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# Evaluation of the Protein Quality of Soybean Meals from Different Sources in Broiler Chicks Fed with Semi-Purified Diets

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**Two experiments (EXP) were conducted to evaluate the protein quality of dehulled soybean meal (SBM) from the US (United States), Argentina, Brazil, Malaysia, and Philippines, and a non-dehulled SBM from India using chemical and bioassay techniques in 320 male Ross broiler chicks fed with a semi-purified diet for 10 days based on corn-starch-dextrose-soy oil calculated to contain 3,200 kcal/kg metabolizable energy, 13.9% crude protein, 0.9% lysine, 0.2% methionine, and 0.4% methionine and cystine. Chemical analysis of SBM in experiment 1 showed that SBM from the US and Malaysia had lower crude fiber contents than the SBM from Argentina and Brazil. Good SBM processing was shown by Malaysia SBM with the highest protein solubility of 83% while poor processing was shown by Brazil SBM with the lowest protein solubility tests of 67% relative to SBM from US (79%) and Argentine (78%). Weight gain, feed:gain, and protein efficiency ratio (PER) of chicks fed the high efficiency SBM from Malaysia were significantly higher than those fed with SBM from US, Argentina, and Brazil. Chicks fed with the poor quality overtoasted SBM from Brazil had significantly low PER compared with those birds fed with the SBMs from the US, Malaysia and Argentina. In experiment 2, weight gain, feed:gain and PER were significantly lower in birds fed with the non-dehulled Indian SBM than those fed with the US or Philippine SBM. In both EXP, the addition of 0.2% DL-methionine to the diet significantly improved the weight gain, feed:gain, and PER of birds. Short term feeding studies in conjunction with chemical assays can serve as sensitive indicators to detect differences in protein quality of SBM from different sources.**

Key Words: Broiler chicks, protein quality, semi-purified diets, soybean meal source

## INTRODUCTION

Soybean oil meal (SBM) is the largest produced oil seed meal in the world and widely used as a protein source in poultry diets (Ward 1996). Soybean oil meals from different countries vary in quality because of several factors such as variety of soybean, planting conditions, and processing methods (Swick 2003). A study conducted by Creswell (1992) and Mateo et al. (1999) compared different sources of SBM and showed large variations in broiler performance among the meals. Simple feeding studies (Mateo et al. 2004; 2005; 2007) comparing SBMs from different sources give significantly different growth rates and feed conversion in broilers. Karr-Lilienthal et al. (2004) reported that SBM produced in Argentina and Brazil had significantly lower true amino acid (TAA) digestibilities than the standard US SBM, indicating that the processing plants in those countries may produce a less digestible SBM than that available in the open market. Because of the expense and time involved in conducting TAA digestibility assays, a short term 10-d bioassay procedure using semi-purified diets was investigated as a rapid method to evaluate the quality of SBM from various sources in broilers. St. John et al. (1932) employed the chick to evaluate the nutritional quality of proteins. The protein efficiency ratio (PER) has been previously examined and proved to be useful to assess different sources of protein in rats and chicks (Baumah &

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Sengsen 1975; Escalona et al. 1986). A high quality protein with balanced amino acid will promote more weight gain per unit of protein consumed than low quality protein (St. John et al. 1932; Scott et al. 1957; 1983).

In general, the nutritional quality of proteins depends on the proportion and availability of the amino acid that they contain. Although present analytical methods approximate the amino acid content of proteins, they reveal very little information concerning their bioavailability. Consequently, any true assessment of the nutritional value of proteins must rely on biological evaluation. Hinners and Scott (1960) devised a growth assay for comparing relative values of various proteins based on the qualitative growth response of the chicks. As in any other growth assay procedures, a low level of protein is fed to accentuate differences in protein quality. An understanding of the quality control and product specifications of SBM is economically prudent, considering that up to 50% of the protein and 75% of the amino acid requirements of a typical broiler diet is supplied by this feed.

This study is an evaluation of the protein quality of the most commonly used SBM in the Philippine feed industry, namely: dehulled SBM from the US, Philippines, Argentine, Malaysia, and Brazil and non-dehulled SBM from India using both chemical and biological assays in broiler chicks fed semi-purified low protein diets.

