Soybean Checkoff-funded Research

Project Title: Evaluation of Nutritive Values of Soybean Meal from Different Geographic Origins As a Broiler Feedstuff

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Summary:
This study was carried out to investigate the nutritional values of soybean meals (SBM) from various geographic origins and the effects of their dietary supplementations on performance of broiler chicken. Nutritional values of dehulled SBM originated from USA, and non-dehulled SBM from India (IND) and Argentina (ARG) were evaluated by analyzing chemical composition, urease activity(UA) and KOH solubility and determining true metabolizable energy (TME), nitrogen corrected TME (TMEn) and true amino acid availability (TAAA). The contents of crude protein ranged from 45.43% (ARG) to 48.47% (USA) and those of crude fiber varied widely from 3.48% (USA) to 7.12% (IND). The measurements of lysine were from 2.79% (IND) to 3.09% (USA) and those of methionine from 0.56% (IND) to 0.65% (USA). The values of TMEn varied from 2986.6 kcal/kg (IND) to 3228.9 kcal/kg (USA) and the averages of TAAA were from 91.61% (IND) to 92.27% (USA). UA were found to be from 0.02 (ARG) to 0.04 (USA) and those of KOH solubility from 73% (ARG) to 84% (USA). A total of three hundred 20-d-old male broiler chicks were divided into three groups and fed isocaloric and isonitrogenous experimental diets containing 27.5% of SBM each and same amounts of lysine and sulfur amino acids for 15 days. Final body weight and body weight gain were highest in USA and lowest in IND although the differences were not significant statistically. The feed/gain in chicks fed diet containing USA SBM was significantly improved ($p<0.05$) compared to those of the other groups. There were no significant differences in carcass characteristics and blood profiles among the treatments. The results of *in vitro* assay and bioassay agreed with performance of broiler chicks, and thus there were close correlation among the broiler performance, and the measured nutritive values of SBM. Economical analysis revealed that USA SBM was highest in price. However, the cost per kg live weght gain was lowest with USA (488 ₩/kg live WT) compared to ₩ 504 of ARG and ₩ 505 of IND. In conclusion, dehulled SBM from USA was superior to non-dehulled SBM from ARG and IND with regard to not only nutritive value but also economical efficiency.

Introduction:
Soybean meal (SBM) is produced by extracting oil from soybean and become one of the most valuable feed ingredients as plant protein source for livestock because the price of SBM is lower and the contents of protein is higher than those of other protein ingredients (Aburto et al., 1998a; Batal and Parsons, 2003). SBM is higher in amino acid content and well balanced in its profile compared to other oil meals. The lysine content of SBM is relatively high but methionine and cystine contents are relatively low compared to those found in other plant meals (Eggum and Beams, 1983; McNaughton et al., 1981).

Most of feedmillers analyze only proximate chemical composition (moisture, crude protein, crude fat, crude fiber, crude ash), calcium and phosphorus for the formulation of mixed feeds. They use book values of mainly ARC and NRC for contents of energy and amino acids regardless of ingredient quality. It may give rise to erroneous formulation in terms of nutritional quality because those book values do not reflect high variation in nutritional quality and economic returns of feedstuffs. For example, pepsin digestibility measurements of 9 samples of local fishmeal in Korea revealed high variation ranging from 35.4% to 65.8% (Kang, 1993) indicating availability of amino acids varied widely. Nutritional quality of SBMs used in Korea also varied widely (Joo et al. 1994).

Even though various vegetable protein meals contain similar chemical compositions, their values for ME (metabolizable energy) and/or amino acid availability can be quite different. Therefore, mixed feeds better be formulated based on ME and amino acid availability rather than proximate analysis of the vegetable protein meals. However, it is difficult to get ME and/or amino acid availability prior to formulating feeds because determination of ME and amino acid availability for every shipment of vegetable protein meals are time-consuming and expensive.

SBM as like as most of the plant protein sources contains anti-nutritional factors (ANF) such as trypsin inhibitor and saponins may exert unfavorable influences on feed quality, especially for non-ruminant animals. However, most of them are easily destroyed by heat tretment and thus SBM must be heat processed in order to be of satisfactory nutritional quality for use in poultry feed. While a certain amount of heat is necessary to deactivate ANF, overheating of SBM may be detrimental to its nutritional value due to the Maillard reaction (Whittle and Araba, 1992).

