1.87	1.95	1.83
Alanine	2.10	2.01	2.04	1.94
Proline	2.47	2.29	2.44	2.36
Valine	2.21	1.96	1.93	1.72
Isoleucine	2.06	1.77	1.76	1.57
Leucine	3.68	3.41	3.45	3.27
Phenylalanine	2.37	2.21	2.29	2.12
Tyrosine	1.44	1.31	1.36	1.29
Threonine	1.90	1.84	1.86	1.74
Lysine	3.10	2.68	2.79	2.69
Histidine	1.24	1.12	1.15	1.13
Arginine	3.43	3.07	3.26	3.15
Methionine	0.58	0.56	0.56	0.53
Cystine	0.71	0.61	0.68	0.64

[1] The U. S. dehulled soybean meal

Table 2. Contents of essential amino acids as % crude protein, and Amino Acid Score of the SBMs (Study 1)

Essential	Origins of soybean meals				EAA Requirement[1]	
amino acids	U. S.	Argentine	Brazil	India	% diet	% protein[2]
	% of protein					
Valine	**4.60**[3]	4.41	4.17	3.80	1.09	4.95
Isoleucine	**4.29**	3.98	3.81	3.47	0.97	4.41
Leucine	**7.67**	**7.67**	7.46	7.22	-	-
Phenylalanine	4.94	**4.97**	4.95	4.68	-	-
Phenyl+Tyrosine	**7.94**	7.92	7.89	7.53	-	-
Threonine	3.96	**4.14**	4.02	3.84	0.94	4.27
Lysine	**6.46**	6.03	6.03	5.94	1.43	6.50
Histidine	**2.58**	2.52	2.49	2.50	-	-
Arginine	**7.14**	6.91	7.05	6.96	1.45	6.59
Methionine	1.21	**1.26**	1.21	1.17	0.51	2.32
Meth +cystine	**2.69**	2.63	2.68	2.58	1.07	4.86
Calculation of Amino Acid Score						
Valine	92.9	89.0	84.2	76.7		
Isoleucine	97.3	90.3	86.3	78.6		
Threonine	92.6	96.9	94.1	89.9		
Lysine	99.3	92.8	92.8	91.4		
Arginine	108.4	104.8	106.9	105.5		
Meth +cystine	55.2	54.1	55.1	53.1		
A. A. Score	55.2	54.1	55.1	53.1		

[1] Ross 308 Broiler Nutrient Specification (Aviagen, 2008)

[2] Calculated based on dietary protein level 22%.

[3] Values in bold form indicate highest % of the specific amino acids.

Table 3. In vitro protein quality of SBMs from different countries (Study 1)

	Origins of soybean meal			
Measurements	U. S.	Argentine	Brazil	India
Pepsin digestibility, %	75.0	81.9	86.8	76.2
N solubility by KOH, %	82.4	-	74.5	74.4
Urease activity, pH	0.02	0.01	0.07	0.06

Study 2. Comparison of in vivo protein qualities of the SBMs

Purpose of the study
To compare protein qualities of the SBMs from different countries by broiler feeding study. PER (protein efficiency ratio), NPR (net protein ratio) and NPUst (net protein utilization standard) values of the SBMs will be compared.

Materials and Methods
Birds: 120, Ross 308 broiler, day-old males
Feeding period: 15 days
Experimental design: 6 treatments x 4 replications x 5 birds/replication

Isolated soy protein diet (control)
U. S. dehulled soybean meal
Argentine soybean meal
Brazilian soybean meal
Indian soybean meal
Nitrogen-free diet

Experimental diets: Semi-purified type diets with ISP and SBMs as the only protein sources in the diets (Table 4). The other ingredients are all purified-type ingredients such as glucose, starch, α-cellulose and soybean oil. The protein sources were added to the diets to the levels to provide 13% crude protein, which was suggested to be the standard protein level to test PER, NPR or NPU values in chicks (Bender and Doell, 1957).

No amino acids were supplemented to the diets. All the other nutrient levels are the similar to the NRC (1994). All the diets except N-free diet were made to be isocaloric and isonitrogenous.

