Soybean Checkoff-funded Research

Project Title: Evaluation of Feeding Values of U.S. Dehulled Soybean Meal and Non-dehulled Soybean Meals from South America and India based on Protein Dispersibility Index (PDI) and Bioassay with Broilers

Investigators: Chee, Kew Mahn, Principal Investigator, Jin Ho Choi, Gi Dae Kim, Eun Jung Choi and Ju Youn Lee

Institution: Korea University, Seoul 136-701, Korea

Reference: Final Report (2770-1202-0020) (December, 2002) for a research project funded by the American Soybean Association-International Marketing and the United Soybean Board, 16405 Swingley Ridge Road, Suite 200, Chesterfield, MO 63017.

Objective of the Study:

The aims of present study are two. First is to evaluate the feeding values, mainly protein quality, of U.S. dehulled soybean meal compared to those of non-dehulled soybean meals from S. America (Brazil) and India. Second is to find out a more sensitive indicator for protein quality control of the meals. Protein dispersibility index(PDI), a most plausible candidate for the work, will be determined on soy flakes SBMs treated at various heating intervals. The PDI scores will be compared to those of conventional indicators such as KOH protein solubility, urease activity and pepsin digestibility.

Various measurements such as chemical composition, in vitro digestibility and a metabolic study for in vivo (broilers) digestibility of amino acids of the meals will be conducted. In addition, protein bioavailability (PER and NPR) of the three soybean meals of various sources will be compared in young broiler chicks. A test farm feeding trial with broilers will also be conducted to compare the overall feeding values of the three soybean meals.

Summary of the Study Results

<u>Sources of soybean meals and soy flake</u>

Three soybean meals (SBM) and one soy flake were used for this study. The three SBMs originated from the U.S., Brazil and India were obatined from local feed mills. The SBM from the U.S. was a dehulled meal. Soy flake was provided by a local soybean processor.

<u>Proximate analyses of the soy flake and three SBMs</u>

Dehulled SBM from the U.S. contained higher level of crude protein (47.6 vs. 44.3 and 44.8%) and less crude fiber (3.9 vs. 5.3 and 5.6%) than the other SBMs. The Soy flake, which was not added with hulls, appeared to have nutrients contents close to those of the dehulled meal except crude fat (0.6%), a very low level compared to 1.5~2.4% of the other meals.

Amino acid composition of the soy flake and three SBMs

Dehulled SBM tended to have higher levels of lysine and methionine+ cystine compared to the other SBMs when expressed as air-dry basis. However, no differences in their contents appeared when expressed as % protein basis. Overall amino acid composition of the soy flake and the SBMs were very similar.

In vitro digestibility of heat-treated soy flakes and three SBMs, and their relations to protein quality evaluation by a feeding trial

Soy flakes were heat-treated for durations of 0, 15, 30, 45 and 60 minutes in an autoclave at 121^{o}C.

Raw soy flake showed higher values in all measurements of in vitro digestibility, although the birds fed this flake performed the worst. Birds fed a diet containing soy flake treated for 30 minutes showed better body weight gain, feed conversion, PER and NPR values than those of the other treatment groups, indicating that the soy flake heat-treated for 30 minutes could be utilized more efficiently in young birds.

The in vitro digestibility scores of the soy flake treated for 30 minutes were 92.8% pepsin digestibility, 79.6% KOH solubility, 21.5% protein dispersibility index(PDI) together with 0.02 urease activity and 2.41% available lysine.

Birds fed the diet containing dehulled SBM showed significantly better body weight gain, PER and NPR than the birds fed the other SBM diets ($p<0.05$). Pepsin digestiblity, KOH solubility and PDI of the dehulled SBM were 95%, 80.6% and 22.2%, respectively.

Considering the in vitro digestibility scores of the three commercial SBMs and the results of the broiler study, PDI value (21.5%) of the flake treated for 30 minutes appeared a more senstitive and plausible indicator for optimum heat treatment compared to the other in vitro digestibility methods.

Amino acid bioavailability of heat-treated soy flakes and three soybean meals

Amino acid bioavailability data obtained by cecal ligation and urethral tubing method appeared in good agreement with the one from birds colostomized plus cecal ligation method. The former simpler and more convenient method was applied to measure the amino acid availability of heat-treated soy flakes and three SBMs.

Overall average availability value tended to increase by heat-treating the soy flake for 30 minutes compared to that of raw flake (69.1 to 93.1%), and to decline as the duration of the heat treatment lasted longer than 30 minutes (93.1 to 83.5% in true availability data). Overall mean true availability values of the SBMs were 94.7% for the dehulled meal, 91.0% for Brazil and 91.5% for India.

Energy utilization of heat-treated soy flakes and three soybean meals

The soy flake heat-treated for 30 minutes showed better energy values expressed as AME and TME compared to those treated under or over 30 minutes. AME and TME values of the flake, 2.0 and 2.3 kcal/g when unheated, respectively, increased to 2.8 and 3.1 kcal/g, respectively, by heating for 30 minutes.

Dehulled SBM showed to have higher AME (2.6 vs. 2.2 and 2.5 kcal/g) and TME (2.9 vs. 2.8 and 2.7 kcal/g) values compared to those of Brazil and India, respectively.

Broiler performances in farm feeding trials to compare feeding values of three SBMs

Birds fed the diets containing the U.S. dehulled SBM showed better body weight gains and feed/gain ratios during starter, grower and overall periods with a consistency compared to the birds fed the other SBM diets in Trials 1 and 2. Performances of the birds fed the diets containing SBM from Brazil and India appeared fairly similar between the two groups in both trials.

Economic analyses of the feeding values of the SBMs with different origins

Feed cost of the diet per kg basis containing the dehulled SBM appeared lower compared to those of the other groups (5.14 and 4.35 won/kg for starter and grower, respectively) because of lower inclusion % of the dehulled meal in the test diet due to its higher protein content.

This lower feed cost and better performances of the broilers fed the diet with dehulled SBM resulted further increase in the economic advantages of the broiler selling price over the other SBM groups. Final income as % of return per kg bird of the dehulled SBM group was higher by about 13~16% over the other SBM groups in both trials.

Study 1. Chemical analyses and in vitro digestibility of a soy flake and three soybean meals of various origins

Samples of three SBMs from the U.S., Brazil and India were obtained from local feed mills. The soybean meal from the U.S. was a dehulled meal. A bag of soyflake, which was defatted, dehulled and untreated with heat, was obtained from a local soybean processor.

Proximate analyses of the SBMs and the soyflake were conducted according to methods described by AOAC (1990). Ca and P contents were analyzed by atomic absorption spectrophotometry and colorimetric method, respectively, after being ashed in a Muffle furnace.

Amino acid contents were determined by ninhydrin reaction. The samples were hydrolyzed by 6 N-hydrochloric acid for 20 hours and the hydrolyzates were injected into an automatic amino acid analyser (Hitachi L-8500).

In vitro digestibilities: The in vitro digestibility of the soy flake and soybean meals were measured and the results were expressed in Study 2 together with performances of the birds fed the diets containing the soy flake and SBMs.