Since SBM needs to be properly heat-treated, some criteria are needed to assess degree of heat treatment. Araba and Dale (1990a) used 0.2% KOH solution for determination of protein solubility and found high correlation between protein solubility and growth of chickens (Araba and dale, 1990b; Joo et al., 1994). Useful methods for determining quality of underheated SBM involve determination of urease and trypsin inhibitor activities (Wright, 1981). The method of Caskey and Knapp (1944) is most widely used for determination of urease activity.

Various methods have been proposed to determine metabolization energy (ME) of poultry feedstuffs. Currently two methods are in use widely for the rapid biological determination of ME of feedstuffs for poultry. They are apparent metabolizable energy (AME) (Farrell, 1978) and true metabolizable energy (TME) (Sibbald, 1979). Results from the both methods are comparable with those from conventional methods and known to be equally accurate (Farrell, 1981).

The efficient evaluation of feed ingredients is important in order to provide the accurate amount of necessary nutrients and to predict performance of livestock (Kang, 1993). The nutritional qualities of SBM differ mainly due to differences in genetic varieties, environmental factors and processing conditions. It is important to evaluate variations in SBM quality occur among geographic regions. The purpose of this study was to compare the nutritional quality of SBM from USA and other leading SBM producing countries by *in vitro* assay, bioassay and subsequent feeding trial. Based on these results, economical efficiency of SBMs from different origin was also evaluated.

Materials and methods

Analytical and availability evaluation of SBMs

SBM samples used in this study were non-dehulled (ARG, IND) and dehulled (USA) ones. SBM from different geographic origins were first analyzed for DM, CP, ether extract, and crude fiber by the methods outlined by the AOAC(2000). The amino acid contents of SBMs from different origins were determined by amino acid analyzer (Amino Acid Analyzer 430, SYKAM GmbH, Germany). True metabolizable energy (TME) and nitrogen corrected true metabolizable energy (TMEn) were assessed, by using Hy-Line Variety Brown roosters according to the force-feeding method as described by Sibbald (1979) with some modifications. Following a 24-h of feed withdrawn, fifteen roosters were given 30 g of SBMs from different origins via crop intubation. Five additional roosters were deprived of feed for 24-h period following the initial 24-h period which were served as a control to correct for metabolic fecal and endogenous urinary losses. All the excreta were collected for 24-h, and dried, lyophilized for determine gross energy by the adiabatic oxygen bomb calorimeter (PARR 1261, PARR Instruments Co., Moline, IL 65265).

The amino acid digestibility was measured using the same procedures as for TMEn assay. The TAAA values were determined and corrected for metabolic fecal and endogenous urinary amino acids, as described by Likuski and Dorrell (1978). This method is relatively rapid and less expensive than other procedures, and thus suited to the practical need for evaluation of feedstuffs in terms of amino acid availability.

Urease activity (UA) was measured by the phenol red indicator method proposed by Caskey et al. (1944), and KOH solubility according to the method proposed by Dale and Araba (1987).

Feeding trial

Twenty-day old Ross male broiler chicks were randomly placed in four replicate pens with 25 birds each per treatment (total of 300 birds) in a floor chicken house. The birds fed one of following three diets containing SBMs from ARG, IND and USA for 15 days. The chicks were raised in a temperature controlled windowless house under continuous lighting. The test diets containing SBMs from different geographic origins were formulated to be equal in the contents of CP (20.00 %), TMEn (3,150 kcal/kg), lysine (1.00 %) and sulfur containing amino acids (0.72 %). The nutrient specifications of the formula were met or exceeded the minimum requirement of NRC (1994). All the chicks were provided free access to feed and water. Feed intake and body weight of each group were recorded weekly.

At the end of experimental period, 10 chicks from each group were randomly selected. Their blood were drawn from wing veins using sterilized syringed for determination of the variously blood profiles. The concentration of total cholesterol was measured according to the colorimetric method using cholesterol diagnostic kit (Total cholesterol kit, Asan Pharmaceutical). The activity of glutamic-oxaloacetic transaminase (GOT) and glutamic-pyruvic transaminase (GPT) were also estimated according to the colorimetric method GOT-GPT assay kit (GOT-GPT assay kit, Asan Pharmaceutical), following the manufacturer's direction.

The main effects between treated groups were subjected to ANOVA using the GLM procedure of SAS (2002), and significant differences were determined using Duncan's multiple range test at the level of $p<0.05$ (Duncan, 1955).

