Biological Times

Volume No. 5 | Issue No. 10 | Pages 5-7

Comparative Evaluation of Nutritional Composition and Protein Quality Indicators of Soybean Meal from Different Geographical Origins for Poultry Feed Applications

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ABSTRACT

The nutritional value assigned to soybean meal (SBM) in poultry diet formulation may be unreliable when commercial sources are assumed to be compositionally interchangeable. To compare proximate composition and potassium hydroxide (KOH) protein solubility across supplier-reported SBM origins received for feed-quality assessment in Karachi, Pakistan. Laboratory records containing six observations for each of four origins (Argentina, Brazil, South Africa, and the United States) were analyzed using one-way ANOVA. Moisture, ash, crude protein (CP), fat and fiber differed across origin categories (overall $P \leq 0.003$), whereas KOH protein solubility did not ($P = 0.368$). The United States group had the greatest mean CP (46.06 ± 0.18%), while Brazilian SBM had the greatest moisture (10.86 ± 0.33%), ash (7.28 ± 0.44%), and crude fiber (6.27 ± 0.50%). KOH protein solubility means ranged from 78.62 to 79.38%. The recorded meals exhibited origin-associated differences in routine nutrient composition, supporting analysis of incoming commercial batches rather than reliance on origin alone. Statistical inferences remain provisional until the independence of the six observations per origin is verified; neither nutrient digestibility nor storage-related stability was measured longitudinally.

Keywords: soybean meal; poultry feed formulation; proximate analysis; protein solubility; ingredient quality control

To cite this article: Ahmad M, MA Babar, M Saad & MT Zafar. Comparative Evaluation of Nutritional Composition and Protein Quality Indicators of Soybean Meal from Different Geographical Origins for Poultry Feed Applications. Biological Times. 2026. October 5(10): 5-7.

Introduction

Soybean meal (SBM) is a principal source of protein and indispensable amino acids in poultry diets, and it is commonly used to complement the amino acid profile of cereal grains. Consequently, its analytical composition is central to determining ingredient inclusion rates, dietary nutrient specifications, and the consistency of feed manufacture. However, the usefulness of SBM cannot be judged by crude protein (CP) concentration alone. Moisture alters the amount of dry matter delivered per kilogram, fiber can dilute nutrient density, residual lipid contributes to the analytical fat fraction, and the degree of processing may affect the usability of protein by birds. Crude protein estimates nitrogen-containing material, whereas ileal amino acid digestibility and metabolizable energy require additional measurements (Ravindran et al., 2014; Aguirre et al., 2024). An important practical problem is that commercial SBM is often formulated using generalized nutrient matrices even though batches differ in composition. These differences may be related to soybean genotype, production environment, dehulling, oil extraction, toasting, and subsequent handling. Earlier comparisons demonstrated between-country and within-country differences in soybean or SBM composition (Grieshop and Fahey, 2001; Karr-Lilienthal et al., 2004). A meta-analysis of commercial SBM likewise identified systematic origin-associated variation in CP, fiber, carbohydrates, and selected protein-quality indicators, but the country rankings were not uniform across all traits (Ibáñez et al., 2020). Origin should therefore be interpreted as a useful descriptive grouping, not an experimentally isolated causal factor.

Several approaches are available to reduce uncertainty in feed formulation. A manufacturer may apply fixed book values, periodically update origin-specific nutrient matrices, or directly assay incoming consignments and revise matrices using batch-specific results. The last approach is particularly relevant when raw-material provenance and processing conditions cannot be standardized. Protein quality can be screened using indicators such as KOH protein solubility, while more definitive evaluation may require trypsin inhibitor assays and direct determination of ileal amino acid digestibility. KOH solubility is an indirect index of processing-related changes, not an estimate of digestible amino acids or bird performance (Araba and Dale, 1990; Aguirre et al., 2022). Moreover, assay concentration and processing history influence interpretation and should be reported explicitly.

International evidence already supports such source-specific assessment. Aguirre et al. (2022) compared commercial meals from Argentina, Brazil, South Africa, and the United States and found variation in chemical composition and protein-quality traits; subsequent broiler work connected variation among commercial SBM sources to digestible amino acids and apparent metabolizable energy (Aguirre et al., 2024). These observations must be interpreted in the context of sampling and testing limitations, rather than as a global ranking of supplying countries.

