



Nutritional Evaluation of *Irvingia gabonensis* seed pericarp as Potential Poultry Feed Supplements in Nigeria

F. B. Adebayo¹, A. A. Oyedeji^{2, 3}, T. V. Borisade², O. E. Ibidiran¹, S. O. Ibikunle⁴

¹Department of Agricultural Sciences and Technology,
School of Agriculture and Agricultural Technology,
Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti,
PMB 250, Ekiti, Nigeria

²Department of Biological Sciences,
School of Agriculture and Agricultural Technology,
Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti,
PMB 250, Ekiti, Nigeria

³Department of Biological Sciences,
School of Life Sciences,
Niger Delta University, PMB 560103, Wilberforce Island, Nigeria

⁴Department of Food Science and Technology,
School of Agriculture and Agricultural Technology,
⁴Federal University of Technology, PMB 340252, Akure, Nigeria

*Corresponding Author: F.B ADEBAYO, Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Department of Agricultural Sciences and Technology, PMB 250, Ekiti, Nigeria

F.B Adebayo; adebayo.francis@bouesti.edu.ng; ORCID No: <https://orcid.org/0000-0002-3614-2997>

A.A Oyedeji; ayodele.oyedeji@ndu.edu.ng; <https://orcid.org/0000-0003-2041-6313>

T.V Borisade; borisade.tolulope@bouesti.edu.ng; ORCID: <https://orcid.org/0000-0002-0967-8411>

O.E Ibidiran; ibidiran.oluwasegun@bouesti.edu.ng; ORCID: <https://orcid.org/0009-0000-3361-3418>

S.O Ibikunle; stephenoluwaseun44@gmail.com; ORCID: <https://orcid.org/0009-0007-8435-3418>

ABSTRACT

The rising cost of conventional feed ingredients and the need for sustainable livestock systems have increased interest in agro-industrial byproducts as alternative poultry feed resources. *Irvingia gabonensis* seed pericarp, typically discarded as waste, offers potential due to its nutritional and functional properties. This study evaluated its suitability for broiler and layer diets through comprehensive analyses, including proximate composition, amino acid and fatty acid profiles, fiber fractions, mineral content, and antioxidant activity, using standard analytical methods. Results showed low crude protein (2.72%) but exceptionally high neutral detergent fiber (76.31%) and acid detergent lignin (18.24%), suggesting limited protein contribution but functional value. Phosphorus (4,046 mg/kg) and calcium (2.56%) levels indicate potential for mineral fortification. Antioxidant capacity (52.83% DPPH inhibition) suggests its use in

mitigating oxidative stress. Inclusion in broiler diets up to 5% may enhance gizzard development and mineral utilization, particularly with phytase. In layers, 3–4% inclusion could reduce inorganic phosphate supplementation while supporting egg production. However, high fiber content necessitates pretreatment strategies such as fermentation to enhance digestibility. Findings support the valorization of *I. gabonensis* pericarp as a cost-effective, functional feed additive for sustainable poultry production, particularly in resource-limited settings.

Keywords: *Irvingia gabonensis*, Valorisation, Antioxidant, Poultry feed, Supplementation

INTRODUCTION

Poultry production plays a crucial role in food security and income generation across many developing nations. In regions like sub-Saharan Africa, the incorporation of natural feed supplements is gaining attention due to their affordability, accessibility, and potential to enhance livestock performance. The poultry industry, in particular, is expanding rapidly, offering a sustainable source of employment and producing nutrient-dense foods such as meat and eggs with relatively low feed input. These animal-based proteins remain vital in addressing widespread nutritional deficiencies across African populations (FAO, 2013).

Despite the increasing demand for cost-effective and nutritious feed ingredients, there remains a significant gap in the literature regarding the nutritional and economic potential of *Irvingia gabonensis* (commonly known as bush mango) in poultry nutrition, especially in Nigeria. Historically, *I. gabonensis* has been recognized as an important Non-Timber Forest Product (NTFP) in West and Central Africa. Its commercial relevance is well established, with farmers in parts of Cameroon earning between US\$15.00 and US\$93.00 per grower or collector from fruit sales, and approximately US\$78.00 from kernel harvests (Ayuk et al., 1999). The plant is primarily cultivated for its seeds, while the leaves and stem bark are traditionally used in African medicine to treat ailments such as fever and stomach discomfort (Ayivor, 2011). Additionally, a mixture of its roots, leaves, and stem bark with palm oil is employed as a remedy for diarrhoea (Lesley & Nick, 2000). Furthermore, it has been traditionally used in the management of dysentery, hernias, yellow fever, and poisoning (Ayuk, 1999).

The seeds of *I. gabonensis*, rich in oil, protein, and beneficial phytochemicals—including tannins, alkaloids, terpenoids, steroids, saponins, and glycosides—are regarded as the most valuable part of the fruit. These bioactive compounds are associated with antimicrobial, immunomodulatory, and growth-enhancing effects in animals (Lillehoj et al., 2018; Mgbemena et al., 2019; Oloruntola et al., 2021). Yet, despite these properties, *I. gabonensis* remains underutilized in mainstream animal feed formulations.