Table 1. Formula and chemical composition of the experimental diets

Ingredients (%)	ARG	IND	USA
Soybean meal[1)]	27.50	27.50	27.50
Corn	52.74	52.82	53.78
Wheat	10.00	10.00	10.00
Corn gluten meal	3.27	2.93	2.51
Tallow	2.89	3.19	2.71
Dicalcium phosphate	1.42	1.42	1.42
Limestone	1.25	1.25	1.25
Choline-chloride (50%)	0.02	0.02	0.02
Salt	0.29	0.29	0.29
Mineral mix[2)]	0.15	0.15	0.15
Vitamin mix[3)]	0.11	0.11	0.11
Lysine (25%)	0.19	0.15	0.09
Alimet (88%)	0.02	0.02	0.02
Antibiotics	0.10	0.10	0.10
Anticoccidials	0.05	0.05	0.05
Total	100.00	100.00	100.00

Calculated value of basal diet	
Crude protein, %	20.00
Ca, %	0.90
Available P, %	0.35
Lysine, %	1.00
Met+Cys, %	0.72
TMEn, kcal/kg	3,150

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Mineral mixture provided following nutrients per kg of diet: Fe, 96mg; Zn, 120mg; Mn, 144mg; Cu, 10mg; I, 2mg; Se, 0.36mg; Co, 0.48mg.
[3)] Vitamin mixture provided following nutrients per kg of diet: vitamin A, 21,000 IU; vitamin D_3, 4,500 IU; vitamin E, 60.0mg; vitamin K_3, 3.6mg; vitamin B_1, 1.8mg; vitamin B_2, 7.5mg; vitamin B_6, 4.5mg; vitamin B_{12}, 0.03mg; niacin, 60.0mg; pantothenic acid, 15.0mg; folic acid, 0.75mg; biotin, 0.1mg.

Results and discussion

Proximate composition and amino acid profiles

Proximate composition and amino acid profiles of SBMs from ARG, IND and USA were provided in Table 2. According to the chemical analysis, the contents of CP ranged from 45.43% (ARG) to 48.47% (USA) and those of crude fat from 1.11% (IND) to 1.96% (ARD). The contents of crude ash varied from 5.89% (ARG) to 7.18% (IND) and those of crude fiber widely from 3.48% (USA) to 7.12% (IND). The amino acid contents of USA were higher than those of the other origins. The contents of lysine were from 2.79% (IND) to 3.09% (USA) and those of methionine from 0.56% (IND) to 0.65% (USA).

The values are comparable with those of non-dehulled SBM and dehulled SBM reported by NRC (1994). These results demonstrated differences in nutritive values between non-dehulled and dehulled SBM. Therefore SBM from USA containing high content of protein

and low content of fiber is superior to SBMs from the others. Overall amino acid profiles of the SBMs appeared very similar among the samples when they were expressed as percent of protein.

Table 2. Chemical and amino acid composition of soybean meals[1) 2)]

Items	Soybean meals					
	ARG		IND		USA	
	---------- % air-dry basis (% protein) ----------					
Moisture	11.30		11.49		12.04	
Crude protein	45.43		45.51		48.47	
Crude fat	1.96		1.11		1.64	
Crude ash	5.89		7.18		6.10	
Crude fiber	4.50		7.12		3.48	
Amino acids						
Aspartic acid	5.15	(11.3)	5.10	(11.2)	5.45	(11.3)
Threonine	1.91	(4.2)	1.82	(4.0)	1.99	(4.1)
Serine	2.30	(5.1)	2.31	(5.1)	2.40	(4.9)
Glutamic acid	8.54	(18.8)	8.50	(18.7)	9.12	(18.8)
Glycine	1.96	(4.3)	1.92	(4.2)	2.07	(4.3)
Alanine	2.08	(4.6)	1.97	(4.3)	2.16	(4.4)
Valine	2.12	(4.7)	1.94	(4.3)	2.27	(4.7)
Isoleucine	1.89	(4.2)	1.74	(3.8)	2.04	(4.2)
Leucine	3.52	(7.7)	3.39	(7.4)	3.68	(7.6)
Tyrosine	1.61	(3.5)	1.56	(3.4)	1.64	(3.4)
Phenylalanine	2.37	(5.2)	2.32	(5.1)	2.47	(5.1)
Lysine	2.83	(6.2)	2.79	(6.1)	3.09	(6.4)
Histidine	1.11	(2.5)	1.10	(2.4)	1.20	(2.5)
Arginine	3.16	(7.0)	3.19	(7.0)	3.50	(7.2)
Cystine	0.57	(1.3)	0.58	(1.3)	0.68	(1.4)
Methionine	0.58	(1.3)	0.56	(1.2)	0.65	(1.3)