The present study therefore adopted a direct laboratory comparison of four supplier-reported SBM origins using moisture, ash, CP, crude fat, crude fiber and KOH protein solubility. We hypothesized that the four origin categories would differ in at least one proximate component, whereas no directional hypothesis was specified for KOH solubility because processing history was incompletely documented. The objectives were to (i) quantify and compare these six measured traits among the four commercial origin groups, (ii) identify the specific mean differences supported by multiplicity-adjusted testing, and (iii) discuss the findings as preliminary quality-control information for poultry feed formulation without inferring storage stability or in vivo nutritional performance.

2. Materials and Methods

2.1. Study setting and sampling

The analytical work described in the original dissertation was undertaken in 2025 at the University of Karachi in collaboration with Pioneer Feeds Industries, Karachi, Pakistan. The laboratory record listed commercial SBM described as originating from Argentina, Brazil, South Africa, or the United States. Six records were available for each group, corresponding to 24 measured observations per response. Approximately 500 g was collected per sample from Karachi-area solvent-extraction or associated feed-material facilities. Country designations were taken from the supplied records; independent traceability of crop origin, the extraction plant, and lot identifiers was not documented.

The dissertation describes a storage period of less than four months and a relative humidity of approximately 65 ± 5% and the present investigation was treated as a cross-sectional comparison. The six records for each origin were labeled as replicates, but it was not documented whether they were independent lots, separate samples from one lot, or analytical repeats. Samples were reportedly ground and passed through a 25-mesh sieve, except that moisture was assessed on the material received.

2.2. Proximate composition

All analytical conditions reported here were transcribed from the original laboratory description rather than reconstructed as methods that were not recorded. Moisture was determined as gravimetric loss after heating approximately 5.0 ± 0.5 g of SBM at 130–132 °C for 2 h, followed by cooling in a desiccator. The dissertation labels the procedure AOAC 930.15, although that official method is ordinarily described at 135 °C for 2 h (Ahn et al., 2014); accordingly, the recorded procedure is reported as performed

and formal method equivalence remains to be verified. Total ash was measured gravimetrically after incinerating approximately 1 g of sample at 590 °C for 2 h.

Crude protein was determined from approximately 0.5 g by Kjeldahl digestion with concentrated sulfuric acid and catalyst, alkaline steam distillation into boric acid, and titration with 0.05 N sulfuric acid. The nitrogen concentration was multiplied by 6.25 to express CP. Crude fat was measured gravimetrically following n-hexane Soxhlet extraction of approximately 5 g of sample. Crude fiber was derived from the loss on ashing after successive 30-min boiling steps in 0.15 M sulfuric acid and 0.23 M sodium hydroxide, washing, drying, and incineration of the residue. Instrument models, analytical blanks and laboratory quality-control results were not provided in the source records.

2.3. KOH protein solubility

A 1.5-g portion of ground SBM was mixed with 75 mL of 0.5% KOH solution for 20 minutes using a magnetic stirrer. The mixture was centrifuged at 3,000 rpm for 15 min, after which 15 ml of supernatant was used for Kjeldahl determination of soluble nitrogen. KOH-soluble protein was expressed relative to total protein. The 0.5% extraction concentration is retained exactly as recorded; the values should not be directly compared against published reference thresholds developed using other KOH concentrations or extraction protocols (Araba and Dale, 1990).

2.4. Statistical analysis

Six observations per origin were verified against the dissertation appendix, and means and standard deviations (SD) were recalculated. Each response was analyzed using one-way ANOVA, followed by Tukey's HSD test for mean comparisons ($P < 0.05$). Model assumptions were assessed using Shapiro–Wilk and Levene's tests. Means sharing superscript letters were considered statistically similar, and P-values were reported to three decimal places or as $P < 0.001$.

3. Results

Brazilian SBM had the largest mean moisture content (10.86 ± 0.33%), exceeding each of the other three groups by Tukey HSD (adjusted $P \leq 0.001$). It also had the largest ash concentration (7.28 ± 0.44%), whereas the United States group had the lowest ash value (5.90 ± 0.10%). Brazilian ash exceeded that of all other groups; South Africa also had higher ash than the United States (adjusted $P = 0.010$).

Crude protein was greatest in the United States group (46.06 ± 0.18%) and lowest in the Argentine group (44.56 ± 0.46%). United States CP exceeded Argentina and Brazil (both $P < 0.001$), but the contrast with South Africa narrowly failed to reach the prespecified threshold (adjusted $P = 0.052$). Brazilian CP was higher than Argentina ($P = 0.030$) but did not differ from South Africa ($P = 0.120$). The crude-fat fraction was lowest for Brazil (0.75 ± 0.13%); compared with Brazil, mean fat was greater for South Africa ($P = 0.039$) and the United States ($P = 0.002$), but not Argentina.