Studies have suggested that supplementation of poultry diets with *I. gabonensis* seed powder may promote fertility and improve growth performance, likely due to its high leucine content—a critical essential amino acid—and its considerable carbohydrate profile (Obianime & Uche, 2010; Gonzalez-Rios et al., 2016; Oloruntola et al., 2021). In traditional practices, farmers also collect and use the leaves of the plant as fodder, further supporting its relevance in animal husbandry (Ayuk et al., 1999).

Given the existing focus on the seeds and kernels, this study aims to evaluate the nutritional composition of the pericarp of *I. gabonensis*—a part often discarded—and explore its potential as a cost-effective, nutrient-rich supplement for poultry feed. By investigating its unique phytochemical and nutrient profile, the research seeks to contribute to the development of more sustainable and efficient feeding strategies in poultry production.

MATERIALS AND METHOD

Study Area, Climate and Distribution

This research work was carried out in the southwestern part of Nigeria, a geographic zone well known for supporting the natural distribution of *Irvingia gabonensis* and related indigenous species. The study area falls within the coordinates of 2°48' to 6°00' E longitude and 5°05' to 9°12' N latitude. It is bordered to the west by the Republic of Benin, to the north by Kwara State, to the east by Kogi and Edo States, and it opens to the Atlantic Ocean via the Gulf of Guinea in the south. The region is typified by a bimodal

climate pattern, with a wet season extending from April through October and a dry season spanning November to March. Average annual temperatures range between 21°C and 34°C, while precipitation levels vary between 1,500 mm and 3,000 mm (Borisade et al., 2021).

Irvingia gabonensis fruits were primarily collected from natural forest ecosystems and abandoned agricultural lands, areas where these species are commonly observed to flourish. Their natural habitat comprises tropical evergreen rainforests and moist semi-deciduous forests, typically at elevations between sea level and 500 meters (CAB, 2000; WAC, 2004). In Nigeria, however, their presence also extends to derived savanna woodlands and secondary forests, although they are notably absent from swampy or waterlogged terrains (Ayuk et al., 1999).

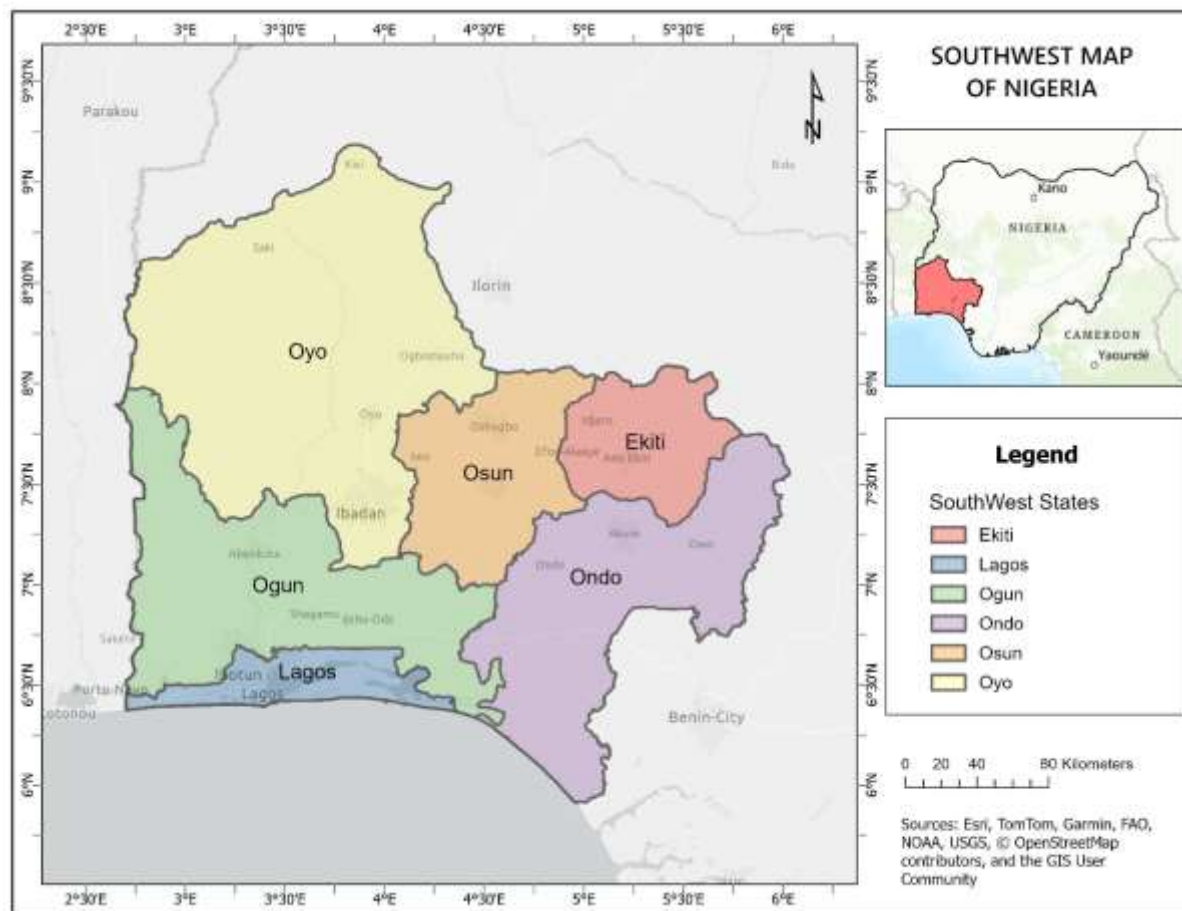


Figure 1: Map showing the geographical location of the sample collection.

