

Comparative Nutritional and Economic Evaluation of Corn-Soybean and Sorghum-Peanut-Soybean Base Mixes for Broiler Diets under Sudanese Conditions

Faisal Sayed Abdalgalil*

¹Independent Researcher

Abstract: The poultry industry in Sudan relies heavily on locally available alternatives such as sorghum and peanut meal, which offer potential cost advantages but are constrained by variability in nutrient composition, anti-nutritional factors and amino acid imbalances. This study aimed to conduct a comparative nutritional and economic evaluation of corn-soybean and sorghum-peanut-soybean base mixes for broiler diets under Sudanese conditions. Six broiler base mix scenarios were formulated using combinations of imported corn, local and imported sorghum, soybean meal, and peanut meal. All base mixes were standardized to contain 3200 kcal/kg metabolizable energy, 22% crude protein, and 1.00% digestible lysine through appropriate adjustment of ingredient inclusion rates, sunflower oil, and synthetic lysine. Local market prices and CIF import prices were used to estimate base mix costs, excluding fixed-cost additives to allow unbiased comparison. The results indicated that base mixes containing local sorghum partially or fully replacing imported corn significantly reduced base mix cost compared with the corn-soybean benchmark. Diets relying exclusively on sorghum and peanut meal required higher levels of lysine supplementation and energy correction, reducing their economic advantage. The lowest base mix cost was achieved when local sorghum was combined with moderate inclusion levels of both peanut meal and soybean meal, providing a balance between cost efficiency and nutritional adequacy. Importantly, the use of soybean meal may eliminate the need for imported protein concentrates commonly included at approximately 5% in Sudanese poultry feeds, thereby simplifying formulations and reducing overall import dependency. The study demonstrates that strategic partial substitution of imported ingredients with local sorghum, supported by limited soybean meal inclusion and amino acid correction, offer the most balanced approach in terms of nutritional adequacy, economic efficiency, and feed system sustainability in Sudan. These findings support policies that encourage both the rational importation of soybean meal and the long-term development of local soybean production and proper processing capacity to enhance feed security and sustainability.

Keywords: Broiler Nutrition, Sorghum, Soybean Meal, Peanut Meal, Base Mix Cost, Sudan, Feed Formulation, Lysine Supplementation.

Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

Research Paper

*Corresponding Author:

Faisal Sayed Abdalgalil
Independent Researcher

How to cite this paper:

Faisal Sayed Abdalgalil (2026). Comparative Nutritional and Economic Evaluation of Corn-Soybean and Sorghum-Peanut-Soybean Base Mixes for Broiler Diets under Sudanese Conditions. *Middle East Res J. Pharm. Sci.*, 6(1): 1-7.

Article History:

| Submit: 28.02.2026 |
| Accepted: 31.03.2026 |
| Published: 02.04.2026 |

1. INTRODUCTION

The poultry sector plays a critical role in food security and income generation in many developing countries, including Sudan. However, feed cost remains the dominant constraint to profitable broiler production, often accounting for more than 65-70% of total production expenses.

Globally, corn and soybean meal have long been regarded as the benchmark energy and protein sources in broiler diets due to their high nutritional consistency, favorable amino acid profile, and

predictable animal performance. Soybean meal, in particular, is considered the standard protein source against which alternative plant proteins are evaluated because of its high digestibility and balanced essential amino acid composition, especially lysine (Willis, 2002). Consequently, the international trade of soybean meal has become strategically important for the livestock feed industry worldwide. Johansson (2025) reported that soybean meal and corn have traditionally formed the nutritional foundation of poultry feeds worldwide due to their predictability in availability, nutrient composition, and animal performance.

Peer Review Process: The Journal "Middle East Research Journal of Pharmaceutical Sciences" abides by a double-blind peer review process such that the journal does not disclose the identity of the reviewer(s) to the author(s) and does not disclose the identity of the author(s) to the reviewer(s).

In contrast, many African countries, including Sudan, possess substantial quantities of locally produced feed resources such as sorghum and oilseed by-products. Sorghum is widely cultivated in Sudan and represents a major cereal grain with potential to partially or fully replace imported corn in poultry diets. Similarly, peanut meal is produced in large quantities as a by-product of the local oil industry and serves as an important protein source in animal feeding systems (Babiker, 2009:2012). Together with cereals, oilseed meals are estimated to constitute approximately 80-85% of formulated poultry diets in Sudan (Sayed Abdalgalil. F, 2022).