In vivo evaluation:

- PER = body weight gain (g) of birds fed the test diet/protein intake (g) from the test diet
- NPR = [body weight gain (g) of birds fed the test diet + weight loss (g) of birds fed
- N-free diet]/protein intake (g) from the test diet
- NPUst = (body N of test protein group – body N of N-free group) x 100/ N intake of test group
- Body weight gain – Empty body weight of the individual birds at the beginning and terminal days of the feeding trial were obtained by fasting (beginning) and by removing intestinal residues after sacrifice of the birds (terminal). Body weight gain was the differences in empty body weight between the initial and final.
- Carcass N contents - After sacrificed by CO_2 gas at the end of the feeding trial,

carcass N contents of individual bird was processed and analyzed according to Chee et al. (1982).

Statistical analysis

All the data were analyzed by one-way ANOVA with SigmaStat (v. 3.5, Systat Software, Inc.). Differences among the means of treatment groups were analyzed by Duncan's new multiple range test. Differences were considered significant at P< 0.05.

Table 4. Diet Formulation for SBM protein evaluation by broiler chicks (Study 2)

	Dietary protein sources					
Ingredients	Isolated soy protein	U.S. SBM	Argentine SBM	Brazilian SBM	Indian SBM	N-free
	--------------------	%	-------------------			
SBM	0.00	0.00	30.50	29.30	30.00	0.00
Dehul. SBM	0.00	28.20	0.00	0.00	0.00	0.00
ISP	15.00	0.00	0.00	0.00	0.00	0.00
Glucose	27.70	13.40	11.08	12.28	11.68	42.75
Starch	40.00	40.00	40.00	40.00	40.00	40.00
Soy oil	3.00	7.30	8.50	8.30	8.30	3.00
a-Cellulose	8.00	5.00	4.00	4.20	4.10	8.00
TriCaP	2.25	2.15	2.05	2.05	2.05	2.50
Limestone	0.60	0.50	0.57	0.57	0.57	0.30
NaCl	0.55	0.55	0.40	0.40	0.40	0.55
Vitamin mix	0.20	0.20	0.20	0.20	0.20	0.20
Mineral mix	2.50	2.50	2.50	2.50	2.50	2.50
Choline-HCl	0.20	0.20	0.20	0.20	0.2	0.20
Total	100.00	100.00	100.00	100.00	100.00	100.00
Nutrient contents, calculated						
AMEn, kcal/kg	3435	3428	3428	3431	3423	3497
C. protein, %	13.50	13.54	13.55	13.55	13.59	0.00
Ca, %	1.10	1.10	1.10	1.10	1.10	1.08
Pavl, %	0.50	0.49	0.49	0.49	0.49	0.50
C.Fiber	8.03	6.1	6.14	6.25	6.2	8.00

Results

Performances of the broilers are as shown in Table 5. Body weight gains (P<0.001), feed intake (P<0.001) and F/G ratio (P<0.01) of the birds fed the diets containing SBMs from different countries appeared significantly better than that of ISP group. No significant differences in those performances were, however, observed among the groups fed the SBM diets. Birds fed the N-free diet lost body weight by average of 16.4 g/b and consumed only 71.1 g/b of the diet during the feeding period.

Table 6 shows results of carcass N analysis and PER, NPR and NPUst measurements. Final carcass N contents (36.7-41.1 g/b), amounts of N retained (27.1-31.75 g/b), and N intake (52.7-57.2 g/b) in broilers during the feeding period were not significantly different among the SBM groups. However, the amounts of final carcass N, N retained, and N intake of the ISP group were lower than those of the SBM groups (P<0.001).

PER, NPR and NPUst values of the ISP (2.33, 2.82 and 48.2, respectively) were significantly lower than those of the SBM groups (P<0.05). No differences in PER and NPR values among the SBM groups appeared, although the U. S. dehulled SBM tended to show higher PER and NPR values (3.42 and 3.71, respectively) compared to the other SBMs.