Results of Study 1

Chemical composition: Chemical compositions of the soy flake and the three SBMs were as shown in Table 1. Of the SBMs, as expected, dehulled meal from the U.S. contained more crude protein (47.6 vs. 44.3~ 44.8%) and less crude fiber (3.9 vs. 5.3~5.6%) compared to those of the other SBMs, which were not dehulled. Soy flake appeared to have similar nutrient contents to those of the dehulled SBM except crude fat (0.6%), which is very low compared to those (1.5~2.4%) of the other meals.

Amino acid compositions: Amino acid compositions of the samples based on % air-dry weight and % of protein were as shown in Table 2. Overall amino acid patterns of the SBMs and the soy flake appeared very similar between the samples when they were expressed as either % air-dry weight basis or % of protein basis. Lysine contents were higher, on air-dry basis, in the order of soy flake (3.06%), the U.S. (3.01%), Brazilian (2.82%) and Indian (2.62%) SBMs. Methionine+cystine (total sulfur-containing amino acids) contents appeared higher in the order of the U.S. (1.44%), Brazilian (1.32%), Indian (1.25%) and the soy flake (1.25%).

Table 1. Chemical compositions of soybean flake and soybean meals of various origins

Composition	Soy flake	Origins of Soybean Meals		
		U.S.[1]	Brazil	India
	% air-dry basis			
Moisture	10.3	10.7	12.3	9.9
Crude Protein	47.1	47.6	44.8	44.3
Crude Fat	0.6	1.5	2.4	2.1
Crude Ash	6.0	6.2	6.0	8.1
Crude Fiber	4.2	3.9	5.3	5.6
Calcium	0.32	0.31	0.29	0.95
Total Phosphorus	0.73	0.68	0.60	0.60

[1]Dehulled soybean meal

Table 2. Amino acid compositions of soybean flake and soybean meals of various origins

Amino acids	Soy flake		Origins of Soybean Meals					
			U.S.[1]		Brazil		India	
	% air-dry basis (% protein)							
Asp+Asn[2]	5.73	(12.2)	5.59	(11.7)	5.33	(11.9)	4.94	(11.1)
Threonine	2.00	(4.2)	1.99	(4.2)	1.87	(4.2)	1.72	(3.9)
Serine	2.32	(4.9)	2.53	(5.3)	2.45	(5.5)	2.29	(5.2)
Glu+Gln[3]	9.25	(19.6)	8.87	(18.6)	8.38	(18.7)	7.84	(17.7)
Glycine	2.15	(4.6)	2.05	(4.3)	1.96	(4.4)	1.84	(4.2)
Alanine	2.16	(4.6)	2.09	(4.4)	2.02	(4.5)	1.89	(4.3)
Valine	2.63	(5.6)	2.32	(4.9)	2.14	(4.8)	1.94	(4.4)
Isoleucine	2.32	(4.9)	2.06	(4.3)	1.94	(4.3)	1.65	(3.7)
Leucine	3.73	(7.9)	3.60	(7.6)	3.47	(7.7)	3.07	(6.9)
Tyrosine	1.72	(3.7)	1.60	(3.4)	1.59	(3.5)	1.43	(3.2)
Phenylalanine	2.38	(5.1)	2.38	(5.0)	2.32	(5.2)	2.06	(4.6)
Lysine	3.06	(6.5)	3.01	(6.3)	2.82	(6.3)	2.62	(5.9)
Histidine	1.14	(2.4)	1.25	(2.6)	1.15	(2.6)	1.15	(2.6)
Arginine	3.56	(7.6)	3.37	(7.1)	3.22	(7.2)	2.98	(6.7)
Cystine	0.68	(1.4)	0.74	(1.6)	0.68	(1.5)	0.63	(1.4)
Methionine	0.57	(1.2)	0.70	(1.5)	0.64	(1.4)	0.62	(1.4)

[1]Dehulled soybean meal

[2]aspartic acid + asparagine

[3]glutamic acid + glutamine

Study 2. Animal room feeding trial with heat-treated soy flakes and three soybean meals of various origins

Purpose: To compare in vivo protein quality of the three SBMs, and soy flakes heat-treated for various durations.

Materials and Methods

Birds: 180, day-old, Ross, male

Period: 14 days

Experimental design: 9 dietary groups x 4 replications x 5 birds/replication

Nitrogen-free diet; Diets containing heat-treated soy flakes (0, 15, 30, 45, and 60 min.) Diets containing the three SBMs – the meals from the U.S. (dehulled), Brazil and India.

Dietary formulations: all feed ingredients were of purified types such as glucose, starch, α-cellulose and soybean oil except protein sources (Table 3). Nitrogen-free diet – prepared to meet all nutritional requirements except amino acid sources.

SBMs and soy flake diets – each protein source was added to the N-free diet by replacing mainly glucose up to the levels to provide 13% crude protein. The soy flake and each of the three SBMs were the only protein sources in each diet.

Heat treatment of soy flake: The flakes were heat-treated in an autoclave for various time durations such as 0, 15, 30, 45 and 60 minutes at 121^{o}C. The autoclaved flakes were spread left at room condition for 4-5 days to become air-dry state.

Measurements:

- PER (protein efficiency ratio) - body weight gain (g) of chicks fed the test diet /protein intake (g) from the test diet (Bender and Doell, 1957)
- NPR (Net protein retention) - [body weight gain (g) of the chicks fed the test diet + weight loss (g) of chicks fed the N-free diet] / protein intake (g) from the test diet
- Pancreas weight - at end of feeding trial, eight birds from each dietary group were sacrificed to measure pancreas weight. The weight was expressed as absolute weight and % body weight.
- Pepsin digestibility – 0.02% pepsin digestibility measured according to AOAC (1990).
- KOH solubility - measured according to a method proposed by Dale and Araba (1987).
- Protein dispersibility index (PDI) – measured following the procedure according to AOCS (1975).
- Urease activity - measured by phenol red indicator method proposed by Caskey et al. (1944).
- Available lysine - measured by a method proposed by Carpenter and Booth (1973).

Table 3. Formulation for semi-purified diets and nitrogen-free diet

Ingredients	Soy flake	Soybean meal			Nitrogen-free diet
		U.S.[1]	Brazil	India	
Soy flake	27.32	-	-	-	-
Soybean meal	-	27.32	29.02	29.34	-
Corn starch	40.00	40.00	42.00	42.00	41.00
Glucose, monohydrate	23.92	23.92	19.22	18.90	45.74
Soybean oil	3.00	3.00	4.00	4.00	2.50
Vitamin mixture	0.20	0.20	0.20	0.20	0.20
Mineral mixture	5.36	5.36	5.36	5.36	5.36
α-Cellulose	-	-	-	-	5.00
Choline chloride	0.20	0.20	0.20	0.20	0.20
Total	100.00	100.00	100.00	100.00	100.00
Nutrients, calculated					
Protein, %	13	13	13	13	0
ME, kcal/kg	3198	3198	3199	3196	3201

[1] Dehulled soybean meal

Results of Study 2

Birds performances: Of the birds fed the SBM diets, the group fed the U.S. dehulled SBM diet grew faster with better feed/gain ratio and showed better PER and NPR compared to those of the other two SBM groups with a significance at $p<0.05$. There were no significant differences observed in those measurements between the birds fed diets containing the SBMs from Brazil and India (Table 4).