## MATERIALS AND METHODS

Two feed demonstration EXP were conducted to evaluate the protein quality of SBM from different countries of origin. Dehulled SBM used in EXP1 were from the US, Argentina, Malaysia, and Brazil. In EXP 2, dehulled SBM used were from the US, Argentina, Philippines and non-dehulled SBM from India. All SBM used in this study were of commercial grade except for the SBM from Malaysia which was made from #1 grade US soybeans processed in a quality optimized crushing plant in Malaysia. This new generation, high efficiency SBM was found to have an advantage over "commercial grade" US dehulled SBM (Neoh 2007). Because of the superior nutrient content of US dehulled SBM, Swick (1999) established its economic advantage over other sources of SBM. Thus, a single source of US dehulled soybean meal was used as the reference SBM in this experiment. The Philippines SBM used in EXP 2 was made of imported US soybeans. Argentine SBM was used because it is the second most popular source of SBM in the Philippines and often used as a substitute for US SBM whenever the latter is unavailable. The Brazilian SBM used in this study was a typical example of an overtoasted and poor quality meal, and was expected to result in poor performance of fed birds (Lee & Garlich 1992). The non-dehulled SBM from India used in EXP 2 is also a common SBM used in the Philippines as it is often priced lower than the other SBM sources. All SBM samples were subjected to complete proximate analysis (moisture, ash, crude fiber, crude protein, crude fat, and nitrogen free extract), urease activity, and protein solubility in 0.2% potassium hydroxide, using AOAC (1984) procedures. The 320 Ross male day-old broiler chicks used in each EXP were fed a corn soybean meal-based starter diet (Table 1) for 7 d following the nutrient requirements of broiler chicks (Philsan 1996). On d 7 the chicks were weighed and randomly allotted to the dietary treatments such that each pen within an EXP would have similar average initial weights and weight range. Each EXP consisted of eight treatments with four replicates and 10 chicks per replicate. The chicks were housed in battery cages with raised bamboo floors and underwent a 24-h photoperiod. The chicks were brooded at a temperature of 32-35°C during the 1st 7 d of age and at 29-32ºC from 8-17 d of age, respectively. The standard management and health procedures recommended for broilers (PCARRD 1996) were given to all experimental birds. The treatments (TRT) in both EXP were the different sources of SBM in semipurified diets. In EXP 1, SBM sources were the US, Argentina, Brazil, and Malaysia. In EXP 2, SBM sources were the US, Philippines, Argentina, and India. In both EXP, a second set of TRT was composed of the PER basal semi-purified diets with 0.2% DL-methionine. The PER basal diet is a low protein semi-purified diet (Table 2) that was fed to the chicks from 7 to 17 d of age. DL-methionine was included in the design of the experiment to stress the need for lysine. Lysine is one of the essential amino acids required for chick growth and is usually destroyed when SBM is overprocessed which significantly affects the weight gain and feed efficiency of birds (Lee & Garlich 1992). Since SBM is deficient in methionine, it is hypothesized that differences among SBM sources should be greater with DL-methionine addition. The test diets were produced by making two batches of the basal diet and mixing the required amount with SBM and corn starch or DL-methionine. Each SBM was included in the same level in each treatment. All PER diets were fed ad libitum in mash form for 10 days. Body weight gain, feed intake, and PER of fed chicks were measured from 7 to 17 d of age. PER was measured following AOAC (1970) procedures calculated as the weight gain of chicks over its protein intake.

**Table 1**. Composition and calculated analysis of pre-trial starter diet.

| Ingredient | Grams per kg | Nutrients | Units | Amount |
|---|---|---|---|---|
| Yellow corn, ground | 482.762 | Weight | kg | 1.000 |
| Soybean oil meal, dehulled | 412.400 | ME kcal | kcal/kg | 3200 |
| Soy oil | 61.110 | Crude protein | % | 23.300 |
| Choline Cl 50 | 1.133 | Arginine | % | 1.715 |
| Monodicalcium phosphate | 17.280 | Lysine | % | 1.400 |
| Na bicarbonate | 1.061 | Methionine | % | 0.639 |
| Mineral concentrate | 0.600 | Met + Cys | % | 1.000 |
| Limestone | 15.542 | Tryptophan | % | 0.309 |
| Salt | 4.027 | Histidine | % | 0.679 |
| Copper sulfate 7 $H_2O$ | 0.512 | Isoleucine | % | 1.054 |
| Iodide | 0.001 | Threonine | % | 0.900 |
| DL-methioine | 2.796 | Valine | % | 1.170 |
| L-Lysine HCl - 78.4 | 0.426 | Crude fat | % | 8.000 |
| Vitamin premix | 0.350 | Crude fiber | % | 2.500 |
| Total batch | 1000.000 | Dry matter | % | 86.800 |
| | | Calcium | % | 1.000 |
| | | Phosphorus, available | % | 0.500 |
| | | Phosphorus, total | % | 0.840 |