Sample Collection and Preparation

Harvested *Irvingia gabonensis* were identified at the BOUESTI herbarium, Department of Biological Sciences, BOUESTI. The pericarp of the seed was separated from the seed using mortar and pestle. The pericarp was then milled using silver crest (C-1589) and Foss CT 293 cyclotec™. The resulting material was then passed through a 0.5 mm sieve to ensure uniform particle size.

Chemical Analyses

Proximate Composition Determination

Moisture Determination

Moisture content determination followed the AOAC official method 934.01.

Moisture content was evaluated in accordance with the AOAC standard protocol 934.01. Approximately 2 grams of the pre-dried sample were weighed and placed into a clean, dry aluminum dish (minimum dimensions: 50 mm diameter and 40 mm depth) with a fitted lid. The sample was then dried in a hot-air oven at 105°C for a duration of three hours under vacuum conditions, ensuring the internal pressure did not exceed 100 mm Hg. Drying continued until a constant weight was achieved, indicating the complete removal of free moisture. The difference in weight before and after drying was calculated and expressed as the moisture content of the sample.

Calculations

$$\% \text{ (w/w) LOD} = \% \text{ (w/w) moisture} = 100 \times \frac{\text{wt loss on drying,g}}{\text{wt test portion,g}} \quad (1)$$

$$\% \text{ Dry matter} = 100 - \% \text{ LOD}$$

Ash Determination

The method used followed AOAC 942.05 with little modification

Ash content was determined by incinerating 1 gram of the dried sample in a pre-weighed porcelain crucible. The crucible containing the sample was placed in a muffle furnace set at 550°C and maintained at this temperature for three hours to ensure complete combustion of organic matter. After incineration, the crucible was carefully removed and allowed to cool in a desiccator to prevent moisture absorption. It was then reweighed, and the ash content was calculated as a percentage of the original sample weight, recorded to one decimal place.

$$\% \text{ (w/w) Ash} = \frac{(\text{weight of test portion,g weight}) - (\text{loss on ashing,g}) \times 100}{\text{weight of test portion,g}} \quad (2)$$

Crude Fat Determination

The crude fat content of the sample was determined using the Soxtec extraction system (FOSS) in accordance with AOAC Official Method 2003.06. The instrument was first powered on, confirming that the “MAINS” indicator light was active. The extraction temperature was adjusted to 230°C to achieve a consistent solvent reflux rate of approximately 3–5 drops per second. Prior to starting, operational parameters for boiling, rinsing, evaporation, and pre-drying were verified and set via the system’s control panel.

To ensure efficient solvent condensation and recovery, the cooling unit was activated with the water flow rate set at 2 L/min and temperature maintained around 15°C. Extraction thimbles were prepared by placing 1 g of homogenized sample into each of six thimbles, followed by a thin layer of defatted cotton to prevent sample loss. These were securely fitted onto the extraction unit using magnetic holders and a thimble handler.

Pre-weighed and oven-dried extraction cups were filled with 70 mL of petroleum ether and carefully inserted into the unit to minimize sudden solvent vaporization. The automated cycle was initiated using the RUN/STOP control, during which the thimbles were immersed in the solvent for the boiling phase, with condenser valves kept open. After the designated boiling time, the system automatically transitioned to the rinsing phase, during which the samples were washed for 30 minutes.

Once rinsing was completed, the condenser valves were shut, and the handle was adjusted to facilitate the recovery of residual solvent. The extraction cups were then removed and placed in a drying oven at 103°C for 30 minutes to eliminate any remaining solvent. After cooling, the cups were weighed, and the fat content was calculated as the difference in mass before and after extraction.

Calculations

$$\% \text{ Crude fat, hexanes/Petroleum Ether extract} = \frac{F-T}{S} \times \frac{100}{1} \quad (3)$$

where F = weight of cup + fat residue, g; T = weight of empty cup, g;

S = test portion weight, g

Crude Fiber Determination

Crude fiber was analyzed following the procedures outlined in AACC Method 32-10, AOAC 978.10, and AOCS Ba 6-84, utilizing a Fibretec hot extraction system. Initially, fritted glass crucibles were conditioned by drying at 130°C for 30 minutes, cooled in a desiccator, and weighed using an analytical balance. Approximately 1.000 g of Celite 545 was introduced into each crucible as a filtration medium, followed by 1.000 g of the dried and milled test sample.

The Fibretec apparatus was activated, and a 1.25% sulfuric acid solution (Reagent 1) was prepared and preheated. Crucibles were mounted onto the system using a crucible holder, securely locked into position in front of the radiator unit. With the safety latch in place and the reflector engaged, all valves were initially closed to ensure safe operation. A continuous flow of cold water, maintained at approximately 1.2 L/min, was used to support the reflux mechanism.