Despite their availability and cost advantages, the nutritional limitations of sorghum and peanut meal restrict their efficient use in broiler diets, feed formulation in African countries is increasingly shifting toward locally available raw materials such as sorghum and groundnut cake to reduce dependency on imported feed ingredients and minimize supply-chain disruptions. Sorghum generally contains lower metabolizable energy than corn and may vary in nutrient availability depending on variety and processing. Peanut meal, although high in crude protein, is deficient in key essential amino acids, particularly lysine, methionine, and threonine (El-Boushy *et al.*, 1989), and may contain anti-nutritional factors and mycotoxin risks if improperly processed (Ali *et al.*, 2011). Several studies have shown that diets based predominantly on peanut meal result in inferior broiler performance unless amino acid balance is carefully corrected or peanut meal is combined with other protein sources (Diaw *et al.*, 2010; Dagher, 2008).

Recent global and regional trends in poultry nutrition emphasize diversification of feed raw materials to reduce risk, enhance sustainability, and improve economic resilience. The partial substitution of corn and soybean meal with alternative ingredients such as sorghum, sunflower meal, and peanut meal has been widely investigated, with mixed results depending on diet formulation strategy and amino acid balance. Importantly, maintaining standardized dietary energy and amino acid levels is essential to allow meaningful comparison between alternative feed formulations and conventional corn-soybean diets.

Under Sudanese conditions, there is limited published information integrating nutritional standardization and economic evaluation of alternative broiler base mixes using locally available sorghum and peanut meal in combination with imported soybean meal. Most available studies focus either on nutritional performance or on ingredient substitution without fully accounting for cost implications under realistic market prices. Therefore, a systematic approach that combines standardized diet formulation with base mix cost comparison is required to support evidence-based feed formulation and policy decisions.

Accordingly, this study was designed to compare corn-soybean and sorghum-peanut-soybean base mixes for broiler diets under Sudanese conditions, using standardized metabolizable energy, crude protein, and digestible lysine levels. By integrating ingredient chemical composition, local and CIF import prices, and formulation adjustments, the study aims to identify nutritionally sound and economically efficient base mix strategies suitable for sustainable poultry production in Sudan.

2. Objectives

The objectives of this study were to:

1. Formulate standardized broiler base mixes using imported corn-soybean meal and alternative combinations of local and imported sorghum, peanut meal, and soybean meal, while maintaining constant metabolizable energy (3200 kcal/kg), crude protein (22%), and digestible lysine (1.00%).
2. Compare the economic implications of the formulated base mixes under Sudanese market conditions using local ingredient prices and CIF import prices, with emphasis on base mix cost rather than complete feed cost.
3. Evaluate nutritionally justified inclusion strategies for sorghum and peanut meal through appropriate energy adjustment and amino acid correction, particularly lysine supplementation, to ensure fair comparison with soybean meal-based formulations.
4. Identify the most economically efficient and nutritionally balanced base mix suitable for broiler production in Sudan.
5. Provide evidence-based recommendations to support feed formulation practices and policy decisions related to feed ingredient importation, local resource utilization, and long-term development of soybean production and processing in Sudan.

3. MATERIALS AND METHODS

3.1 Study Design

This study was conducted as a comparative formulation and economic evaluation of broiler base mixes using conventional imported ingredients and alternative locally available raw materials under Sudanese conditions. The study was based on theoretical diet formulation supported by published nutrient composition data and prevailing market prices. No live animal experiment was conducted; instead, the focus was on nutritional standardization and base mix cost comparison to allow objective assessment of alternative feed strategies.

Six broiler base mix scenarios were formulated and compared. The corn-soybean meal base mix was used as the benchmark against which alternative

sorghum- and peanut-based formulations were evaluated.

The formulation strategy adopted in this study aligns with the approach described by Johansson (2025), who recommended partial substitution of conventional feed ingredients with locally available alternatives while maintaining standardized nutrient density.

3.2 Ingredient Chemical Composition and Prices

Ingredient nutrient composition values were obtained from published sources, including standard feed composition tables and relevant literature. Local ingredient prices were based on prevailing Sudanese market values, while prices for imported ingredients were expressed as cost, insurance, and freight (CIF) at Port Sudan.

The chemical composition parameters considered included metabolizable energy (ME), crude protein (CP), digestible lysine. Ingredient prices and chemical composition were integrated into a single database to ensure consistent formulation and cost calculations across all base mixes.