NPUst value (60.7%) of the U. S. dehulled SBM was significantly higher (P<0.05) than that of the Indian (52.4%). No differences in NPUst values appeared among the SBMs from Argentine, Brazil and India. Birds fed the N-free diet lost body N by 2.86 g/b during the 15 days of feeding period.

Table 5. Body weight gain, feed intake, protein intake and Feed/Gain ratio of birds fed diets containing ISP or different sources of soybean meals (Study 2)

Protein sources	Body wt gain	Feed intake	Feed/ Gain
	g/b	g/b	
Isolated soy protein	80.3a	253.3a	3.31a
Dehulled SBM	195.5b	417.9b	2.14b
Argentine SBM	180.0b	407.6b	2.27b
Brazil SBM	176.0b	388.6b	2.21b
India SBM	193.2b	439.1b	2.28b
N-free	(-16.4)	(71.1)	-
Probability	P<0.001	P<0.001	P<0.01

Table 6. Dietary protein quality assay by carcass analysis, PER, NPR and NPU measurement[1] (Study 2)

Sources of	Carcass nitrogen			Nitrogen			
Protein	Initial	Final	Retention	intake	PER[2]	NPR[2]	NPUst[2]
	………… …………….			g/ bird			%
Isolated soy protein	9.41	22.87a	13.47a	34.04a	2.33a	2.82a	48.2a
US dehulled SBM	9.39	41.14b	31.75b	57.18b	3.42b	3.71b	60.7b
Argentinian SBM	9.52	36.70b	27.18b	55.47b	3.24b	3.54b	54.5bc
Brazilian SBM	9.40	36.82b	27.42b	52.73b	3.34b	3.65b	57.4bc
Indian SBM	9.37	37.94b	28.57b	55.94b	3.22b	3.49b	52.4c
N-free	9.41	6.55c	(-2.86[3])	-	-	-	-
Probability	-	-	P<0.001	P<0.001	P<0.001	P<0.005	P<0.05

[1] Means of 20 birds.

[2] PER = protein efficiency ratio, NPR = net protein ratio, NPUst = net protein utilization standard.

[3] Loss of carcass N of birds fed the N-free diet

Conclusion

There were no significant differences in performances and in vivo protein quality measurements among the various SBM groups. However, the birds fed the U. S. dehulled SBM diet tended to show numerically higher body weight gain, feed intake, better F/G ratio, PER and NPR values than the other SBM groups.

NPUst value (60.7%) of the dehulled SBM was significantly higher ($P<0.05$) than that of the Indian (52.4%). No differences in NPUst values appeared among SBMs from Argentine, Brazil and India.The ISP diet caused the birds to perform lower than the SBM diets. Birds fed the N-free diet lost body weight by average of 16.4 g/b, and body N by 2.86 g/b during the 15 days of feeding period.

Study 3. Farm-level broiler feeding trial with a dehulled soybean meal from the U. S. and non-dehulled soybean meals from Brazil and India

Purpose of the trial was to compare practical feeding values of the three SBMs (the U. S. dehulled SBM, Brazilian and Indian non-dehulled SBMs) by broiler feeding trial at a farm.
To compare economic feasibility of the three SBMs

Materials and Methods
Place of the trial: A commercial broiler test farm locating at Anseong city, GyeongGi-Do province
Feeding period: 35 days
Birds: 728, Ross 308 broilers, day-old. The sexed birds were allocated by 13 males and 13 females into each pen.

Experimental design: Four treatments (commercial diet, dehulled SBM from the U. S., non-dehulled SBMs from Brazil and India) x 7 replications x 26 birds/rep = 728 birds (female : male = 1 : 1). A commercial diet was used for the control group.

Diets: Experimental diets were prepared for three feeding phases, i.e., starter (0-7 days), grower (8-21 days) and finisher (22-35 days). Nutrient levels of the diets (Table 7) were modified according to the broiler nutrient recommendation from Ross 308 Nutrition (Aviagen, 2007) based on nutrient/energy ratios.