Birds fed the diet with soy flake heat-treated for over 15 minutes showed significantly ($p<0.05$) more feed intake, better body weight gain, feed efficiency, PER and NPR values compared to those fed the diet containing raw soy flake. Of the birds fed diets of which soy flakes were heat-treated over 15 minutes, the chicks fed the diet containing soy flake heat-treated for 30 minutes tended to show better feed/gain ratio and significantly better ($p<0.05$) body weight gain, PER and NPR values than the birds of the other groups.

The longer the duration of heat-treatment over 30 minutes, the poorer performances such as body weight gain, feed/gain, PER and NPR were observed. The shorter the duration of heat treatment under 30 minutes, the same trend in performances were observed. This suggests that soy flake heat treated for 30 minutes at 121^{o}C could be utilized with better efficiency as dietary protein source.

Pancreas weight expressed as % body weight appeared significantly ($p<0.05$) heavier in birds fed the diet containing raw soy flake than those of the birds whose diets contained the heat-treated soy flake or commercial SBMs.

In vitro digestibility and PDI: In vitro digestibility values of the SBMs and the heat-treated soy flakes were as shown in Table 5 and Figure1. Raw soy flake showed higher values in all aspects of in vitro digestibility measurements, although the birds fed the diet containing the soy flake performed the worst.

Soy flake heat-treated for 30 minutes showed 92.8% pepsin digestibility, 79.6 % KOH solubility, 21.5% protein dispersibility index (PDI), 0.02 urease activity and 2.41% available lysine. These values appeared to be in the ranges observed from the commercial soybean meals. Most of those values except PDI of the soy flakes heat-treated for 15 or 45 minutes also matched pretty well with those of commercial soybean meals. The PDI values of the soy flakes heat-treated for 15 or 45 minutes were 40.3 and 17.4%, respectively, meanwhile the PDI values of the flake treated for 30 minutes and those of the SBMs were 21.5, 22.2, 20.2 and 17.5%, respectively, in the order as in Table 5.

The measurements such as 0.2% pepsin digestibility, KOH solubility, urease activity and available lysine were not sensitive enough to differentiate protein quality of the soy products compared to PDI value.

Table 4. Measurement of protein quality of heat-treated soy flakes and three soybean meals of various origins in broiler birds[1]

Diets		Feed intake	Body weight gain	Feed/ Gain	PER	NPR	Pancreas weight (Pancreas weight/ Body weight)
		------- g/bird -------					g (%)
N-free		59.2	-5.3	-	-	-	0.15 (0.14)
Soy flake	0 min.	145.3[b]	34.5[e]	4.22[a]	1.83[d]	2.12[d]	0.59[b] (0.20)[x]
	15 min.	180.3[a]	78.5[c]	2.30[c]	3.35[a]	3.58[b]	0.52[b] (0.10)[y]
	30 min.	181.8[a]	86.1[ab]	2.11[d]	3.64[a]	3.87[a]	0.64[ab] (0.08)[y]
	45 min.	180.2[a]	79.9[c]	2.26[cd]	3.42[b]	3.65[b]	0.59[b] (0.10)[y]
	60 min.	181.9[a]	69.8[d]	2.60[b]	2.96[c]	3.19[c]	0.56[b] (0.06)[y]
Soybean Meals	U.S.[2]	190.0[a]	90.9[a]	2.09[d]	3.68[a]	3.90[a]	0.78[a] (0.11)[y]
	Brazil	190.0[a]	82.3[bc]	2.31[c]	3.33[b]	3.55[b]	0.61[b] (0.07)[y]
	India	193.7[a]	83.5[bc]	2.32[c]	3.32[b]	3.53[b]	0.60[b] (0.12)[y]

[1]Values in the same column with different superscripts are significantly different ($p<0.05$).
PER = protein efficiency ratio, NPR = net protein retention
[2]Dehulled soybean meal

Table 5. Comparison in vitro protein quality measurements between soy flakes heat-treated for various time durations and between soybean meals of various origins

Diets		0.02% pepsin digestibility	Nitrogen solubility by KOH	Protein Dispersibility Index	Urease activity	Available lysine
		% protein	% protein	% protein	pH unit	% protein
Soy flake	0 min.	95.5	92.8	65.2	1.52	2.95
	15 min.	92.7	85.8	40.3	0.03	2.48
	30 min.	92.8	79.6	21.5	0.02	2.41
	45 min.	91.5	74.3	17.4	0.03	2.30
	60 min.	92.3	50.6	9.0	0.02	1.98
Soybean meal	U.S.[2]	95.0	80.6	22.2	0.10	2.65
	Brazil	94.2	74.8	20.2	0.03	2.58
	India	93.5	74.3	17.5	0.08	2.43

[1]Values in the same column with different superscripts are significantly different as determined by one-way ANOVA and Duncan's multiple range test ($p<0.05$).
[2]Dehulled soybean meal