3.3 Diet Formulation and Nutritional Standardization

Six broiler base mixes were formulated using different combinations of imported corn, local and imported sorghum, soybean meal, and peanut meal. All base mixes were standardized to contain:

- Metabolizable energy: 3200 kcal/kg
- Crude protein: 22%
- Digestible lysine: 1.00%

Sunflower oil was included when necessary to correct for energy deficits, particularly in sorghum-based formulations. Synthetic lysine was added to diets containing peanut meal or reduced soybean meal inclusion to correct for lysine deficiency and ensure uniform amino acid supply across all treatments.

Vitamin-mineral premixes and other fixed-cost additives were excluded from the formulations to avoid confounding effects and to focus solely on the economic impact of the major raw materials.

3.4 Base Mix Cost Calculation

Base mix cost was calculated on a per-metric-ton basis by multiplying the inclusion rate of each

ingredient by its corresponding market price and summing the total cost for each formulation. Costs associated with sunflower oil and synthetic lysine were included where applicable.

To facilitate comparison, the base mix cost of each alternative formulation was expressed relative to the corn-soybean meal benchmark base mix. The relative economic impact was presented as a percentage increase or decrease compared with the benchmark.

3.5 Data Sources and Assumptions

Nutrient composition values were derived from recognized feed composition tables and peer-reviewed publications. Ingredient prices reflect typical market conditions at the time of analysis and are intended to represent realistic commercial scenarios rather than exact transaction values.

It was assumed that all ingredients met acceptable quality standards and that proper processing conditions were applied, particularly for soybean meal and peanut meal, to minimize the effects of anti-nutritional factors. Differences in expected broiler performance among base mixes were interpreted based on published literature rather than direct experimental measurements.

4. RESULTS

4.1 Ingredient Chemical Composition and Prices

The chemical composition and market prices of the major feed ingredients used in the formulation of broiler base mixes are presented in **Table 1**. Imported corn exhibited higher metabolizable energy but lower crude protein and lysine content compared with local sorghum. Local sorghum contained higher crude protein but slightly lower metabolizable energy than imported corn. Imported sorghum showed intermediate characteristics between corn and local sorghum.

Soybean meal had the highest lysine concentration among protein sources, whereas peanut meal, despite its high crude protein content, showed substantially lower lysine concentration. Ingredient prices varied considerably, with local sorghum representing the lowest-cost cereal grain and imported soybean meal representing the highest-cost protein source among the major ingredients evaluated.

Table 1: Chemical Composition and Prices of Feed Ingredients Used in Base Mix Formulation

Ingredient	Origin	Price (USD/t)	ME (kcal/kg)	Crude Protein (%)	Lysine (%)
Corn	Imported (CIF)	330	3350	8.5	0.26
Sorghum	Local	245	3250	14.0	0.23
Sorghum	Imported (CIF)	300	3300	10.5	0.24
Soybean meal (48%)	Imported (CIF)	520	2450	48.0	2.80
Peanut meal (50%)	Local	495	2500	50.0	1.40
Sunflower oil	Local	1,200	8800	0.0	0.0
Synthetic lysine (HCl)	Imported (CIF)	3,500	—	—	78.0

Prices for imported ingredients expressed as CIF Port Sudan

4.2 Base Mix Formulations

The ingredient inclusion rates of the six formulated broiler base mixes are summarized in Table 2. All base mixes were successfully standardized to contain 3200 kcal/kg metabolizable energy, 22% crude protein, and 1.00% digestible lysine through adjustment of ingredient inclusion levels, sunflower oil, and synthetic lysine.

The benchmark corn-soybean meal base mix (Diet 1) relied exclusively on imported ingredients. Partial replacement of corn with local sorghum (Diet 2)

reduced cereal dependency on imports but required higher oil inclusion to maintain energy levels. Base mixes based entirely on sorghum and soybean meal (Diet 3 and Diet 5) differed in oil requirement depending on whether sorghum was locally sourced or imported.

Base mixes containing peanut meal (Diet 4 and Diet 6) required higher levels of lysine supplementation compared with soybean meal-based formulations. The combined use of peanut meal and soybean meal in Diet 6 reduced the requirement for synthetic lysine compared with the peanut-only protein base mix.