Dietary formulations for each feeding phase are as shown in Table 8. The levels of the SBMs added to the starter, grower and finisher diets were 35, 25 and 20% by weight, respectively, and these levels of the SBMs provided about 66, 52 and 44% of dietary proteins in each phase. Synthetic amino acids such as L-lysine HCl, DL-methionine and L-threonine were added to the diets to satisfy their requirements based on digestible amino acids.

Table 9 shows the calculated proximate composition and major essential amino acid contents of SBM diets in each feeding phase. AMEn levels of all diets were set identical at 3150 kcal/kg. Crude protein levels were set at 23, 21 and 20% for starter, grower and finisher diets, respectively. The commercial control diets appeared to have similar ranges of crude protein for every feeding phase compared to the SBM diets (Table 10).

Table 7. Broiler nutrient requirements[1] for each feeding phase (Study 3)

	Starter	Grower	Finisher
Age fed, days	0-7	8-21	22-35
Energy, kcal/kg	3150	3150	3150
Crude protein, %	23	21	20
Calcium, %	1.05	0.9	0.85
P available, %	0.5	0.45	0.42
Amino acids, %			
Lysine			
Total	1.43	1.24	1.09
Digestible	1.27	1.10	0.97
Methionine			
Total	0.51	0.45	0.41
Digestible	0.47	0.42	0.38
Methionine+cystine			
Total	1.07	0.95	0.86
Digestible	0.94	0.84	0.76
Threonine			
Total	0.94	0.83	0.74
Digestible	0.83	0.73	0.65
Tryptophan			
Total	0.24	0.20	0.18
Digestible	0.20	0.18	0.16
Arginine			
Total	1.45	1.27	1.13
Digestible	1.31	1.14	1.02

[1] modified from ROSS 308 Broiler Nutrition (Aviagen, 2007)

Table 8. Diet formulations for starter (0-7 d), grower (8-21 d) and finisher (22-35 d) broilers (Study 3)

	Starter diets containing			Grower diets containing			Finisher diets containing		
Ingredients	U. S. SBM[1]	Brazilian SBM	Indian SBM	U. S. SBM	Brazilian SBM	Indian SBM	U. S. SBM	Brazilian SBM	Indian SBM
	----------	%	-------- -	----------	%	---------	----------	%	---------
Corn, yellow	52.38	51.02	50.03	62.05	61.08	60.28	67.98	67.01	66.39
Soybean meal	35.00	35.00	35.00	25.00	25.00	25.00	20.00	20.00	20.00
Meat & bone meal	2.00	4.00	5.30	2.25	3.70	4.70	2.70	4.10	4.90
Yellow grease	4.90	5.10	5.30	2.70	2.80	3.00	1.70	1.85	2.00
Limestone	1.00	0.84	0.60	0.76	0.65	0.46	0.66	0.53	0.38
DCP	1.51	0.80	0.50	1.20	0.68	0.46	0.95	0.48	0.30
Lysine-HCl	0.31	0.32	0.32	0.27	0.32	0.32	0.25	0.28	0.27
L-Threonine	0.03	0.02	0.04	0.00	0.00	0.00	0.04	0.03	0.04
DL-Methionine	0.32	0.35	0.36	0.22	0.22	0.23	0.17	0.17	0.17
Miscellaneous[2]	2.55	2.55	2.55	5.55	5.55	5.55	5.55	5.55	5.55
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1] Dehulled SBM

[2] Miscellaneous ingredients include corn gluten (2.0, 5.0 and 5.0% for starter, grower and finisher diets, respectively), and NaCl (0.3%), vitamin + mineral mix (0.1%), choline-Cl (0.1% as 50% solution), and coccidiostat (0.05%) for the diets of each phase.