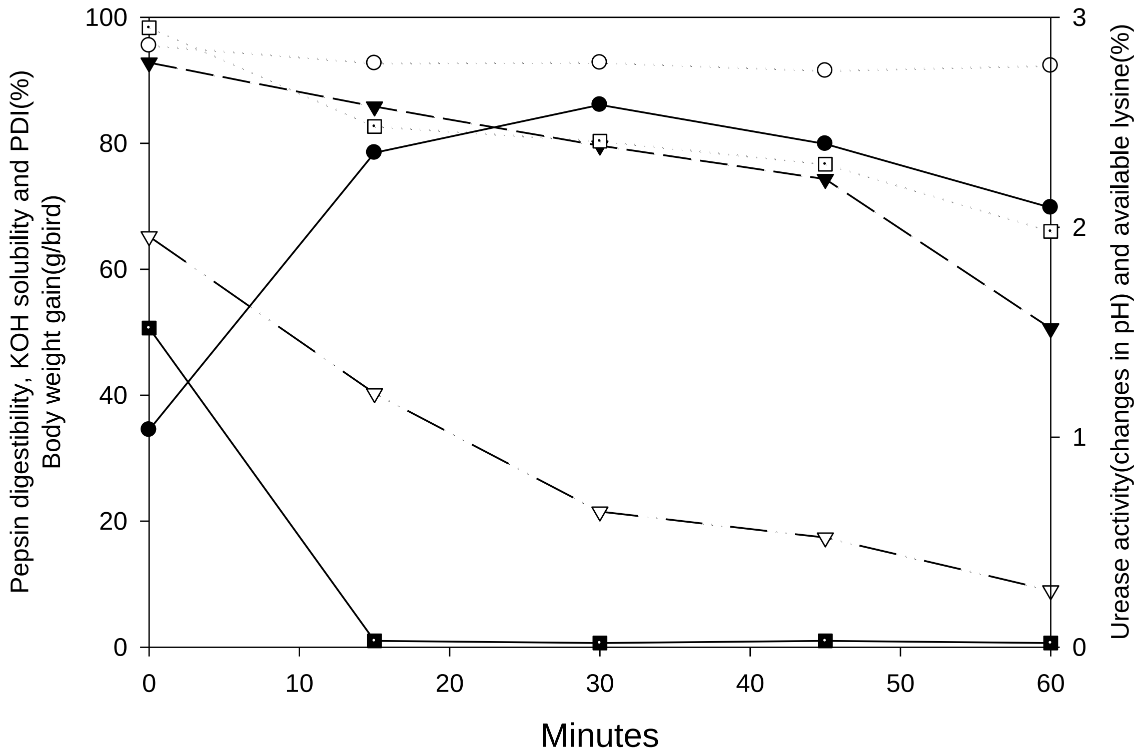

Figure 1. Changes of in vitro digestibility values of soy flakes heat-treated for 0, 15, 30, 45 and 60 minutes at 121 °C and of body weight gain(—●—) of broilers fed diets containing those soy flakes. Digestibility by 0.02% pepsin(○), nitrogen solubility by KOH(—▼—), protein dispersibility index(—▽), urease activity(—■—) and available lysine(⊡) were measured with the soy flakes heat-treated for indicated durations.

Study 3. Metabolic study to measure amino acid bioavailability and energy utilization of heat-treated soy flakes and three soybean meals of various origins

Purpose to estimate the effect of heat treatment on utilization of amino acids and energy efficiency in soy flake; and to compare amino acids bioavailability and energy utilization of SBMs from various origins.

Materials and Methods

- Birds: 132, 3~4-week old, Ross broilers
- Amino acid bioavailability: The birds were surgically operated for artificial anus and cecal ligation. Broilers attached with urethral tubing for separation of urine from feces were also prepared. Fecal samples from the birds were freeze-dried and analyzed for amino acids concentration.
- Measurement of energy utilization: apparent (AME) and true metabolizable energy (TME) values of the samples were measured by method according to Sibbald (1982).
- Test meals: Indian SBM obtained from a local feed mill was used for procedures to

prove validity of urethral tubing to separate urinary components from intestinal contents (Tables 6 and 7). The heat-treated soy flakes and the three SBMs of various origins were estimated for their amino acid availability and energy utilization.

Results of Study 3: Tables 6 and 7 show the results of apparent and true bioavailability measurements, respectively, of a SBM in birds intact or surgically operated to separate urine from feces or to prevent intestinal contents from mixing with cecal materials.

Intact birds showed higher values in overall amino acid bioavailability measurements than the birds surgically treated ($p<0.05$) in Tables 6 and 7. The bioavailability of glycine from birds intact and with cecal ligation were significantly lower than those of the other groups, indicating that urinary contamination occurred in the samples collected.

The apparent or true availability values from birds with cecal ligation plus urethral tubing appeared to be in good agreement with the data from birds colostomized plus cecal ligation in Tables 6 and 7. This observations suggest that urethral tubing was successfully conducted and can replace colostomy, introducing a simpler and more convenient way to collect fecal samples without cecal and urinary contamination.

Measurement of amino acid bioavailability of the soy flakes and the SBMs in birds attached with urethral tubing and cecal ligation:

Soy flakes heat-treated for various durations and the SBMs of various origins were compared in their amino acid availability in broiler birds operated to set up cecal ligation and urethral tubing (Tables 8 and 9).

The trends in amino acid data of the soy flakes and the SBMs appeared the same whether expressed as apparent or true bioavailability. Of the soy flakes, the average true availability values tended to increase from 69.1% for raw to 93.1% for the flake heat-treated for 30 minutes. However, the mean values tended to decline from 93.1 to 83.5% for the flake of which heat-treatment lasted longer than 30 minutes. These tendency in overall amino acid bioavailability appeared similar to those of lysine in the heat-treated soy flakes.

The overall mean true availability values of SBMs were 94.7% for the U.S., 91.0% for Brazil and 91.5% for India. The mean true values were generally higher by 1.4~2.0% than the apparent values (Tables 8 and 9).

Soy flakes heat-treated for various durations and the SBMs of various origins were estimated for their energy utilization in normal broilers (Table 10). Apparent metabolizable energy (AME) and true metabolizable energy (TME) values of the soy flakes appeared to increase from 2.0 to 2.8 for AME and from 2.3 to 3.1 kcal/g for TME, as the duration for heat treatment changes from zero to 30 minutes. The energy values of the flakes treated over 30 minutes tended to be stabilized.

AME value of dehulled SBM was similar to those of the other meals. However, TME of the dehulled meal appeared significantly higher (2.9 vs. 2.7 kcal/g) than that of the Indian meal ($p<0.05$).

Table 6. Apparent amino acid digestibility of soybean meal in chicks intact, with cecal ligation, cecal ligation plus colostomy or cecal ligation plus urethral tubing[1]

Amino acids	Intact	Cecal ligation	Cecal ligation + colostomy	Cecal ligation + urethral tubing
	% air-dry basis			
Asp+ Asn	91.5±0.6	88.9±1.1	89.2±0.6	89.6±1.4
Threonine	88.7±0.8^{a}	84.6±0.8^{b}	84.0±0.4^{b}	84.4±0.4^{b}
Serine	91.8±0.5^{a}	87.2±1.2^{b}	87.8±0.6^{b}	88.0±1.5^{b}
Glu+Gln	93.2±0.6	91.2±0.9	90.9±0.7	91.5±1.3
Glycine	47.1±3.8^{a}	45.8±3.5^{a}	81.6±1.1^{b}	80.8±1.0^{b}
Alanine	81.1±1.0	79.8±1.2	80.5±0.9	80.2±1.2
Valine	87.2±1.2	82.1±1.8	82.8±1.4	81.7±2.7
Isoleucine	88.1±1.2	86.5±1.0	85.4±0.3	86.3±2.1
Leucine	89.9±1.1	87.5±1.0	87.1±0.4	87.5±1.7
Tyrosine	92.8±2.3^{a}	87.1±1.0^{b}	87.4±1.1^{b}	88.0±0.9^{b}
Phenylalanine	93.8±2.0^{a}	88.6±0.9^{b}	87.7±0.4^{b}	87.6±1.7^{b}
Lysine	90.2±0.6	88.1±1.1	89.0±0.4	89.7±1.0
Histidine	90.5±0.7^{a}	85.5±0.9^{b}	86.6±1.0^{b}	87.4±1.0^{b}
Arginine	94.0±0.3^{a}	92.8±0.4^{ab}	92.3±0.4^{b}	93.2±0.5^{ab}
Cystine	85.8±0.9	82.7±1.1	82.8±1.1	82.9±0.8
Methionine	90.1±1.0	88.9±0.3	88.1±1.0	89.2±1.1
Mean	87.2±0.7^{a}	84.2±0.9^{b}	86.4±0.5^{ab}	86.8±1.0^{ab}
Mean without glycine[2]	89.9±0.6^{a}	86.8±0.8^{b}	86.8±0.4^{b}	87.1±1.1^{b}

[1]Values are means±SE. Values in the same row with different superscripts are significantly different as determined by one-way ANOVA and Duncan's multiple range test ($p<0.05$)
[2]Values are mean±SE for the same column values except glycine.