Crude fiber was greatest in Brazilian SBM (6.27 ± 0.50%) and lowest in Argentine SBM (4.73 ± 0.28%). Brazil had greater fiber than all other groups; South Africa and the United States did not differ significantly. Mean KOH protein solubility ranged narrowly from 78.62 ± 1.17% in the United States group to 79.38 ± 0.30% in the Brazilian group, without a significant overall effect. Median-centered Levene tests did not reject equal variances in the six outcomes (all $P > 0.05$), but Shapiro–Wilk testing flagged nonnormal moisture-model residuals ($P = 0.020$), which warrants cautious interpretation of the small-sample parametric contrasts.

Table 1: Proximate nutritional composition and potassium hydroxide (KOH) protein solubility of commercial soybean meal from four reported geographical origins.

Parameter (%)[2]	Argentina[1]	Brazil[1]	South Africa[1]	United States[1]	P-value[3]
Moisture	8.93 ± 0.90[b]	10.86 ± 0.33[a]	8.85 ± 0.19[b]	9.57 ± 0.25b	<0.001
Ash	6.17 ± 0.28[b]	7.28 ± 0.44[a]	6.51 ± 0.27[b]	5.90 ± 0.10c	<0.001
Crude protein	44.56 ± 0.46[c]	45.12 ± 0.26[b]	45.55 ± 0.31[ab]	46.06 ± 0.18a	<0.001
Crude fat	1.01 ± 0.13[ab]	0.75 ± 0.13[b]	1.05 ± 0.24[a]	1.19 ± 0.17a	0.003
Crude fiber	4.73 ± 0.28[c]	6.27 ± 0.50[a]	5.45 ± 0.32b	5.27 ± 0.13b	<0.001
KOH protein solubility	79.15 ± 0.47	79.38 ± 0.30	79.22 ± 0.80	78.62 ± 1.17	0.368

[1] Values are presented as mean ± standard deviation (SD), with 6 observations per reported geographical origin (n = 6).

[2]Within a row, means sharing at least one superscript letter (a–c) are not significantly different according to Tukey's honestly significant difference (HSD) test (adjusted $P \geq 0.05$).

[3] P-values are for the overall effect of reported geographical origin in one-way analysis of variance (ANOVA); significance was defined as $P < 0.05$.

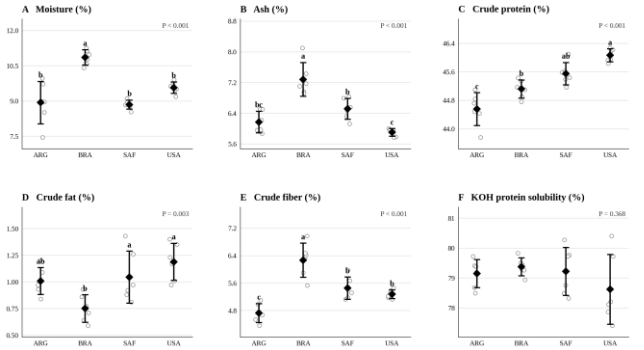


Fig. 1: Distribution of nutritional measurements in soybean meal from four supplier-reported origins

Open circles are individual observations (six per origin); black diamonds and error bars are group means ± SD. Letter labels identify Tukey HSD groupings (adjusted $P < 0.05$) for outcomes with a significant overall ANOVA. Origin abbreviations: ARG, Argentina; BRA, Brazil; SAF, South Africa; USA, United States. Panel axes are independently scaled; comparisons between different outcomes must not be based on apparent vertical distances.