**Table 2**. Composition of Protein Efficiency Ratio (PER) basal diet fed from 7 to 17 day in Experiments 1 and 2.

| Ingredients | % |
|---|---|
| Soybean oil meal | 30.00 |
| Corn starch | 25.68 |
| Dextrose | 30.00 |
| Soy oil | 6.00 |
| Alpha cellulose | 4.00 |
| Monodicalcium phosphate | 2.00 |
| Limestone | 1.50 |
| Salt | 0.50 |
| Choline Cl (50%) | 0.20 |
| Mineral premix | 0.08 |
| Vitamin premix | 0.04 |
| Total | 100.00 |
| Calculated nutrients | |
| Metabolizable Energy, kcal/kg | 3213 |
| Crude Protein, % | 13.90 |
| Methionine, % | 0.20 |
| Methionine + Cystine, % | 0.40 |
| Lysine, % | 0.89 |

**Statistical Analysis**
Both EXP employed a 2 x 4 factorial arrangement of treatments. The factors were the four sources of SBM and two levels of DL-methionine addition (0.0% and 0.2%). PROC GLM of SAS (1989) was used to analyze the data. Any significant effect due to treatments was further analyzed using the least square differences.

## RESULTS AND DISCUSSION

**Experiment 1**
The analyses of SBM from different sources by chemical and biological methods in EXP 1 are presented in Table 3. Chemical assay showed that all test SBM were of high protein variety with CP ranging from 47-48%. Although all SBM were of the dehulled variety, the crude fiber content of the Malaysia and US SBM were lower than those of the Argentine and Brazil SBM. The Malaysian SBM gave a slightly higher CP, crude fat, and lower fiber content compared with the commercial grade SBM from the US and SBM from Argentine and Brazil. Moreover, this meal was well processed as its protein solubility was 4% higher compared with that of the US and Argentine SBM. The protein solubility test using a solution of 0.2% potassium hydroxide is useful in determining if SBM is overcooked (Dale & Araba 1987). The good qualities of this new generation high efficiency SBM from Malaysia support the claim that this SBM was found to have an advantage over "commercial grade" US dehulled SBM (Neoh 2007).

**Table 3**. Analyses of Soybean Meal (SBM) from different sources by chemical and biological methods in Experiment 1.

**Chemical Analysis**

| SBM Source | US | Argentina | Brazil | Malaysia |
|---|---|---|---|---|
| Crude Protein, % | 47.4 | 46.8 | 47.4 | 48.0 |
| Crude Fiber, % | 3.6 | 4.2 | 4.9 | 2.3 |
| Crude Fat, % | 0.80 | 1.13 | 1.14 | 1.51 |
| Protein Solubility, %1 | 78.9 | 78.1 | 66.9 | 83.3 |
| Urease Activity (pH Change) | 0.02 | 0.02 | 0.03 | 0.03 |

**Bioassay analysis**[2]

| SBM Source | US | Argentina | Brazil | Malaysia |
|---|---|---|---|---|
| Weight gain (g) | $127^{ab}$ | $125^{ab}$ | $113^{b}$ | $139^{a}$ |
| Feed:gain | $3.31^{ab}$ | $3.31^{b}$ | $3.84^{a}$ | $2.91^{c}$ |
| PER[3] | $2.34^{b}$ | $2.36^{b}$ | $1.83^{c}$ | $2.64^{a}$ |

| Methionine addition | 0.00% | 0.20% |
|---|---|---|
| Weight gain (g) | $95^{b}$ | $157^{a}$ |
| Feed:gain | $3.19^{a}$ | $2.77^{b}$ |
| PER[3] | $1.93^{b}$ | $2.66^{a}$ |

[a-c]In a row, means lacking a common superscript differ (P<0.05).
[1]Protein solubility in 0.2% potassium hydroxide.
[2]Growth performance of male broiler chicks fed the PER diet with and without DL-methionine added from 7-17 d. Values are means of 4 pens of 10 chicks per pen.
[3]PER=Protein efficiency ratio calculated as weight gain over protein intake.