Table 9. Calculated proximate composition and major essential amino acid contents of the starter, grower and finisher diets (Study 3)

Nutrients	Starter diets containing			Grower diets containing			Finisher diets containing		
	U. S. SBM	Brazilian SBM	Indian SBM	U. S. SBM	Brazilian SBM	Indian SBM	U. S. SBM	Brazilian SBM	Indian SBM
AMEn, kcal/kg	3157.0	3158.0	3154.0	3157.0	3155.0	3155.0	3154.0	3157.0	3157.0
Crude protein, %	23.3	23.6	23.8	21.3	21.3	21.7	19.6	19.7	20.0
Calcium, %	1.06	1.05	1.05	0.90	0.90	0.90	0.85	0.85	0.85
P available, %	0.50	0.50	0.50	0.45	0.45	0.45	0.42	0.42	0.42
Methionine, %									
Total	0.703	0.705	0.712	0.579	0.582	0.590	0.515	0.519	0.517
Digestible	0.676	0.681	0.687	0.554	0.557	0.565	0.491	0.494	0.493
Total sulfur-containing amino acids, %									
Total	1.074	1.075	1.075	0.926	0.930	0.934	0.839	0.845	0.840
Digestible	0.988	0.991	0.992	0.845	0.849	0.853	0.762	0.768	0.763
Lysine, %									
Total	1.462	1.460	1.456	1.225	1.224	1.223	1.078	1.075	1.066
Digestible	1.328	1.327	1.324	1.114	1.117	1.117	0.981	0.981	0.973
Threonine, %									
Total	0.979	0.985	0.981	0.862	0.874	0.858	0.739	0.741	0.739
Digestible	0.865	0.869	0.868	0.759	0.769	0.755	0.655	0.656	0.655
Tryptophan, %									
Total	0.324	0.328	0.331	1.258	1.259	1.262	0.223	0.226	0.228
Digestible	0.275	0.279	0.281	1.145	1.146	1.148	0.190	0.192	0.193
Arginine, %									
Total	1.502	1.502	1.503	1.258	1.259	1.262	1.124	1.132	1.134
Digestible	1.366	1.367	1.368	1.145	1.146	1.148	1.023	1.030	1.032

Table 10. Analyzed proximate composition of the commercial diet (Study 3)

Phase diets	Moisture	C. protein	C. fat	C. fiber	C. ash	NFE	Ca / P
		----------------------------------		%	------------------------------		
Starter	10.56	22.50	9.72	3.60	6.49	47.13	1.12 / 0.63
Grower	11.73	21.93	7.30	3.02	6.03	49.99	1.01 / 0.59
Finisher	10.53	19.87	9.00	3.82	5.86	50.92	0.95 / 0.59

Economic feasibility analysis

Prices of single feed ingredients are as shown in Table 11. These prices represent local market prices in the fall, 2008. The prices of individual SBM were calculated based on average C&F import to port Inchon during a period of five months from April to August, 2008. This period matches the timing of the present study from the starting to the beginning of the feeding trial.

The average C&F prices appeared $462.2, $446.6 and $474.2/MT for the U. S., Brazil, and India SBMs, respectively. The monthly (15th day every month) exchange rates between Korean won and U. S. dollar from the Korean Foreign Exchange Bank were applied to get the prices of the SBMs in Korean won(₩). Consequently, the prices of the SBMs from the U. S., Brazil, and India were ₩472.4, ₩456.5 and ₩484.5, respectively. The reason for the high price of the Indian SBM was associated with the higher C&F price during July and August than those of the U. S. and Brazil SBMs.

The production cost included only feed and chicks prices. The prices of the day-old broiler chicks and broiler selling according to the monthly market information of the Korea Poultry Association were ₩220/bird and ₩1600/kg live body weight, respectively.

Statistical analysis of the data from the feeding trial

All the data were analyzed by one-way ANOVA with SigmaStat (v. 3.5, Systat Software, Inc.). Differences among the means of treatment groups were analyzed by Tukey's test. Differences were considered significant at $P < 0.05$.