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Mean

The TME, TMEn, and TAAA values

The values of TME and TMEn of SBMs from ARG, IND and USA were provided in Table 3. The values of TME ranged from 3,011.1 kcal/kg (IND) to 3,245.4 kcal/kg (USA) and those of TMEn from 2,986.6 kcal/kg (IND) to 3,228.9 (USA), which indicate the superiority of USA SBM in terms of ME values.

True amino acid availabilities (TAAA) of SBMs from ARG, IND and USA were provided in Table 4. The averages of TAAA were 92.27% for the USA., 91.98% for ARG and 91.61% for IND. The availabilities of lysine were 93.94% for USA, 93.27% for ARG and 92.46% for IND and those of methionine that is also limiting amino acid were 92.03% for USA, 90.98%

for IND and 90.36% for ARG.

The overall mean of their TAAA (92.0%) were similar to the values reported by Lee and Garlich (1992) (90.37-92.16%), Likuski and Dorrell (1978) (94%), Green and Kiener (1989) (92%). The overall mean of lysine TAAA of USA SBM were tended to be higher than those of the others, but not significantly.

Table 3. Energy values of soybean meals (dry matter basis)[1),2)]

Items	Soybean meals					
	ARG		IND		USA	
	---------- kcal/kg ----------					
TME	3113.1	±30.03	3011.1	±100.29	3245.4	±51.52
TMEn	3092.4	±28.24	2986.6	±96.90	3228.9	±48.33

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Mean±SE

Table 4. True amino acid availability of soybean meals (dry matter basis)[1),2)]

Items	Soybean meals					
	ARG		IND		USA	
	---------- % ----------					
Aspartic acid	93.07	±0.47	92.62	±1.01	92.89	±0.04
Threonine	91.29	±0.19	90.86	±1.50	90.95	±0.52
Serine	92.26	±0.89	92.35	±0.97	92.46	±0.62
Glutamic acid	94.53	±0.04	94.32	±0.62	94.71	±0.12
Alanine	88.13	±0.96	88.04	±2.88	88.98	±0.68
Valine	90.39	±0.68	89.22	±2.11	90.84	±0.05
Isoleucine	90.57	±0.66	89.28	±1.94	90.89	±0.03
Leucine	91.71	±0.15	91.35	±1.24	91.36	±0.05
Tyrosine	91.87	±0.80	91.02	±1.79	92.27	±0.18
Phenylalanine	91.98	±0.09	92.42	±1.28	92.28	±0.21
Lysine	93.27	±0.81	92.46	±1.00	93.94	±0.07
Arginine	96.36	±0.40	95.98	±0.50	95.91	±0.12
Methionine	90.36	±1.08	90.98	±3.11	92.03	±0.35
Total average	91.98		91.61		92.27	

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Mean±SE

Urease activity and KOH solubility as indicator of in vitro digestibility

In vitro protein digestibility of SBMs from ARG, IND and USA were provided in Table 5. The values of UA ranged from 0.02 (ARG) to 0.04 (USA) but the differences were not significant. The values of KOH solubility were 84.15% for USA, 82.93% for IND and 73.49% for ARG. KOH of ARG SBM was significantly lower than the others ($p<0.01$).

UA is widely applied to distinguish underprocessing SBM (Kang and Chae, 2001), and the values lower than 0.2 were regarded as optimum processing condition for SBM (Vohra and Kratzer, 1991). On the contrary, KOH solubility is suitable to distinguish overprocessing SBM (Araba and Dale, 1990), and proper range of KOH solubility is known to be from 73% to 85% (Dale et al., 1987). Therefore, SBMs from ARG, IND and USA were not underprocessed or overprocessed SBMs as shown by the values of UA and KOH solubility.

Table 5. *In vitro* assays to predict protein digestibility of soybean meals[1)]

Items	Soybean meals					
	ARG		IND		USA	
Urease activity, pH unit	0.02	±0.01	0.03	±0.00	0.04	±0.02
KOH solubility, % protein	73.49	±0.52[b]	82.93	±0.39[a]	84.15	±0.39[a]

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[a-b] Mean ± SE within a same row with no common superscripts differ significantly ($P<0.05$).