Table 7. True amino acid digestibility of soybean meal in chicks intact, with cecal ligation, cecal ligation plus colostomy or cecal ligation plus urethral tubing[1]

Amino acids	Intact	Cecal ligation	Cecal ligation + colostomy	Cecal ligation + urethral tubing
	% air-dry basis			
Asp+Asn	94.1±0.6	91.3±1.2	92.0±0.5	91.3±1.5
Threonine	93.1±0.9[a]	89.3±0.8[b]	88.9±0.6[b]	87.2±0.4[b]
Serine	94.8±0.6[a]	91.4±1.3[ab]	91.4±0.5[ab]	90.1±1.5[b]
Glu+Gln	95.4±0.6	93.1±1.0	93.5±0.6	93.0±1.3
Glycine	51.8±3.8[a]	52.6±3.4[a]	86.9±0.8[b]	84.2±1.0[b]
Alanine	85.8±0.8	83.6±1.2	84.8±0.7	83.1±1.1
Valine	91.4±1.2	86.2±1.9	87.2±1.1	85.5±2.7
Isoleucine	91.7±1.1	89.7±1.1	89.6±0.4	88.7±2.1
Leucine	93.0±1.1	90.2±1.0	90.5±0.6	89.3±1.7
Tyrosine	95.6±1.4[a]	91.0±1.1[b]	92.0±1.6[ab]	91.7±0.9[b]
Phenylalanine	95.8±1.4[a]	90.9±1.0[b]	90.5±0.5[b]	89.7±1.7[b]
Lysine	92.9±0.6	90.5±1.2	91.6±0.3	91.7±1.0
Histidine	94.2±0.7[a]	89.2±1.0[b]	90.8±1.4[b]	90.4±1.0[b]
Arginine	95.6±0.3[a]	94.4±0.4[ab]	93.8±0.3[b]	94.1±0.5[b]
Cystine	92.1±0.7[a]	89.7±1.1[ab]	90.9±0.9[a]	88.1±0.8[b]
Methionine	94.2±0.9	91.7±0.4	91.9±1.4	92.1±1.1
Mean	90.7±0.7[a]	87.8±0.9[b]	90.4±0.5[ab]	89.4±1.1[ab]
Mean without glycine[2]	93.3±0.6[a]	90.2±0.9[b]	90.6±0.5[b]	89.7±1.1[b]

[1]Values are means±SE. Values in the same row with different superscripts are significantly different as determined by one-way ANOVA and Duncan's multiple range test ($p<0.05$)

[2]Values are mean±SE for the same column values except glycine.

Table 8. Apparent amino acid digestibility of soy flakes heat-treated for various durations and soybean meals of various origins in chicks with cecal ligation and urethral tubing[1]

Amino acids	Soy flake, duration of heat treatment					.Soybean meal		
	0 min.	15 min.	30 min.	45 min.	60 min.	U.S.[2]	Brazil	India
	% air-dry basis							
Asp+Asn	71.8 ± 1.5^{e}	90.2 ± 0.8^{bc}	92.1 ± 0.6^{ab}	87.6 ± 0.7^{c}	79.9 ± 1.0^{d}	94.3 ± 1.2^{a}	91.0 ± 0.5^{ab}	91.0 ± 1.5^{ab}
Threonine	64.3 ± 1.0^{d}	85.5 ± 1.2^{b}	88.2 ± 0.6^{b}	88.0 ± 0.9^{b}	81.6 ± 0.3^{c}	92.0 ± 1.4^{a}	88.1 ± 0.6^{b}	86.6 ± 0.4^{b}
Serine	70.6 ± 1.4^{d}	88.5 ± 1.1^{b}	91.0 ± 0.5^{ab}	90.3 ± 0.9^{ab}	79.9 ± 0.7^{c}	93.5 ± 1.2^{a}	90.1 ± 0.2^{ab}	89.6 ± 1.6^{ab}
Glu+Gln	79.4 ± 0.9^{e}	92.8 ± 0.5^{bc}	90.7 ± 0.4^{c}	92.0 ± 0.5^{bc}	84.9 ± 0.3^{d}	95.4 ± 0.8^{a}	91.4 ± 0.5^{bc}	92.9 ± 1.4^{ab}
Glycine	66.8 ± 1.2^{e}	83.0 ± 0.8^{bc}	86.5 ± 0.5^{a}	82.0 ± 0.9^{c}	73.0 ± 0.4^{d}	85.3 ± 1.0^{ab}	81.8 ± 0.6^{c}	81.6 ± 0.8^{bc}
Alanine	57.4 ± 1.3^{e}	83.1 ± 1.4^{bc}	86.7 ± 0.5^{b}	83.3 ± 1.1^{bc}	75.4 ± 0.8^{d}	90.7 ± 1.6^{a}	85.4 ± 1.5^{bc}	82.3 ± 1.4^{c}
Valine	60.0 ± 1.2^{e}	88.0 ± 1.0^{abc}	89.6 ± 0.5^{ab}	87.1 ± 1.1^{abc}	79.3 ± 1.0^{d}	91.4 ± 1.2^{a}	86.2 ± 1.2^{bc}	82.9 ± 3.1^{c}
Isoleucine	63.1 ± 1.2^{e}	90.4 ± 1.0^{abc}	92.6 ± 0.3^{ab}	89.2 ± 1.1^{bc}	83.5 ± 1.0^{d}	93.5 ± 1.0^{a}	89.2 ± 0.7^{bc}	87.7 ± 2.5^{c}
Leucine	65.0 ± 1.5^{d}	90.7 ± 1.2^{ab}	92.5 ± 0.4^{ab}	89.4 ± 1.1^{b}	84.2 ± 1.2^{c}	93.7 ± 1.1^{a}	90.3 ± 0.4^{ab}	89.0 ± 2.0^{b}
Tyrosine	66.3 ± 1.6^{d}	92.4 ± 1.3^{ab}	94.6 ± 0.5^{a}	94.5 ± 1.0^{a}	84.8 ± 0.7^{c}	94.9 ± 1.0^{a}	92.6 ± 0.8^{ab}	89.8 ± 1.1^{b}
Phenylalanine	67.3 ± 1.6^{e}	92.2 ± 1.0^{abc}	93.6 ± 0.3^{ab}	91.0 ± 1.1^{bc}	86.5 ± 1.1^{d}	95.4 ± 0.8^{a}	91.5 ± 0.5^{bc}	89.1 ± 2.0^{cd}
Lysine	73.7 ± 1.1^{d}	92.2 ± 1.0^{ab}	92.8 ± 0.6^{ab}	90.9 ± 0.8^{b}	81.6 ± 0.4^{c}	94.8 ± 1.2^{a}	91.0 ± 0.7^{b}	91.6 ± 1.1^{b}
Histidine	71.7 ± 1.1^{e}	88.9 ± 1.0^{c}	92.8 ± 0.6^{a}	92.8 ± 0.8^{a}	80.6 ± 0.6^{d}	94.9 ± 1.5^{a}	92.0 ± 1.0^{ab}	90.0 ± 1.0^{bc}
Arginine	80.2 ± 1.3^{c}	95.6 ± 0.5^{a}	95.1 ± 0.4^{a}	95.0 ± 0.7^{a}	88.2 ± 0.4^{b}	96.2 ± 1.3^{a}	93.8 ± 0.3^{a}	95.3 ± 0.6^{a}
Cystine	56.1 ± 1.1^{d}	84.3 ± 1.4^{ab}	87.0 ± 1.2^{a}	82.4 ± 0.7^{bc}	80.4 ± 1.7^{c}	87.2 ± 0.7^{a}	83.7 ± 1.1^{abc}	84.8 ± 0.9^{ab}
Methionine	62.8 ± 1.0^{f}	88.9 ± 1.2^{cd}	92.1 ± 0.7^{ab}	89.2 ± 1.1^{bcd}	81.6 ± 1.0^{e}	94.1 ± 0.4^{a}	86.7 ± 1.4^{d}	91.0 ± 1.0^{abc}
Average	67.3 ± 1.0^{d}	89.2 ± 1.0^{b}	91.1 ± 0.5^{ab}	89.1 ± 0.8^{b}	81.6 ± 0.3^{c}	93.0 ± 1.0^{a}	89.1 ± 0.5^{b}	88.5 ± 1.1^{b}