4. Discussion

The most useful observation from this dataset is the coexistence of measurable differences in basic nutrient composition with no detectable overall difference in KOH protein solubility. Within the four groups available at the Karachi laboratory, the United States samples had the highest mean CP and Brazilian samples had higher moisture, ash, and crude fiber. These findings show why feed mills may need to verify the characteristics of purchased SBM rather than assuming that all commercial sources meet a single proximate specification. They do not imply that origin itself produced the differences, because neither soybean cultivar nor extraction method, hull fraction, heat-processing history, or commercial lot was experimentally controlled. The CP ranking in this small dataset should not be generalized as a universal geographical hierarchy. Karr-Lilienthal et al. (2004) reported higher protein in meal processed in the United States within one comparison, whereas the broader meta-analysis by Ibáñez et al. (2020) identified relatively high CP in Brazilian commercial SBM. The more recent four-origin study by Aguirre et al. (2022) likewise documented important heterogeneity and evaluated indicators not determined in the present work. These differences between published rankings are unsurprising because origin is correlated with production and processing practices, and studies may also report nutrient concentrations on different moisture bases. Thus, the relevant application is continued local measurement, not country-based acceptance or rejection of ingredients. Crude protein differed by approximately 1.51 percentage points between the highest and lowest group means. In a formulation based on a fixed matrix, differences of that size could change the quantity of SBM required to meet a target CP concentration. However, CP is calculated from nitrogen and cannot alone quantify utilizable protein. Ravindran et al. (2014) found that origin-associated variation extended to ileal digestibility and metabolizable energy, while Aguirre et al. (2024) demonstrated that digestible amino acid concentrations need not follow crude composition exactly. Therefore, the present dataset cannot support claims of superior broiler growth, feed conversion, or amino acid supply from any origin. Measurements of standardized ileal digestibility, trypsin inhibitor activity, and available energy would be needed before making these claims.

The higher crude fiber in Brazilian meal is consistent with the practical concern that increased hull content may dilute the protein-rich meal fraction, although the present record does not quantify hull inclusion or detergent fiber fractions. Greater moisture reduces the dry matter supplied per kilogram of meal and may affect specifications used at delivery, but the current cross-sectional comparison provides no evidence that one origin undergoes faster moisture gain or spoilage during storage. The ash result describes total inorganic residue rather than the concentrations of calcium, phosphorus, or trace elements; the crude-fat measurement describes solvent-extractable lipid rather than directly measured feed energy. Each indicator is therefore most useful as part of a wider batch acceptance profile (Ibáñez et al., 2020; Liu et al., 2024). KOH solubility requires particular care. Although the four group means were similar, non-significance should not be equated with equivalence in protein quality. Araba and Dale (1990) established the value of protein-solubility screening for excessive thermal processing, yet the test does not diagnose all forms of insufficient

processing or independently predict amino acid availability. The laboratory protocol recorded here used 0.5% KOH and thus should not be judged against cutoffs originating from other KOH extraction procedures. Additionally, variation in initial processing conditions was not recorded. In a quality-assurance program, solubility would be better interpreted alongside urease activity, trypsin inhibitor analysis, and other validated indicators of processing adequacy. Serrano et al. (2013), by contrast, measured selected indicators at multiple storage intervals and could explicitly assess the effect of storage duration. The present study instead supplies a cross-sectional record of laboratory measurements from commercial samples said to have been stored for less than four months. Describing the work as an evaluation of origin-associated composition is therefore more scientifically defensible.

The six measurements per origin were entered as separate observations, but the source material does not establish whether they represent six independently sourced batches. If the observations are technical repeats from one or a few lots, the ANOVA degrees of freedom overstate the independent sample size and the reported inferential P-values cannot be used as confirmatory evidence (HANAN et al., 2025). Other limitations include incomplete provenance and storage logs, uncertain consistency of the percentage reporting basis, nonnormal moisture-model residuals, and the absence of laboratory reference materials or explicit analytical quality-control information. These limitations constrain the strength of all between-origin claims and should be resolved before a journal submission. With verified independent batch sampling, the existing comparison could provide a modest, practice-oriented contribution to commercial ingredient-quality control in Pakistan.

5. Conclusions

Among the recorded commercial soybean meals, five routine proximate measurements varied across supplier-reported origins, while KOH protein solubility did not show a detectable origin-associated difference. United States meal had the highest mean CP, and Brazilian meal had the highest moisture, ash, and crude fiber. These observations favor periodic analysis of received SBM batches and adjustment of feed formulation matrices to measured composition rather than reliance on a generic country ranking. They do not demonstrate effects on digestible amino acids, poultry performance, or nutritional stability during storage. Confirmation of sample-unit independence, analytical method details, and consistent nutrient reporting basis is essential before interpreting the statistical contrasts as confirmatory.

6. Acknowledgments

The authors gratefully acknowledge the Nutritional Biochemistry Laboratory (NBL), Institute of Animal and Dairy Sciences (IADS), University of Agriculture, Faisalabad (UAF), Pakistan, for providing laboratory facilities and technical support.

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