Table 11. Prices of feed ingredients (Study 3)

Ingredients	Cost (₩/kg)
Corn, yellow	350
Soybean meals[1]	
U.S. (dehulled)	472.4
Brazil	456.5
India	484.5
Mean	471.1
Meat & Bone Meal	550.0
Corn gluten meal	913.0
Yellow grease	1150.0
Limestone	30.0
Dicalcium phosphate	1050.0
NaCl	150.0

Vit-Min mixture	3500.0
Lysine-HCl	2300.0
L-Threonine	3400.0
DL-Methionine	5500.0
Choline-Cl (50%)	1380.0
Coccidiostat	3300/7500

[1] calculated from average C&F Inchon for individual SBM imported from April to August, 2008, and at monthly exchange rates (₩ : dollar) during the five months.

Results

Performances of broilers on farm level feeding trial with the diets containing SBMs from different countries; Broiler performances during each phase are as shown in Table 12. Birds of the control group used to perform better during the first three weeks ($P<0.05$) in terms of body weight gain during whole period, and F/G ratio compared to those fed the SBM diets. Overall F/G ratios were not different among the dietary groups, although the F/G ratio of the birds fed the Indian SBM appeared numerically higher than those of the other groups.

Birds fed the SBMs from the U. S. and Brazil did not show any significant differences in feed intake, body weight gain, and F/G ratio during starter, grower, finisher or overall period, although the U. S. dehulled SBM tended to show numerically better than the Brazilian.

Body weight gain of the birds fed the U. S. SBM were heavier than those fed the Indian SBM in every feeding phase including overall period (1445.9 vs. 1283.9 g/b) with a significance ($P<0.03$).

Overall feed intake per bird appeared higher in the order of control > U. S. >Brazil > India, and the same tendency was observed in final body weight and body weight gain. The overall F/G ratios appeared better in the order of U. S. = Brazil (2.04) < control (2.07) < Indian SBM (2.18).

Table 12. Performances of broilers fed diets containing soybean meals from different sources (Study 3)

	Control	Soybean meals from USA	Brazil	India	Probability
Starter (0-7 d)					
Feed intake, g/b	128.8a	146.9b	145.0b	140.1ab	P<0.02
Body wt gain, g/g	96.7a	88.2ab	82.9bc	74.0c	P<0.005
Feed/Gain	1.33a	1.67b	1.75b	1.89b	P<0.02
Grower (8-21 d)					
Feed intake, g/b	1086.3a	933.5b	918.8b	887.2b	P<0.001
Body wt gain, g/g	576.9a	546.1b	555.1ab	498.2c	P<0.02
Feed/Gain	1.88a	1.71b	1.66b	1.78ab	P<0.05
Finisher (22-35 d)					
Feed intake, g/b	2015.0a	1864.8ab	1838.8b	1772.8b	P<0.05
Body wt gain, g/g	883.8a	811.5ab	786.2bc	711.7c	P<0.001
Feed/Gain	2.28	2.30	2.34	2.49	P=0.158
Overall (0-35 d)					
Feed intake, g/b	3230.4a	2945.3b	2902.6b	2800.1b	P<0.02
Final body wt, g/b	1603.5a	1492.1b	1470.2b	1330.1c	P<0.03
Body wt gain, g/g	1557.4a	1445.9b	1424.2b	1283.9c	P<0.03
Feed/Gain	2.07	2.04	2.04	2.18	P=0.185

Comparison of economic feasibility of the dehulled SBM and non-dehulled SBMs in broiler diets; Table 13 compares the economic feasibility of the U. S. dehulled SBM and non-dehulled SBMs from Brazil and India in a broiler feeding trial. Feed costs of the SBM diets for each feeding phase are as shown in Table 13. The feed costs of the starter diets with SBMs from the U. S., Brazil and India appeared ₩483.2, ₩480.2 and ₩494.0, respectively. The costs for the grower diets were ₩462.5, ₩459.9, ₩470.1, and for the finisher diets ₩446.1, ₩444.3 and ₩452.0, respectively, in the order.

Feed cost/bird for the Indian SBM group (₩1287.6) appeared lower than those of the U. S. and Brazil even though feed cost/kg diet was higher with the Indian SBM diet. It was because of the less feed intake of the former group.