Each digestion column was charged with 150 mL of the hot 1.25% H₂SO₄ solution along with two drops of n-Octanol to minimize foaming. The heating control was set to maximum to initiate boiling, after which the heat was adjusted to sustain a gentle boil for 30 minutes. Once acid digestion was complete, the heating unit was turned off, and the system was switched to vacuum mode. Cold water flow was increased to assist rapid filtration using a vacuum suction pump. Residual acid was removed by rinsing the samples three times with 30 mL portions of hot deionized water, with brief reverse suction applied between rinses to promote efficient cleaning.

For the alkaline digestion phase, each column received 150 mL of preheated 1.25% sodium hydroxide solution (Reagent 2), and the digestion and rinsing steps were repeated in the same manner as the acid treatment.

Upon completion of both digestion steps, the crucibles were carefully removed using a safety hook and transferred to the Fibretec cold extraction unit. To eliminate residual reagents, each crucible was treated with 25 mL of acetone, followed by vacuum filtration. This acetone wash was repeated three times. The crucibles were then left to air-dry at ambient temperature to prevent fiber decomposition from direct heat exposure.

Finally, the crucibles were oven-dried at 130°C for at least two hours, cooled in a desiccator, and weighed to the nearest 0.1 mg to determine crude fiber content gravimetrically.

Calculation

$$\% \text{ Crude Fibre} = \frac{W_2 - (W_3 + C) \times 100}{W_1} \quad (4)$$

W₁ = Sample weight

W₂ = Crucible + Residue

W₃ = Crucible + ash residue

C = Blank

Crude Protein Determination

Crude protein content was quantified following AOAC Official Method 2001.11, JAOAC protocols, and guidance from the Foss Tecator Application Note AN 300, using a block digestion system. Prior to analysis, the digestion block was preheated to a stable temperature of 420°C. A 1 g portion of the finely milled, homogenized sample was accurately weighed into individual digestion tubes. To ensure data reliability, a reagent blank was included in each batch, containing only 12 mL of concentrated sulfuric acid and two copper-based Kjeltabs catalyst tablets.

Each sample tube received two Kjeltabs Cu tablets, followed by 12 mL of concentrated H₂SO₄ dispensed with a pipetting device. For safe digestion, side heat shields were installed around the tube rack, and a

fume extraction manifold was secured above the digestion tubes. Initially, the water aspirator was set to maximum flow to facilitate the rapid evacuation of acid vapors. The sample rack was then positioned in the preheated digestion block.

After an initial 10-minute period, the aspirator flow rate was reduced to enhance the containment of acid fumes under the fume hood while maintaining a visible condensation zone within the tubes. As digestion progressed and sulfur dioxide emission decreased, vacuum strength was gradually reduced to prevent excessive loss of sulfuric acid. The digestion process was continued for approximately 50 additional minutes, resulting in a total digestion time of around one hour.

Upon completion, the heating block was turned off, and the digestion tubes were removed carefully, keeping the fume extraction system active. The hot tubes were placed on a metal rack and allowed to cool for about 20 minutes. Accelerated cooling was achieved using an air blower or by adjusting the fume hood sash to increase ventilation. Once fumes had visibly dissipated, the fume manifold was detached, the water aspirator was shut off, and protective shields were removed. Tubes were then left at room temperature to complete the cooling phase before further nitrogen analysis could be performed.

Distillation

During the distillation phase, a 40% sodium hydroxide (NaOH) solution was introduced into the alkali reservoir of the automated distillation apparatus. When available, the system's automatic dilution feature was activated to optimize the reagent concentration. A 250 mL Erlenmeyer flask, pre-filled with 30 mL of boric acid (H_3BO_3) containing a mixed pH indicator, was placed on the collection platform of the distillation unit. The outlet tube from the condenser was carefully immersed beneath the boric acid surface to ensure effective trapping of volatilized ammonia.

The sample distillation proceeded under regulated settings, and the resulting ammonia-laden distillate was captured in the boric acid medium. Upon completion of distillation, the content of the receiving flask was titrated with standardized 0.1851 N hydrochloric acid (HCl) until a persistent pink coloration signalled the endpoint of the reaction, confirming that all ammonia had been neutralized.

Calculations

Calculate the % Nitrogen according to the formula below:

$$\% \text{ Kjeldahl Nitrogen} = \frac{(V_s - V_b) \times N \times 14.007}{W \times 10} \quad (5)$$

Where:

V_s = ml of standardized acid used to titrate a sample

V_b = ml of standardized acid used to titrate a reagent blank

N = normality of standard HCl

0.2000 = normality of standard HCl

14.007 = atomic weight of nitrogen

W = weight, in grams, of sample or standard

10 = factor to convert mg/gram to percent

Calculate the % crude protein according to the formula below:

$$\% \text{ Crude Protein} = \% \text{ Kjeldahl Nitrogen} \times F \quad (6)$$

F = factor to convert nitrogen to protein

F-factors are: 6.25 = Feeds, Meats, Other samples not specified below

5.70 = Wheat

Carbohydrate Determination

Carbohydrate content was derived by subtracting the sum of moisture, ash, protein, fat, and crude fiber percentages from 100%. The caloric value (energy content) was estimated using the Atwater conversion factors, by summing the energy contributions from carbohydrates, proteins, and lipids, calculated as 4 kcal/g for both carbohydrates and proteins, and 9 kcal/g for lipids.

$$\text{Energy (kcal)} = [(4 \times \text{carbohydrate}) + (4 \times \text{protein}) + (9 \times \text{fat})] \quad (7)$$

Near-Infrared Reflectance Spectroscopy (NIRS) Instrument Analysis

To ensure analytical precision and consistency, Near-Infrared Reflectance Spectroscopy (NIRS) was employed using a FOSS DS2500 Forage Analyzer equipped with the WinISI II software suite. This system utilized globally validated calibration models developed by the International Livestock Research Institute (ILRI), based on standard laboratory procedures (AOAC, 1990; Van Soest et al., 1994), thereby enabling high-throughput and reliable data generation.