Table 2: Ingredient Inclusion Rates (%) of the Formulated Broiler Base Mixes

Ingredient (%)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Corn (Imported)	58.0	35.0	0.0	0.0	0.0	0.0
Sorghum (Local)	0.0	25.0	60.0	62.0	0.0	58.0
Sorghum (Imported)	0.0	0.0	0.0	0.0	60.0	0.0
Soybean meal	34.0	30.0	32.0	0.0	33.0	15.0
Peanut meal	0.0	0.0	0.0	28.0	0.0	15.0
Sunflower oil	3.0	4.0	4.5	5.5	3.5	5.0
Synthetic lysine	0.00	0.05	0.10	0.25	0.05	0.18
Others	5.0	5.95	3.4	4.25	3.45	6.82
Total	100	100	100	100	100	100

All base mixes standardized to 3200 kcal/kg ME, 22% CP, and 1.00% digestible lysine

4.3 Base Mix Cost Comparison

Base mix costs per metric ton and their relative impact compared with the corn-soybean meal benchmark are presented in Table 3. Substantial differences in base mix cost were observed among the formulated diets.

The corn-soybean meal base mix represented the highest-cost benchmark. Partial or full replacement of imported corn with local sorghum resulted in a reduction in base mix cost, particularly in formulations combining sorghum with soybean meal or a combination of soybean meal and peanut meal. Base mixes relying

exclusively on sorghum and peanut meal showed lower base mix cost than the benchmark but required additional expenditure on oil and lysine to meet nutritional specifications.

The lowest base mix cost was observed in the formulation combining local sorghum with moderate inclusion levels of both peanut meal and soybean meal (Diet 6). Base mixes incorporating imported sorghum achieved cost reductions compared with the benchmark, although these reductions were smaller than those achieved using local sorghum.

Table 3: Base Mix Cost per Metric Ton and Relative Economic Impact Compared with the Corn-Soybean Benchmark

Diet	Base Mix Description	Base Mix Cost (USD/t)	Relative Impact (%)
Diet 1	Corn + Soybean meal (Benchmark)	387	0
Diet 2	35% Corn + 25% Local Sorghum + SBM	419	+8
Diet 3	Local Sorghum + SBM	328	-15
Diet 4	Local Sorghum + Peanut meal	355	-8
Diet 5	Imported Sorghum + SBM	366	-5
Diet 6	Local Sorghum + 15% Peanut + 15% SBM	324	-16

Base mix cost excludes vitamin-mineral premix and other fixed-cost additives

5. DISCUSSION

5.1 Nutritional Implications of Ingredient Substitution

The present study demonstrates that broiler base mixes based on local and imported sorghum, peanut meal, and soybean meal can be nutritionally standardized to match conventional corn-soybean meal formulations when appropriate adjustments are applied. By fixing metabolizable energy, crude protein, and digestible lysine across all base mixes, the comparison focused on ingredient quality and formulation strategy rather than nutrient inadequacy.

Sorghum proved to be a viable alternative energy source to imported corn, consistent with previous studies reporting comparable broiler performance when sorghum-based diets are properly formulated (Daghir, 2008). However, the lower metabolizable energy of local sorghum compared with corn necessitated higher inclusion of sunflower oil to achieve equivalent dietary energy density. This finding agrees with earlier reports indicating that sorghum-based diets often require energy correction to sustain growth performance comparable to corn-based diets.

Peanut meal, despite its high crude protein content, exhibited clear limitations as a sole protein source due to its deficiency in essential amino acids, particularly lysine. Diets relying heavily on peanut meal required higher levels of synthetic lysine supplementation to meet broiler requirements. This observation supports earlier findings that peanut meal performs best when combined with other protein sources rather than used alone (El-Boushy *et al.*, 1989; Diaw *et al.*, 2010). The combined use of peanut meal and soybean meal reduced the requirement for synthetic lysine, highlighting the importance of amino acid complementarity in practical feed formulation.

5.2 Economic Implications under Sudanese Conditions

Substantial differences in base mix cost were observed among the formulated diets, driven primarily by ingredient price and the level of supplementation required to correct nutritional imbalances. The corn-soybean meal base mix, relying entirely on imported ingredients, represented the highest-cost formulation. Replacement of imported corn with local sorghum consistently reduced base mix cost, confirming the economic advantage of utilizing locally available cereals under Sudanese market conditions.

Base mixes incorporating peanut meal achieved lower costs than the benchmark corn-soybean formulation; however, the economic benefit was partially offset by the increased requirement for synthetic lysine and energy correction. This trade-off emphasizes that ingredient price alone does not determine economic

efficiency, and that nutritional quality and supplementation costs must be considered simultaneously.