Income/bird was calculated based on broiler selling price, ₩1600/kg live body weight. The return over production/bird was obtained by the difference between income/bird and production cost. The return over production cost/kg bird appeared ₩558.2, ₩560.0 and ₩466.6 for the U. S., Brazil and India SBM groups, respectively. When the return over production cost/kg bird was expressed as a percentage of the U. S. group (100.0), Brazil and India SBM groups appeared 100.3 and 83.6, respectively.

An equal single price for the three SBMs was applied for a purpose of comparison. A simple arithmetic mean (₩471.1/kg) of the final prices of the three SBMs (Table 11) was applied to get feed costs for each diet of every feeding phase. The applying of the same SBM price resulted in lower feed costs for the SBM diets from the U. S. (<0.1%) and India (~0.7%), but higher cost for the Brazil SBM diet (~0.8%). As a consequence, the final return over production cost/kg bird of the Brazil and India SBM diet groups appeared 99.1 and 84.6%, respectively, compared to 100% of the U. S. SBM diet group.

Table 13. Economic analysis for return over feed cost of broilers fed the diets containing SBMs from different countries (Study 3)

	Origins of SBMs		
Items	U. S.	Brazil	India
Based on individual SBM cost			
	Feed cost, ₩/kg diet		
Starter diet	483.2	480.2	494.0
Grower diet	462.5	459.9	470.1
Finisher diet	446.1	444.3	452.0
	Return over production cost, ₩		
Feed cost/bird	1334.5	1309.1	1287.6
Feed cost/kg bird	894.4	890.5	968.0
Production cost[1]	1554.5	1529.1	1507.6
Income/bird[2]	2387.4	2352.3	2128.2
Return over production/bird	832.9	823.2	620.6
Return over production /kg bird	558.2	560.0	466.6
% Return over production/kg bird	100.0	100.3	83.6
Based on a single price for all SBMs[3]			
	Feed cost, ₩/kg diet		
Starter diet	482.7	485.3	489.3
Grower diet	462.2	463.5	466.7
Finisher diet	445.8	447.2	449.4
	Return over production cost, ₩		
Feed cost/bird	1333.7	1318.6	1279.2
Feed cost/kg bird	893.8	896.9	961.8
Production cost[1]	1553.7	1538.6	1499.2
Income/bird	2387.4	2352.3	2128.2
Return over production/bird	833.7	813.7	628.9
Return over production /kg bird	558.8	553.5	472.9
% Return over production/kg bird	100.0	99.1	84.6

[1] Production cost includes feed cost/b and chick price (₩220/b).
[2] Income from birds (₩1600/kg live wt) was calculated based on monthly market information of the Korea Poultry Association (October 6, 2008)
[3] The average price (₩471.1/kg) of the three SBMs was considered as the single
price.

Conclusion and discussion

Control group performed better in every feeding phase (P<0.05) in terms of body weight gain during whole period, and F/G ratio during the first three weeks compared to those fed the SBM diets. Overall F/G ratios were not different among all the dietary groups.

The better performances of the birds fed the commercial diets over the SBM diets are understandable. The SBM diets were formulated to provide the essential amino acids to satisfy the requirements without enough margins to have more sensitive responses from the differences in protein quality.

The SBMs from the U. S. and Brazil did not show any significant differences in feed intake, body weight gain, and F/G ratio during every feeding phases or overall period. However, the U. S. SBM improved body weight gain of the birds in each feeding phase and overall period better than the Indian SBM with a significance (P<0.03).

The higher feed costs/kg diet of the Indian SBM than the feed costs of the U. S. dehulled SBM diets was unusual. It was because of the unusually high C&F prices of the July and August SBMs from India.

Feed cost/bird for the Indian SBM group (₩1287.6) appeared lower than those of the U. S. and Brazil even though feed cost/kg diet was higher with the former. It was because of the lower feed intake of the former group due to an unknown reason. When applying an equal price, an arithmetic mean of the three SBMs, to every SBM, the % return over production cost/kg bird of the Indian SBM group was still 84.6% of the U. S. SBM group. The higher feed costs and relatively low growth rate of the Indian SBM group appeared to be associated with the lowest return over production cost/kg bird weight.

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