[1]Values are means±SE. Values in the same row with different superscripts are significantly different ($p<0.05$)

[2]Dehulled soybean meal

Table 9. True amino acid digestibility of soy flakes heat-treated for various durations and soybean meals of various origins in chicks with cecal ligation and urethral tubing[1]

Amino acids	Soy flakes, duration of heat treatment					.Soybean meal		
	0 min.	15 min.	30 min.	45 min.	60 min.	U.S.[2]	Brazil	India
	% air-dry basis							
Asp+Asn	73.0±1.5[e]	91.3±0.8[bc]	93.4±0.6[ab]	89.0±0.6[c]	81.1±0.9[d]	95.4±1.2[a]	92.2±0.4[abc]	93.4±1.5[ab]
Threonine	66.2±1.0[e]	87.4±1.2[c]	90.3±0.6[b]	90.1±0.8[bc]	84.6±0.2[d]	93.8±1.4[a]	90.1±0.6[bc]	89.3±0.4[bc]
Serine	72.2±1.3[d]	90.2±1.1[b]	92.8±0.5[ab]	92.2±0.8[ab]	81.6±0.7[c]	95.0±1.2[a]	91.7±0.2[ab]	92.2±1.5[ab]
Glu+Gln	80.3±0.8[e]	93.7±0.6[bc]	91.8±0.4[c]	93.1±0.4[bc]	85.9±0.3[d]	96.4±0.7[a]	92.5±0.5[c]	95.1±1.3[ab]
Glycine	69.0±1.2[e]	85.3±0.9[bc]	89.0±0.4[a]	84.7±0.8[c]	75.3±0.4[d]	87.6±1.0[ab]	84.3±0.5[c]	86.3±1.0[bc]
Alanine	59.4±1.3[e]	85.1±1.4[c]	89.0±0.5[b]	85.7±1.0[bc]	77.4±0.9[d]	92.7±1.5[a]	87.5±1.5[bc]	85.2±1.1[c]
Valine	62.2±1.1[d]	90.2±1.1[ab]	92.0±0.5[ab]	89.6±1.0[ab]	81.6±1.0[c]	93.8±1.1[a]	88.9±1.1[b]	87.6±2.7[b]
Isoleucine	64.4±1.1[d]	91.8±1.1[ab]	94.1±0.3[ab]	90.8±1.0[b]	84.9±1.0[c]	95.0±1.0[a]	90.9±0.6[b]	90.8±2.1[b]
Leucine	66.1±1.5[d]	91.9±1.2[ab]	93.9±0.3[ab]	90.8±1.0[b]	85.4±1.1[c]	94.9±1.1[a]	91.5±0.5[ab]	91.4±1.7[ab]
Tyrosine	68.7±1.5[d]	94.8±1.4[ab]	97.2±0.4[a]	97.3±0.9[a]	87.3±0.7[c]	97.5±0.9[a]	95.3±0.7[ab]	93.8±0.9[b]
Phenylalanine	68.7±1.5[d]	93.6±1.0[ab]	95.1±0.2[ab]	92.6±1.0[b]	87.9±1.2[c]	96.8±0.8[a]	93.0±0.5[b]	91.8±1.7[b]
Lysine	75.0±1.0[d]	93.6±0.9[ab]	94.3±0.5[ab]	92.5±0.7[b]	83.0±0.4[c]	96.1±1.1[a]	92.5±0.7[b]	93.8±1.0[ab]
Histidine	74.1±1.1[e]	91.4±1.1[c]	95.5±0.5[a]	95.6±0.7[a]	83.1±0.6[d]	97.1±1.4[a]	94.4±0.9[ab]	92.5±1.0[bc]
Arginine	80.8±1.3[c]	96.2±0.5[a]	95.8±0.4[a]	95.7±0.7[a]	88.8±0.4[b]	96.8±1.2[a]	94.4±0.3[a]	96.2±0.5[a]
Cystine	59.8±1.0[e]	88.1±1.5[abc]	91.2±1.0[a]	86.8±0.6[cd]	84.3±1.7[d]	90.6±0.6[ab]	87.5±0.9[bcd]	90.2±0.8[abc]
Methionine	65.2±1.0[f]	91.4±1.3[cd]	94.9±0.5[ab]	92.1±1.0[bc]	84.2±1.0[e]	96.0±0.4[a]	88.9±1.4[d]	94.2±1.1[abc]
Average[2]	69.1±1.0[d]	91.0±1.0[b]	93.1±0.4[ab]	91.1±0.7[b]	83.5±0.3[c]	94.7±1.0[a]	91.0±0.4[b]	91.5±1.1[b]

[1]Values are means±SE. Values in the same row with different superscripts are significantly different ($p<0.05$).

[2]Dehulled soybean meal

Table 10. Energy values of soy flakes heat-treated for various durations and soybean meals of various origins measured in broiler

Ingredients		AME[1]	TME[1]	GE
		----------------	kcal/g -------------------	
Soy flake	0 min.	2.0 ± 0.02^{d}	2.3 ± 0.04^{d}	4.24
	15 min.	2.6 ± 0.03^{abc}	2.9 ± 0.02^{ab}	
	30 min.	2.8 ± 0.06^{a}	3.1 ± 0.06^{a}	
	45 min.	2.7 ± 0.06^{ab}	3.0 ± 0.07^{ab}	
	60 min.	2.7 ± 0.08^{a}	3.0 ± 0.06^{a}	
Soybean meal	U.S.[2]	2.6 ± 0.05^{abc}	2.9 ± 0.07^{ab}	4.18
	Brazil	2.5 ± 0.07^{bc}	2.8 ± 0.05^{bc}	4.10
	India	2.4 ± 0.11^{c}	2.7 ± 0.10^{c}	3.97

[1]All values are means±SE of 6 birds. Values in the same column with different superscripts are significantly different as determined by one-way ANOVA and Duncan's multiple range test ($p<0.05$).
[2]Dehulled soybean meal

Study 4. Farm level feeding trials to compare feeding values of three soybean meals of various origins

Purpose is to compare feeding value of SBMs of various origins in broilers and to compare economical aspects in broiler production between the various SBMs.