Broiler feeding trial

Dietary effects of SBMs from ARG, IND and USA on body weight(BW), BW gain, feed intake and feed conversion rate (FCR) in broiler chicken were shown in Table 6. The average feed intakes were simillar amoung the treatments. The daily BW gain of USA group (81.74 g/d) was highest and that of IND (77.45 g/d) was lowest even though the differences amoung the treatment were not significant at 5% level. The FCR in the chicks fed diet containing USA SBM was significantly improved ($p<0.05$) as compared to those of the other groups.

The dietary effects of SBM from ARG, IND and USA on carcass characteristics and blood profiles in broiler chicks were shown in Table 7 and 8, respectively. There were no significant differences in relative weight of liver, bursa of Febricius, abdominal fat, muscles of breast and leg among the treatments. Total-C, GOT and GPT activities did not vary significantly. The results indicate that the SBMs are safe to be used in broiler chickens.

Table 6. Dietary effects of different origins of soybean meal on growth performances in

broiler chicken[1)]

Items	Soybean meals					
	ARG		IND		USA	
Initial BW, g/bird	753.5	±1.9	755.1	±0.2	754.2	±1.3
Final BW, g/bird	1857.8	±13.6	1839.4	±12.4	1898.6	±25.7
BW gain, g/bird/day	78.88	±1.05	77.45	±0.89	81.74	±1.76
Feed intake, g/bird/day	137.94	±1.63	137.26	±1.37	136.14	±2.59
FCR, feed/gain	1.75	±0.01[a]	1.77	±0.01[a]	1.67	±0.01[b]

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[a-b] Mean ± SE within a same row with no common superscripts differ significantly (P<0.05).

Table 7. Dietary effects of different origins of soybean meal on carcass characteristics in broiler chicken[1),2)]

Items	Soybean meals					
	ARG		IND		USA	
	---------- g/100g BW ----------					
Liver	1.73	±0.04	1.76	±0.03	1.77	±0.06
Bursa of Fabricius	0.06	±0.00	0.05	±0.00	0.05	±0.01
Abdominal fat	2.09	±0.11	1.99	±0.08	1.80	±0.12
Breast muscle	9.36	±0.16	9.08	±0.14	9.53	±0.20
Leg	9.27	±0.12	9.51	±0.10	9.30	±0.14

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Mean±SE

Table 8. Dietary effects of different origins of soybean meals on blood profiles in broiler chicken[1),2),3)]

Items	Soybean meals					
	ARG		IND		USA	
TOTAL-C, mg/*dl*	80.90	±3.20	78.94	±2.39	79.00	±1.61
GOT, U/*dl*	307.25	±10.00	319.80	±9.06	326.31	±7.18
GPT, U/*dl*	6.55	±0.77	5.69	±0.46	5.44	±0.55

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Abbreviation: TOTAL-C, total cholesterol; GOT, glutamic-oxaloacetic transaminase; GPT, glutamic-pyruvic transaminase
[3)] Mean±SE

Economical efficiency of SBMs

Economical efficiency of SBMs from ARG, IND and USA were shown in Table 9. The formula cost of broiler feed was highest for USA group (292.19 ₩/kg) and lowest for IND (285.28 ₩/kg) because of the variation in SBM prices. However, the use of USA SBM resulted in the highest economical efficiency (487.96 ₩/kg), the second one was for ARG (503.52 ₩/kg), and the lowest economical efficiency was obtained from IND (504.95 ₩/kg). The result indicate that USA SBM produced the highest returns economically even though its price was most expensive. Its economical efficiency was superior by more than 20% (SBM cost basis) to those of IND SBM as expected from the defference in feed conversion rate which seemed to be resulted from the highest nutrient densities and biological availabilities of the amino acids and ME of dehulled USA SBM.

Table 9. Economical efficiency of soybean meals from different origin

Items	Soybean meals		
	ARG	IND	USA
Feed price, won/kg	287.73	285.28	292.19
Economical efficiency			
Feed cost/BW gain	503.52	504.95	487.96
Index	104	100	120

[1)] Originated from Argentina(ARG), India(IND) and U.S.A.(USA).
[2)] Mean

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