Prior to analysis, samples were oven-dried to approximately 12% moisture and ground to a consistent particle size of 0.5 mm. The spectral data obtained were used to evaluate a broad range of nutritional parameters including proximate composition (such as crude protein, crude fiber, ash, and ether extract), fiber fractions (neutral detergent fiber [NDF], acid detergent fiber [ADF], and acid detergent lignin [ADL]), and in vitro organic matter digestibility (IVOMD). Metabolizable energy (ME) was calculated and presented in megajoules per kilogram of dry matter (MJ/kg DM).

The technique also enabled detailed profiling of minerals—both macro and micro elements—quantified in parts per million (ppm). These included calcium, magnesium, potassium, sodium, phosphorus, iron, zinc, manganese, and copper. Amino acid concentrations were determined and expressed in grams per 100 grams of dry matter (g/100 g DM), covering a wide spectrum such as glutamic acid, aspartic acid, lysine, methionine, leucine, isoleucine, and tryptophan, among others.

Additionally, the fatty acid profile was characterized and reported in milligrams per 100 grams dry matter (mg/100 g DM). This included assessments of saturated, monounsaturated, and polyunsaturated fatty acids, with specific attention to omega-3 and omega-6 groups.

Antioxidant Potential

Determination of the Ferric Reducing Antioxidant Potential (FRAP)

The ferric-reducing antioxidant capacity of *Irvingia gabonensis* seed pericarp was assessed following a modified protocol adapted from Zhang et al. (2008). A test solution was prepared by dissolving the sample and a standard (L-ascorbic acid, 10 mg) in 1 mL of 0.2 M phosphate buffer (pH 6.6). A 250 µL aliquot of this solution was combined with 250 µL of phosphate buffer and 250 µL of 1% potassium ferricyanide.

The mixture was homogenized using a centrifuge set at 1,000 rpm for 10 minutes, then incubated in a water bath at 50°C for 20 minutes to promote reduction. Following the incubation, 250 µL of 10% trichloroacetic acid was added to stop the reaction. This was followed by the sequential addition of 50 µL of 0.1% ferric chloride solution (prepared in double-distilled water) and 750 µL of deionized water to achieve a final sample concentration of 2.5 mg/mL in the reaction mixture.

The prepared solution was allowed to stand at ambient temperature for 10 minutes before undergoing centrifugation at 1,000 rpm for another 10 minutes. Finally, 200 µL of the supernatant was transferred into a cuvette, and the absorbance was measured at 700 nm. L-ascorbic acid served as the positive control for the assay.

Determination of Antioxidant Activity of *Irvingia gabonensis* by Reaction with 2,2'-Diphenyl-1-Picrylhydrazyl (DPPH)

The antioxidant activity of the extract was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method, with slight modifications to the procedure described by Brand-Williams et al. (1995). A 1 mM DPPH solution was freshly prepared in ethanol and stored in a brown bottle at room temperature to minimize light-induced degradation. The extract was prepared at a concentration of 5 mg/5mL (1 mg/mL) in ethanol.

For the assay, 4.0 mL of the extract solution was mixed with 1.0 mL of the DPPH solution in a test tube. The mixture was vortexed briefly, then incubated in the dark at room temperature for 30 minutes. The absorbance was measured at 517 nm using a UV-Visible spectrophotometer (Cecil 3041), with ethanol serving as the blank. All measurements were conducted in duplicate.

The percentage inhibition of DPPH radical was calculated using the following formula:

$$\% \text{ Inhibition: } \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100 \dots \dots \dots (8)$$

Where A_{control} = is the absorbance of the DPPH solution without extract, A_{sample} = is the absorbance of the reaction mixture containing the extract.

Statistical Analysis

The data obtained were analysed using descriptive statistics. A Student's t-test was performed to compare the mean nutritive values between *Irvingia gabonensis* and FAO recommended nutrient values in order to identify conformance or deviations from the standard values recommended by the FAO.

RESULTS

Table 1: Nutritional and phytochemical properties of *Irvingia gabonensis* seed pericarp (mean $\pm$ SD, n=3)