Materials and Methods

- Birds: 720, day-old, Ross, males and females (1:1)
- Three SBM groups x four replications x 60 birds/replication
- The birds were fed starter diets for 21 days and grower diets for 14 days. This feeding trial was repeated two times with exactly the same experimental designs including feed formulations and breeds of birds at the same test farm.
- Feed formulations: Nutrient contents of the test diets were adjusted to match to local standards which were basically modified from NRC (1994) feeding standard for poultry (Tables 11 and 12).
- SBMs from various sources in the test diets were formulated to provide same proportion of the crude protein (54%) of total dietary protein levels (21.0%). Consequently, the levels of the meals added to the diets were 24.0, 25.52 and 25.8% for U.S. dehulled, Brazilian and Indian SBM, respectively, depending on

their protein contents.

- Levels of the limiting amino acids in the diets were set to satisfy the required amount of the amino acids based on NRC requirement calculated per M.E. basis. Thus, the requirement levels of total sulfur-containing amino acid and lysine were 0.88 and 1.07%, respectively, in the experimental diets whose M.E. contents were 3100 kcal/kg. All test diets were in mash form

Table 11. Formulation of experimental diets

Ingredients	Starter diets			Grower diets		
	U.S.[2]	Brazil	India	U.S.[2]	Brazil	India
	%					
Corn, yellow	59.6	56.38	56.01	56.49	55.2	54.85
Wheat	2.0	2.0	2.0	8.0	8.0	8.0
Soybean meal	24.0	25.52	25.8	24.0	25.53	25.8
Corn gluten	6.2	6.37	6.38	2.62	3.09	3.10
Rapeseed meal	1.0	1.3	1.3	-	-	-
Soybean oil	2.32	3.56	3.62	2.76	3.53	3.58
Wheat bran	1.0	1.0	1.0	3.0	1.5	1.5
Di-Ca phosphate	1.2	1.2	1.2	0.7	0.7	0.7
Limestone	1.7	1.67	1.67	1.7	1.7	1.7
NaCl	0.3	0.3	0.3	0.3	0.3	0.3
DL-Methionine (99%)	0.13	0.14	0.14	0.04	0.05	0.05
L-Lysine HCl	0.09	0.10	0.12	0.03	0.04	0.06
Miscellaneous[1]	0.46	0.46	0.46	0.36	0.36	0.36
Total	100.0	100.0	100.0	100.0	100.0	100.0
Nutrients, calculated						
AMEn, kcal/kg	3100			3100		
Crude protein, %	21.0			19.0		
TSAA, %	0.88			0.71		
Lysine, %	1.07			0.97		

[1]Miscellaneous contains vitamin mixture 0.05%, mineral mixture 0.10%, choline-chloride 0.10%, antibiotics 0.20% and antimicrobial 0.01%.

[2] Dehulled soybean meal

Economic analysis of the feeding values of the three SBMs showed return over kg bird in each dietary group containing each of the three sources of SBM was calculated to compare economic aspects from the feeding trials. Costs of the SBMs applied for this study based on average prices for their imports during year 2002 by applying an exchange ratio of 1250 won to 1 U.S. dollar were 263.12, 251.0 and 249.38 won/kg for the U.S., Brazilian and Indian meals, respectively. Feed costs were calculated to be 229.39, 234.22 and 234.83 won/kg for starter diets, and 209.76, 213.83 and 214.40 for grower diets containing the SBMs from the U.S., Brazil and India, respectively.

Day-old broiler cost was 414.8 won/bird, an average from January to November, 2002. Average broiler selling prices from January to November, 2002 was 1,112.5 won/kg live weight.

Table 12. Chemical compositions of experimental diets

	Starter diets			Grower diets		
Compositions	U.S.[1]	Brazil	India	U.S.[1]	Brazil	India
	% air-dry basis					
Moisture	12.6	12.6	12.3	12.6	12.5	12.1
Crude protein	21.5	20.8	20.8	19.7	18.6	19.7
Crude fat	5.2	6.5	6.6	5.4	6.0	6.4
Crude fiber	5.4	5.5	5.9	3.2	3.7	3.3
Crude ash	3.1	3.4	3.8	5.0	5.2	5.6
Calcium	1.11	1.10	1.34	0.96	0.99	1.05
Phosphorus	061	0.59	0.59	0.52	0.50	0.49

[1] Dehulled soybean meal

Results of Study 4 indicated that birds fed the diet containing U.S dehulled SBM during the starter period were better in body weight gain and feed/gain ratio (1.55 vs. 1.68 and 1.70) compared to those of the other SBM groups with a significance at $p<0.05$ (Table 13). This trend continued through the whole feeding period with significantly better feed/gain ratios for the birds fed the dehulled SBM diet.

Broilers fed the dehulled soybean meal in Trial 2 performed consistently better in weight gain and feed conversion with a significance at $p<0.05$ compared to those of the other groups (Table 15). Performances of the birds fed diets containing SBMs from Brazil and India appeared fairly similar between the two groups in both trials.

This observation provides a significant implication in terms of feeding values of the SBMs of which origins are different. Since chemical contents of limiting amino acids such as methionine+cystine and lysine, and levels of metabolizable energy in the three diets were set equal, the differences in performances could only be resulted from differences in biological availability of proteins and energy utilization of the meals.

Results of economic analyses based on return over kg bird weight in Trials 1 and 2 are as shown in Tables 14 and 16, respectively. Feed cost of the diet containing the dehulled SBM appeared lower per kg basis compared to those of the others (average 5.14 and 4.35 won/kg for starter and grower, respectively) because inclusion % of the dehulled meal in the test diet was lower due to its higher protein content (Table 11).
This lower feed cost added up the broiler income per bird for the dietary group containing dehulled SBM, resulting in over 75 won in income/bird. Final income as % of return per kg bird of the dehulled SBM group was higher by about 15% over the other two SBM groups in Trial 1. The % of return per kg bird of Brazilian SBM group was higher by 3% compared to that of Indian group (Table 14).

Results in economic analyses in Trial 2 appeared to follow exactly the same pattern as in Trial 1 (Table 16). Birds fed the dehulled SBM from the U.S. showed better income as % of return per kg bird by an average of 13.7% over those fed the other SBMs.