On the other hand, the SBM sample from Brazil had the lowest protein solubility among the four meals compared, 16% lower when compared with the protein solubility of the Malaysian meal, and 12% lower compared with the US SBM, respectively. This is an indication that the Brazil SBM used in this study was overprocessed (Parsons et al. 1991; Araba and Dale 1990; Whittle and Araba 1992), a poor quality meal that resulted in poor feed efficiency and PER (P<0.05) performance of birds fed with this meal. This observation is in agreement with previous studies (Swick 1999; Dale & Araba 1987; Parsons et al. 1992) asserting that the quality and processing of SBM will serve as good indicators of overall bird performance. SBM quality then is dependent on proper processing. Over processing can reduce both the digestibility and the availability of the essential amino acids, especially lysine and cystine, that are essential for chick growth. Growth performance in terms of feed:gain (P<0.05) and PER (P<0.05) was best obtained in birds fed with the Malaysian meal. Weight gain was highest in birds fed with SBM from Malaysia but not different from those fed with the US and Argentine SBM. Weight gain was lowest in birds fed with the Brazilian SBM but not different from those fed with the US and Argentine SBM. Birds fed the Malaysian SBM had significantly higher feed:gain and PER compared with those fed with SBM from the US, Argentina, and Brazil. Birds fed the Brazilian SBM had significantly low PER compared with those fed with other SBM. There was no significant interaction noted between SBM source and DL-methionine addition. As SBM is deficient in methionine, addition of 0.2% DL-methionine significantly improved weight gain by 65%, feed:gain by 13%, and PER by 38% in birds fed all SBM sources relative to the unsupplemented birds.

**Experiment 2**

The chemical and biological analyses of US, Philippines, Argentine, and India SBM in EXP 2 are presented in Table 4. Although the Indian SBM was non-dehulled, its CP content was comparable with the CP of the US, Philippines, and Argentina SBM. However, Indian SBM has lower amino acid levels than those of the US high protein SBM (48%) despite having quite similar protein content. The fiber, fat content, and percentage of protein solubilities of the four tested SBM were comparable, except for urease activity. However, SBM from different sources can perform differently in poultry nutrition despite similar chemical analyses (Vohra & Kratzer 1991). The urease activity of the SBM, which is useful in detecting undercooked meal (Firestone 1990), was highest in the Indian meal which gave a value of 0.10 pH units rise compared with the 0.02 to 0.06 pH rise obtained from the US, Philippines, and Argentina SBM. Indian meal usually tends to have higher urease levels (Swick & Tan 1995). In general, undercooked SBM may contain antinutritional factors such as lectins and trypsin inhibitors that interfere

**Table 4**. Analyses of Soybean Meal (SBM) from different sources by chemical and biological methods in Experiment 2.

| **Chemical analysis** | | | | |
|---|---|---|---|---|
| SBM Source | US dehulled | Philippines dehulled | Argentine dehulled | India non-dehulled |
| Crude protein, % | 48.5 | 48.6 | 47.7 | 47.6 |
| Crude fiber, % | 4.2 | 4.0 | 3.9 | 4.1 |
| Crude fat, % | 1.6 | 1.7 | 2.0 | 1.9 |
| Protein solubility, %1 | 82 | 79 | 75 | 78 |
| Urease activity (pH change) | 0.06 | 0.02 | 0.03 | 0.10 |
| **Bioassay analysis**[2] | | | | |
| SBM Source | US dehulled | Philippines dehulled | Argentine dehulled | India non-dehulled |
| Weight gain (g) | 276[a] | 272[a] | 256[ab] | 246[b] |
| Feed:gain | 1.74[c] | 1.85[bc] | 1.99[ab] | 2.04[a] |
| PER[3] | 4.24[a] | 3.98[b] | 3.77[bc] | 3.68[c] |
| Methionine addition | | 0.00% | 0.20% | |
| Weight gain (g) | | 188[b] | 388[a] | |
| Feed:gain | | 2.24[a] | 1.57[b] | |
| PER[3] | | 3.26[b] | 4.58[a] | |

[a-c]In a row, means lacking a common superscript differ (P<0.05).
[1]Protein solubility in 0.2% potassium hydroxide.
[2]Growth performance of male broiler chicks fed the PER diet with and without DL-methionine added from 7-17 d. Values are means of 4 pens of 10 chicks per pen.
[3]PER=Protein efficiency ratio calculated as weight gain over protein intake.

with normal digestive processes in the chick (Dale & Araba 1991). Despite the high protein content of the Indian SBM, the performance of the birds fed this meal was significantly less than the dehulled SBMs. The lower yield characteristics and less moisture content of Indian meals result in higher crude protein content which is often similar to the protein levels of the US high protein SBM. However, the Indian SBM typically has amino acid levels that are lower and variable digestibility than those in the US meal. This could explain the inferior performance of birds fed with the Indian meal in this study.