Parameter	Content	Unit
Proximate Composition		
Moisture	9.35 $\pm$ 0.05	%
Crude Protein	2.72 $\pm$ 0.04	%
Crude Fat	3.11 $\pm$ 0.06	%
Crude Fiber	30.42 $\pm$ 0.06	%
Ash	2.56 $\pm$ 0.21	%
Carbohydrate	51.84 $\pm$ 0.26	%
Metabolisable Energy	2462.2 $\pm$ 7.4	kcal/kg
Fiber Fractions		
Acid Detergent Fiber (ADF)	63.39 $\pm$ 0.36	%
Acid Detergent Lignin (ADL)	18.24 $\pm$ 0.20	%
Neutral Detergent Fiber (NDF)	76.31 $\pm$ 0.31	%
Antioxidant Activity		
DPPH Radical Scavenging Activity	52.83 $\pm$ 0.25	% inhibition
FRAP	0.055 $\pm$ 0.001	mM Vit C equivalent/mL
Mineral Content		
Sodium	3237.5 $\pm$ 12.6	mg/kg
Potassium	12384.4 $\pm$ 267.5	mg/kg
Manganese	82.6 $\pm$ 5.8	mg/kg
Iron	182.6 $\pm$ 28.5	mg/kg
Copper	10.65 $\pm$ 0.11	mg/kg
Zinc	24.63 $\pm$ 0.15	mg/kg
Phosphorus	4046.6 $\pm$ 42.7	mg/kg
Digestibility		
In vitro Organic Matter Digestibility	31.71 $\pm$ 0.11	%
Fatty Acid Profile		
Omega-6 Fatty Acids	10646.0 $\pm$ 130.4	mg/100g
Trans Fatty Acids	5.61 $\pm$ 0.09	mg/100g
Saturated Fatty Acids	1810.9 $\pm$ 209.1	mg/100g
Polyunsaturated Fatty Acids	10861.7 $\pm$ 187.3	mg/100g
Amino Acid Profile		
Glycine	0.73 $\pm$ 0.03	%
Alanine	0.40 $\pm$ 0.01	%
Proline	0.83 $\pm$ 0.01	%
Valine	0.12 $\pm$ 0.01	%
Methionine	0.05 $\pm$ 0.01	%
Leucine	0.45 $\pm$ 0.01	%

Table 2: FAO poultry feed requirement for broilers (starter and finisher)

Nutrient	Starter (0–3 weeks)	Finisher (4–6 weeks)	Finisher (6-8 weeks)
Crude Protein (%)	23	20	18
Calcium (%)	1.0	0.90	0.80
Phosphorus (%)	0.45	0.35	0.35
Chlorine (%)	0.20	0.15	0.12
Potassium (%)	0.30	0.30	0.30
Sodium (%)	0.20	0.15	0.12
Metabolisable Energy (kcal/kg)	3200	3200	3200
Linoleic Acid	1.00	1.00	1.00
Lysine (%)	1.10	1.00	0.85
Methionine (%)	0.50	0.38	0.32
Methionine+ Cystine (%)	0.90	0.72	0.60
Threonine (%)	0.80	0.74	0.64
Tryptophan (%)	0.20	0.18	0.16
Arginine (%)	1.25	1.10	1.00
Valine (%)	0.90	0.82	0.70
Isoleucine (%)	0.80	0.73	0.63
Leucine (%)	1.20	1.09	0.93
Histidine (%)	0.35	0.32	0.27
Phenylalanine + Tyrosine (%)	1.34	1.22	1.04
Phenylalanine (%)	0.72	0.65	0.56

Source: Ravindran, (2013)

Table 3: FAO poultry feed requirement for laying birds

Nutrient	Requirement
Crude Protein (%)	15
Calcium (%)	3.25
Phosphorus (%)	0.25
Potassium (%)	0.15
Chlorine (%)	0.13
Sodium (%)	0.15
Metabolisable Energy (kcal/kg)	2900
Linoleic Acid (%)	1.00
Lysine (%)	0.69
Methionine + Cystine (%)	0.58
Methionine (%)	0.30
Threonine (%)	0.47
Tryptophan (%)	0.16
Arginine (%)	0.70
Valine (%)	0.70
Isoleucine (%)	0.65
Leucine (%)	0.82
Histidine (%)	0.17
Phenylalanine + Tyrosine (%)	0.83
Phenylalanine (%)	0.47

Source: Ravindran, (2013)

Table 4. Key nutritional parameters of *Irvingia gabonensis* seed pericarp compared to FAO poultry feed requirements

Parameter	<i>I. gabonensis</i> (Mean $\pm$ SD)	Unit	FAO Broiler Requirement (Starter/Finisher)	FAO Layer Requirement	Gap Analysis
Crude Protein	2.72 $\pm$ 0.04	%	23/20/18	15	Severe deficit
Crude Fat	3.11 $\pm$ 0.06	%	5–8	3–5	Marginal deficit
Crude Fiber	30.42 $\pm$ 0.06	%	$\leq$ 5	$\leq$ 5	Excessively high
Metabolisable Energy	2462.2 $\pm$ 7.4	kcal/kg	3200	2900	Significant deficit
Calcium	2.56 $\pm$ 0.21	%	1.0/0.9/0.8	3.25	Layers: Deficit Broilers: Excess
Phosphorus	4046.6 $\pm$ 42.7	mg/kg	4500/3500/3500	2500	Broilers: Marginal deficit
Sodium	3237.5 $\pm$ 12.6	mg/kg	2000/1500/1200	1500	Excess
Potassium	12384.4 $\pm$ 267.5	mg/kg	3000	1500	Excess
Lysine	NA	%	1.10/1.00/0.85	0.69	NA
Methionine + Cystine	NA	%	0.90/0.72/0.60	0.58	NA
Valine	0.12 $\pm$ 0.01	%	0.90/0.82/0.70	0.70	Severe deficit
Leucine	0.45 $\pm$ 0.01	%	1.20/1.09/0.93	0.82	Severe deficit