Table 13. Performances of broilers fed diets containing soybean meals of various origins (Trial 1)

Treatments	Feed intake	Body weight		Body weight gain	Feed/Gain ratio
		Initial	Final		
Starter	-------------------------	g/bird	-------------------------		
U.S.[1]	1102.7± 23.5	41.9 ± 0.5	754.3 ± 17.3[a]	712.4 ± 17.1[a]	1.55 ± 0.04[a]
Brazil	1102.5± 43.7	41.1 ± 0.2	697.9 ± 17.2[b]	656.8 ± 17.3[b]	1.68 ± 0.09[b]
India	1113.6± 42.8	41.3 ± 0.3	696.6 ± 16.2[b]	655.2 ± 16.3[b]	1.70 ± 0.08[b]
Grower					
U.S.[1]	979.7 ± 31.1[a]	754.3 ± 17.3[a]	1241.3± 42.0	499.6 ± 20.1	1.96 ± 0.11[a]
Brazil	997.5 ± 34.3[ab]	697.9 ± 17.2[b]	1170.8± 47.9	472.9 ± 47.3	2.12 ± 0.18[ab]
India	1045.1± 46.3[b]	696.6 ± 16.2[b]	1171.3± 71.9	474.7 ± 63.8	2.21 ± 0.18[b]
Overall					

U.S.[1]	2086.7± 58.0	41.9 ± 0.5	1241.3± 42.0	1199.3± 42.2	1.74 ± 0.11[a]
Brazil	2100.0± 59.9	41.1 ± 0.2	1170.8± 47.9	1129.8± 47.8	1.86 ± 0.11[b]
India	2158.8± 65.6	41.3 ± 0.3	1171.3± 71.9	1129.9± 71.8	1.91 ± 0.10[b]

[1] Dehulled soybean meal

Table 14. Return over feed cost of broilers fed diets containing soybean meals of various origins (Trial 1)

Diets	Origins of SBM		
	U.S.[1]	Brazil	India
	Feed cost, won/kg		
Starter diet	229.39	234.22	234.83
Grower diet	209.76	213.83	214.40
	Return over production cost, won		
Feed cost/bird	459.43	471.52	485.59
Feed cost/kg bird	370.43	403.40	415.43
(Feed + bird) cost/bird	874.23	886.32	900.39
Broiler income/bird	1380.93	1302.55	1303.02
Return over (F+B)/bird	506.70	416.23	402.63
Return/kg bird	407.65	354.40	341.94
% of Return/kg bird	100.0	86.9	83.9

[1] Dehulled soybean meal

Table 15. Performances of broilers fed diets containing soybean meals of various origins (Trial 2)

Treatments	Feed intake	Body weight		Body weight gain	Feed/Gain ratio
		Initial	Final		
Starter	---------------------------	g/bird	--------------------------		
U.S.[1]	954.6 ± 31.4	42.0 ± 0.6	678.6 ± 17.2[a]	636.6 ± 17.1[a]	1.50 ± 0.07[a]
Brazil	989.9 ± 6.3	41.7 ± 0.8	666.9 ± 12.2[a]	625.2 ± 11.5[ab]	1.58 ± 0.03[ab]
India	977.3 ± 14.4	42.1 ± 0.3	642.8 ± 15.0[b]	600.7 ± 14.8[b]	1.63 ± 0.06[b]
Grower					
U.S.[1]	1173.8± 29.7	678.6 ± 17.2[a]	1275.9± 33.7[a]	597.3 ± 30.7[a]	1.97 ± 0.10[a]
Brazil	1186.7± 78.0	666.9 ± 12.2[a]	1217.4± 25.9[b]	550.5 ± 22.9[b]	2.16 ± 0.13[b]
India	1151.7± 32.3	642.8 ± 15.0[b]	1209.7± 30.0[b]	566.9 ± 25.1[ab]	2.10 ± 0.08[ab]
Overall					
U.S.[1]	2128.5± 55.0	41.9 ± 0.5	1275.9± 33.7	1233.9± 33.2[a]	1.73 ± 0.07[a]
India	2167.8± 30.0	41.3 ± 0.3	1209.7± 30.0	1167.6± 29.9[b]	1.86 ± 0.04[b]
Brazil	2176.7± 74.3	41.1 ± 0.2	1217.4± 25.9	1175.7± 25.5[b]	1.85 ± 0.06[b]

[1] Dehulled soybean meal

Table 16. Return over feed cost of broilers fed diets containing soybean meals of various origins (Trial 2)

Diets	Origins of SBM		
	U.S.[1]	Brazil	India
	Feed cost, won/kg		
Starter diet	229.39	234.22	234.83
Grower diet	209.76	213.83	214.40
	Return over production cost, won		
Feed cost/bird	465.20	485.62	484.74
Feed cost/kg bird	377.26	413.10	415.32
(Feed + bird) cost/bird	880.00	900.42	899.54
Broiler income/bird	1372.72	1307.97	1298.93
Return over(F+B)/bird	492.71	407.54	399.39
Return/kg bird	398.89	346.46	341.75

% of Return/kg bird	100.0	86.9	85.7

[1] Dehulled soybean meal

Conclusion

1. Protein dispersibility index (PDI) appeared as the better and more sensitive indicator to test the effect of heat treatment on feeding values of soy flake. Heating soy flake for 30 minutes at 121^{o}C produced better scores in protein quality such as PER and NPU in young birds compared to the flakes heated under or over 30 minutes.

2. Feeding values of dehulled SBM from the U.S. were evaluated together with non-dehulled SBMs from Brazil and India by various means, in vitro and in vivo including farm level feeding trials. The dehulled meal was higher in protein content, better in protein efficiency ratio (PER) and net protein retention (NPR) scores, higher in amino acid bioavailability and in energy utilization (AME and TME) compared to the other SBMs. No differences in feeding values between the meals from Brazil and India were observed.

3. Two farm-feeding trials also showed repeatedly that broilers fed the dehulled SBM diets tended to grow faster with better feed efficiency than the birds fed the diets containing the other sources of SBMs. This result suggests an important implication in terms of feeding values of the dehulled SBM from the U.S. Since chemical compositions of the three experimental diets including limiting amino acids and energy levels were set equal, the differences in performances could only be associated with the differences in biological availability of nutrients such as amino acids and energy of the meals.

4. Birds fed the dehulled SBM resulted in a higher income as % of return per kg bird by about 13-16% over the groups fed the other SBM diets in both trials. The advantages in economical aspects from feeding the dehulled SBM diets could be due to better performances of the birds and lower feed cost resulting from higher protein content of the meal.

Literatures cited:

AOAC. 1990. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists, Inc., Arlington, VA.

AOCS. 1975. American Oil Chemists' Society, Official and Tentative Methods. BA 10-65.

Bender AE, Doell BH. 1957. Biological evaluation of protein: a new aspect. British J of Nutrition 11:140-148.

Carpenter KJ, Booth VH. 1973. Damage to lysine in food processing: its measurement and its significance. Nutritional Abstracts Review 43:324-451.

Caskey CD, Knapp FC, 1944. Method for detecting inadequately heated soybean oil meal. Industrial Engineering Chemistry 16:641-642.

Dale NM, Araba M. 1987. Protein solubility as an indicator of over-processing of soybean meal. Poultry Science 66 (Suppl. 1): 10.

National Research Council. 1994. Nutrient Requirement of Poultry. 9th ed. National Academy of Sciences, Washington D.C.

Poppema TF, Duke GE. 1992. The effectiveness of ligating or detaching ceca: an alternative to cecectomy. Poultry Science 71:1384-1390.

Sibbald IR. 1982. Measurement of bioavailable energy in poultry feeding stuffs. Canadian J Animal Science 62:983-1048.