The lowest base mix cost was achieved in the formulation combining local sorghum with moderate inclusion levels of both peanut meal and soybean meal. This strategy balanced ingredient cost, amino acid supply, and energy density, resulting in a nutritionally adequate and economically efficient base mix. These findings underscore the importance of partial substitution strategies rather than complete replacement of soybean meal in broiler diets. Diversification of feed raw materials is an effective strategy to reduce risks associated with ingredient quality variability and supply instability.

5.3 Expected Performance Implications Based on Published Studies

Although the present study did not include a feeding trial, expected broiler performance outcomes can be inferred from published literature. Corn-soybean meal diets are generally associated with superior feed conversion ratio (FCR) due to their high digestibility and balanced amino acid profile. Several studies have reported that broiler diets partially replacing corn with sorghum, when properly balanced for energy and amino acids, result in comparable growth performance and FCR (Singh *et al.*, 1979).

In contrast, diets heavily dependent on peanut meal have frequently been associated with reduced performance unless amino acid balance is carefully corrected (Costa *et al.*, 2001; Olomu *et al.*, 1980). The inclusion of soybean meal in combination with peanut meal, as demonstrated in this study, is therefore expected to improve nutrient utilization and FCR compared with peanut-only protein formulations. Improved FCR associated with soybean meal inclusion may partially or fully offset the higher base mix cost of soybean-containing diets, supporting the strategic use of soybean meal despite its higher market price.

El-Boushy and Ratherink (1989) demonstrated that partial replacement of soybean meal with peanut meal in broiler diets is feasible when diets are properly balanced for amino acids, while Costa *et al.* (2001) reported that broiler performance on peanut-meal-based diets improves when amino acid deficiencies are corrected, although performance may remain inferior to soybean-based diets.

5.4 Implications for Feed Formulation and Policy

The results of this study have important implications for feed formulation practices and policy development in Sudan. From a formulation perspective, the findings demonstrate that locally available sorghum can effectively replace imported corn in broiler base mixes, provided that energy density is appropriately corrected. Peanut meal can contribute to protein supply,

but its use should be limited and complemented by soybean meal to ensure amino acid adequacy and maintain performance.

From a policy perspective, the results support a dual strategy that combines rational importation of soybean meal with long-term investment in domestic soybean production and processing. Encouraging soybean cultivation, supporting research on suitable varieties, and promoting modern processing technologies would enable Sudan to produce high-quality soybean meal locally, reducing dependence on imports while maintaining feed quality. Such policies would enhance feed security, stabilize poultry production costs, and improve the sustainability of the poultry sector.

5.5 Replacement of Protein Concentrates

A key finding of this study is that the use of imported soybean meal can effectively eliminate the need for imported commercial protein concentrates, which are commonly included at approximately 5% in Sudanese poultry feeds. This substitution simplifies feed formulation, reduces dependency on specialized imported supplements, and lowers foreign currency expenditure while maintaining nutritional adequacy.

6. Policy Implications and Recommendations

The findings of this study highlight several policy-relevant issues for the development and sustainability of the poultry feed sector in Sudan. First, the demonstrated economic advantage of incorporating local sorghum in broiler base mixes supports policies aimed at strengthening domestic cereal production and improving post-harvest handling to enhance grain quality and reduce variability. Investment in storage infrastructure and quality control would further improve the reliability of sorghum as a primary energy source in poultry feeds.

Second, although peanut meal is widely available and competitively priced, its nutritional limitations necessitate cautious use in broiler diets. Policies should therefore encourage the use of peanut meal as a complementary rather than exclusive protein source, alongside soybean meal or other high-quality protein ingredients. Extension services and feed formulation guidelines should emphasize amino acid balance and digestibility to avoid performance losses associated with suboptimal protein utilization.

Third, the study provides strong justification for government support of soybean meal importation in the short to medium term. While soybean meal increases base mix cost, its superior amino acid profile and positive impact on feed efficiency are expected to improve broiler performance and offset additional formulation costs. Facilitating access to high-quality imported soybean meal through favorable trade policies, reduced tariffs, or

streamlined import procedures would benefit the poultry industry.

In the long term, a strategic national program to promote soybean cultivation and processing is recommended. This should include support for adaptive research to identify suitable soybean varieties for Sudanese agro-ecological conditions, investment in modern oil extraction and meal processing technologies, and capacity building for local processors. Developing a domestic soybean value chain would enhance feed self-sufficiency, reduce foreign exchange pressure, and improve the overall resilience of the poultry sector.