In general, amino acid levels of the Indian meal are usually lower than the US meal of the same protein content (Swick 1994), which explains why the CP analysis cannot be relied on to compare and value SBM in the market. There was no significant SBM source by methionine level interaction (P>0.05). DL-methionine addition significantly improved performance in all parameters measured and PER of birds. Weight gain improved (P<0.05) by 80%; feed gain improved by 30%; and PER was better by 40% with 0.20 DL-methionine supplementation. Birds fed with the US meal gave a significantly better feed:gain ratio; 14% better than those fed with the Argentine meal and 17% better than those fed with the Indian meal. PER was 6% higher (P<0.05) in birds fed with the US meal compared with those fed with the Philippine meal and 11% better (P<0.05) than the Argentine meal. Birds fed with the Indian meal had significantly lower PER compared with those fed with the US and Philippine SBM, but not different from those fed with the Argentine meal. Amino acid composition differences exist between these SBM so that the weight gain, feed:gain, and PER were significantly lower in birds fed with the non-dehulled SBM than those birds fed the US or Philippine SBM. The growth performance in terms of weight gain; feed:gain, and PER of birds fed on the US and Philippine dehulled SBM were similar, and the performance of birds fed the Argentine dehulled and Indian non-dehulled SBM were also not different. Overall performance and PER of birds fed the US and Philippine SBM are not significantly different which indicate that processing of US soybeans was comparable in both places.

In both EXP, the addition of 0.2% DL-methionine in the diet significantly improved the weight gain, feed:gain, and PER of birds. This study showed the relative advantage of good quality SBM that are made from soybeans from the US (US, Malaysia, and Philippine SBM) over those SBM made from Argentina, Brazil, and Indian soybeans, respectively, in the overall performance of broiler chicks. The effect of poor processing on the protein quality of the SBM was likewise demonstrated in significantly poor chick growth.

## SUMMARY AND CONCLUSION

The protein quality of SBM from Argentina, Brazil, Malaysia, Philippines, and the US were evaluated using both chemical and biological assays. The biological assay involved broiler chicks fed with a low protein semi-purified diets where the SBM from different origins served as the sole source of dietary protein from 7 to 17 d of age to accentuate differences in protein quality of SBM from different sources. This is based on the fact that a high quality protein with balanced amino acids will promote more weight gain per unit of protein consumed than a low quality protein (Hinners & Scott 1960; Baumah & Sengsen 1975; Escalona et al. 1986). This study demonstrated that the 10 d biological assay using weight gain, feed:gain, and PER of fed chicks proved to be a quick sensitive procedure to distinguish the differences in the protein quality of SBM from different sources. Since SBM from various origins can perform differently in poultry nutrition despite similar chemical analysis such as the proximate analysis, urease activity, trypsin inhibitor activity, protein dispersibility index, and protein solubility, the biological assay would then be a more confirmatory test to distinguish SBM quality. However, the chemical evaluation of the SBM which involved a complete proximate analysis of the moisture, crude fiber, crude protein, crude fat, ash and nitrogen free extract, and protein solubility in 0.2% KOH and urease should be done in conjunction with the growth trial. Results of these analyses will reveal the variation in the nutrient composition and quality of processing of the SBM which affect growth performance of birds. Utilization of high variable SBM leads to overestimation of the energy and amino acid content of the finished feed which then can give negative effects both on the cost and level of poultry production. This study demonstrated that the protein qualities of SBM from various origins are largely due to the processing technology applied and the variety of soybeans used. In this study, the SBM (US, Malaysia, and Philippines) made from US soybeans had relative advantage over those SBM made from Argentine, Brazilian, and Indian soybeans. The use of proper processing technology of SBM was demonstrated in the performance of SBM from Malaysia, Philippines, Argentina, and US in contrast with the poor processing of the SBM from Brazil. The growth performance and PER of chicks were significantly affected when fed with poorly processed meals as shown in this study. This is largely due to the destruction of the essential amino acids needed for growth and the presence of antinutritional factors in soybeans that are not destroyed during inadequate processing.

In conclusion, the protein quality of SBM from various origins can be quickly evaluated using both chemical and biological assays in a 10-d procedure using chicks fed semi-purified low protein diets. Differences in bird performance, which include body weight gain, feed: gain, and PER, were observed by using SBM feeds from the US, Malaysia, Argentina, Brazil, and India. Likewise, the differences in the results of different chemical analysis among SBM due to inadequate processing technology or source of soybeans significantly affected performance of chicks as well. However, the study suggests that, in determining feeding value of SBM, tests employing live birds may be more meaningful than chemical tests.

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