NA: Not Available

DISCUSSION

The nutritional characteristics of *Irvingia gabonensis* seed pericarp offer promising, though specialized, applications within poultry feeding systems, particularly when utilized as a functional supplement rather than a core protein source. Its markedly high neutral detergent fiber (76.31%) and acid detergent lignin (18.24%) content limit its inclusion as a conventional feed ingredient but open avenues for specific functional roles. For instance, lignocellulosic-rich ingredients with similar profiles have been shown to promote gizzard development and improve nutrient utilization when incorporated at low levels—typically around 5%—in finisher diets. This mechanical stimulation of the gizzard supports enhanced feed efficiency and gastrointestinal health (Jiménez-Moreno et al., 2010).

Moreover, the pericarp's substantial phosphorus concentration (4,046 mg/kg) holds potential for reducing reliance on inorganic phosphate additives. When combined with exogenous phytase enzymes, the bioavailability of phytate-bound phosphorus can be significantly improved, thereby supporting skeletal integrity and minimizing phosphorus losses in excreta—an effect well-documented in poultry nutrition research (Selle et al., 2009; Walk & Rama Rao, 2020).

In addition, the pericarp's antioxidant potential, evidenced by its 52.83% DPPH radical scavenging activity, suggests its suitability as a dietary antioxidant carrier. This function could be particularly advantageous in heat-stressed broilers, where oxidative stress impairs meat quality and overall performance. Incorporating natural antioxidants in such conditions has been shown to enhance immune function, reduce oxidative damage, and improve production outcomes (Alagawany et al., 2021).

In layer production systems, *Irvingia gabonensis* pericarp addresses distinct nutritional priorities. Its phosphorus content (0.40%) surpasses the typical requirement for layers (0.25%), suggesting potential to reduce dependence on imported mineral phosphates. Incorporating the pericarp at 3–4% inclusion in post-peak diets can provide moderate metabolizable energy (2,462 kcal/kg) and slow digestibility, aiding in maintaining egg mass while controlling feed costs. Studies have shown that agro-industrial by-products, when included at similar levels, can support egg production without adverse effects (El-Hack et al., 2019). Although the calcium content (2.56%) of the pericarp is insufficient as a sole source, its favourable Ca:P ratio can enhance the utilization of supplemental calcium sources like oyster shells. Research indicates that appropriate balancing of calcium and phosphorus, along with the inclusion of fibrous materials, can improve eggshell quality and prevent issues associated with excessive limestone supplementation (Masa'deh et al., 2011).

CONCLUSION

This study demonstrates that *Irvingia gabonensis* seed pericarp, while nutritionally inadequate as a standalone feed ingredient, holds promise as a functional supplement in poultry diets when strategically processed and incorporated. For broilers, its high fiber and mineral content (particularly phosphorus) may serve as a gut health modulator and partial mineral replacement at ≤5% inclusion. In layers, the pericarp's mineral profile and antioxidant properties could support egg production efficiency when balanced with calcium sources and amino acid fortification.

Key challenges persist regarding fiber digestibility and optimal inclusion levels, necessitating further research into cost-effective processing methods like solid-state fermentation. However, these findings provide a scientifically grounded framework for valorizing *I. gabonensis* byproducts in poultry nutrition—not as soybean alternatives, but as complementary ingredients that address specific nutritional gaps in resource-limited settings.

Author Contribution Statement

Conceptualization: Conceptualization of the study was carried out by **Francis Adebayo, Ayodele Oyedeji, and Tolulope Borisade**, with support from **Stephen Ibikunle** and **Oluwasegun Ibidiran**.

Data Curation: Conducted by all five authors.

Laboratory and Data Analysis: Performed by **Stephen Ibikunle** and validated by the remaining four authors.

Resources: Provided by all five authors.

Writing – Original Draft: Prepared by all five authors.

Draft Review and Editing: The final draft was reviewed by **Francis Adebayo, Ayodele Oyedeji, Tolulope Borisade, and Stephen Ibikunle.**

Fund Statement

This research was funded by the Tertiary Education Trust Fund (TETFund) under the Institutional-Based Research (IBR) scheme. The support provided by the TETFund Office at Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti (BOUESTI), and the Centre for Research and Development (CERAD), BOUESTI, was instrumental in the successful completion of this study.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this research. The funding agency, Tertiary Education Trust Fund (TETFund), had no role in the study's design, data collection, analysis, interpretation, manuscript preparation, or decision to publish. The authors affirm that there are no financial, personal, or professional relationships that could have influenced the outcomes of this research.

Acknowledgement

The authors gratefully acknowledge the Tertiary Education Trust Fund (TETFund) for funding this Institutional-Based Research (IBR). Appreciation is also extended to the Vice-Chancellor of Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, for cultivating a supportive research environment. The contributions of the TETFund Office and the Centre for Research and Development (CERAD) at BOUESTI are deeply appreciated, as their unwavering support played a pivotal role in the successful execution of this study.