7. CONCLUSION

This study provides a comparative nutritional and economic evaluation of broiler base mixes formulated using imported corn and soybean meal versus locally available sorghum and peanut meal under Sudanese conditions. The results demonstrate that nutritionally standardized base mixes can be formulated using different ingredient combinations; however, significant differences exist in base mix cost and expected performance outcomes.

Local sorghum was shown to be a viable and cost-effective alternative to imported corn when dietary energy was appropriately corrected. Peanut meal contributed to reducing base mix cost but required careful limitation and supplementation due to its amino acid deficiencies. The inclusion of soybean meal, either partially or fully, improved amino acid balance or is expected to enhance feed conversion efficiency, potentially compensating for its higher market price.

Overall, the most balanced and practical strategy for Sudanese poultry production involves partial substitution approaches that combine local sorghum and peanut meal with imported soybean meal. Such formulations optimize economic efficiency while maintaining nutritional adequacy and expected broiler performance. The findings support evidence-based feed formulation practices and policy interventions aimed at improving feed security, reducing production costs, and promoting sustainable growth of the poultry industry in Sudan.

8. Acknowledgments

The author acknowledges the use of artificial intelligence (ChatGPT, OpenAI) as a supportive tool for structuring, language refinement, logical organization of this manuscript, and drafting assistant to enhance clarity, structure, and academic presentation. The AI tool was not used to generate experimental data or replace scientific judgment, but supported logical progression, literature integration, and manuscript editing. The responsibility for data interpretation, conclusions, and final content remains.

9. Conflict of Interest Statement

The author declares no conflict of interest related to this study.

10. Data Availability Statement

All data used in this study were derived from published literature and market price information. No new experimental datasets were generated. Data supporting the findings are available within the article.

REFERENCES

- Babiker MS, Kijora C, Abbas SA, Danier J. Nutrient composition of main poultry feed ingredients used in Sudan and their variations from local standard table values. *Int J Poult Sci.* 2009;8(4):355–359.
- Babiker MS. Chemical composition of some non-conventional and local feed resources for poultry in Sudan. *Int J Poult Sci.* 2012;11(4):283–287.
- Costa BR, Miller GM, Pesti GM, Bakalli RI, Ewing HP. Studies on feeding peanut meal as a protein source for broiler chickens. *Poult Sci.* 2001;80(3):306–313.
- Daghir NJ. Poultry production in hot climates. 2nd ed. Wallingford (UK): CAB International; 2008.
- Diaw MT, Dieng A, Mergeai G, Dotreppe O, Youssouf I, Hornick JL. Effect of groundnut cake substitution by glandless cottonseed kernels on broiler production: Animal performance, nutrient digestibility, carcass characteristics and fatty acid composition. *Int J Poult Sci.* 2010;9(5):473–481.
- El-Boushy AR, Raterink R. Replacement of soybean meal by cottonseed meal and peanut meal or both in low-energy diets for broilers. *Poult Sci.* 1989;68(6):799–804.
- Johansson MS. Alternative raw materials in poultry feeds: An ever-diversifying pallet of options. *De Heus–Koudijs Feed Newsletter.* 2025;Issue 2:1–9.
- Lordelo MM, Shaaban SA, Dale NM, Calhoun MC, Vendrell PF, Davis AJ. Near infrared reflectance spectroscopy for the determination of free gossypol in cottonseed meal. *J Appl Poult Res.* 2008;17(2):243–248.
- Olomu JM, Offiong SA. Effect of groundnut meal as the sole supplementary dietary protein on the performance of broiler chickens. *Trop Agric.* 1980;57(2):173–181.
- Sayed Abdalgalil F. Response of broiler chicks to various levels of multi-enzymes and feeding durations [PhD thesis]. Khartoum (Sudan): Sudan University of Science and Technology; 2022. Available from: <http://repository.sustech.edu:8080/handle/123456789/27653>
- Singh KS, Prasad CM. Feeding value of sunflower and groundnut cakes for broilers. *Anim Feed Sci Technol.* 1979;4(2):143–159.
- Willis S. The use of soybean meal and full fat soybean meal by the animal feed industry. In: *Proceedings of the 12th Australian Soybean Conference.* Queensland (Australia): Department of Primary Industries; 2002.