REFERENCES

- Abd El-Hack, M. E., Mahrose, K. M., Attia, F. A., Swelum, A. A., Taha, A. E., Shewita, R. S., & Alowaimier, A. N. (2019). Laying performance, physical, and internal egg quality criteria of hens fed distillers dried grains with solubles and exogenous enzyme mixture. *Animals*, 9(4), 150.
- Alagawany, M. M., Farag, M. R., Kuldeep Dhama, K. D., El-Hack, M. E. A., Ruchi Tiwari, R. T., & Alam, G. M. (2015). Mechanisms and beneficial applications of resveratrol as feed additive in animal and poultry nutrition: a review.
- AOAC (1990). *Official Methods of Analysis* (15th ed.). Association of Official Analytical Chemists, Arlington, VA, USA.
- Ayivor, J. E. (2011). Evaluation of Elemental Contents of Wild Mango (*Irvingia gabonensis*) Fruit in Ghana. *Advance Journal of Food Science and Technology* 5: 381-384.
- Ayuk, E.T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki-Manga, T. & Zenkekeng, P. (1999). "Uses, Management and Economic Potential of *Irvingia gabonensis* in the Humid Lowlands of Cameroon". *Forest Ecology and Management* 113 (5): 36-42
- Ayuk, E. T. (1999). Uses, management and economic potential of *Irvingia gabonensis* in the humid lowlands of Cameroon. *Forest Ecology and Management* 113: 1 pp.1-9.
- Borisade, T.V., Odiwe, A.I., Akinwumiju, A.S., Uwalaka, N.O. & Orimoogunje, O.I. (2021). Assessing the impact of land use on riparian vegetation dynamics in Osun State, Nigeria. *Trees, Forests and People* 5(100099)
- Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology*, 28(1), 25–30. [https://doi.org/10.1016/S0023-6438\(95\)80008-5](https://doi.org/10.1016/S0023-6438(95)80008-5)
- CAB (2000). *Forestry Compendium Global Module 1*. Wallingford, Uk, CAB International. pp 1-2.
- Food and Agriculture Organization. (2013). *Poultry development review*. FAO. <https://www.fao.org/4/i3531e/i3531e.pdf>
- González-Ríos, H., Dávila-Ramírez, J. L., Peña-Ramos, E. A., Valenzuela-Melendres, M., Zamorano-García, L., Islava-Lagarda, T. Y. & Valenzuela-Grijalva, N. V. (2016). Dietary supplementation

- of ferulic acid to steers under commercial feedlot feeding conditions improves meat quality and shelf life. *Animal Feed Science and Technology* 222: 111–121.
- Jiménez-Moreno, E., González-Alvarado, J. M., González-Sánchez, D., Lázaro, R., & Mateos, G. G. (2010). Effects of type and particle size of dietary fiber on growth performance and digestive traits of broilers from 1 to 21 days of age. *Poultry Science*, 89(10), 2197-2212.
- Lesley, A., & Nick, B., (2000). *Irvingia gabonensis* & *Irvingia wombolu*. A State of Knowledge Report undertaken for The Central African Regional Program for the Environment by Oxford Forestry Institute. Department of Plant Sciences, University of Oxford United Kingdom.
- Lillehoj, H., Liu, Y., Calsamiglia, S., Fernandez-Miyakawa, M. E., Chi, F., Cravens, R. L., & Gay, C. G. (2018). Phytochemicals as antibiotic alternatives to promote growth and enhance host health. *Veterinary research*, 49, 1-18.
- Masa'deh, MK., Purdum, SE., & Hanford, KJ. (2011) Dried distillers grains with solubles in laying hen diets. *Poult Sci.* doi: 10.3382/ps.2010-01184. PMID: 21844261.
- Mgbemena, M. M., Ilechukwu, I., Okwunodolu, F. U., Chukwurah, J. O. & Lucky, I. B. (2019). Chemical composition, proximate and phytochemical analysis of *Irvingia gabonensis* and *Irvingia gombolu* peels, seed coat, leaves, and seeds. *Ovidius University Annals of Chemistry* 30: 65–69
- Obianime, A.W. & Uche F. I. (2010). Effects of aqueous extracts of *Irvingia gabonensis* seeds on the hormonal parameters of male guinea pigs. *Asian Pacific Journal of Tropical Medicine* (2010) 200-204
- Ravindran, V. (2013). Poultry feed availability and nutrition in developing countries. *Poultry Development Review*, 60-63.
- Selle, P. H., Cowieson, A. J., & Ravindran, V. (2009). Consequences of calcium interactions with phytate and phytase for poultry and pigs. *Livestock science*, 124(1-3), 126-141.
- Van Soest, P. V., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of dairy science*, 74(10), 3583-3597.
- WAC, 2004: *Irvingia gabonensis*. In: World Agroforestry Center, Botanical Nomenclature. <http://www.worldagroforestry.org/Site/TreeDBS/Botanic/Speciesinfo.cfm?SpID=4413>.
- Walk, C. L. & Rao, S. R. (2020). Dietary phytate has a greater anti-nutrient effect on feed conversion ratio compared to body weight gain and greater doses of phytase are required to alleviate this effect as evidenced by prediction equations on growth performance, bone ash and phytate degradation in broilers. *Poultry science*, 99(1), 246-255.
- Zhang, S.B., Wang, Z., Xu, S.Y. (2008). Antioxidant and anti-thrombotic activities of rapeseed peptides. *Journal of the American Oil Chemists' Society*, 85(6), 521–527.