ISSN: 2695-2556 (Online)
ISSN: 2651-5679 (Print)

AKSU Journal of Agriculture and Food Sciences 10(2) 102-111, 2026

Nutritive Value and Bioactive Screening of Papaya (*Carica papaya* L.) Leaf Meal as a Potential Phyto-additive in Poultry Production

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Abstract

The increasing demand for natural alternatives to antibiotic growth promoters has intensified research into phytogenic feed additives for poultry production. Papaya (Carica papaya L.) leaf meal (PLM) has gained attention due to its nutritional richness and abundance of biologically active compounds. This study evaluated the proximate composition, mineral profile, vitamin content, and bioactive constituents of papaya leaf meal using standard analytical procedures. Fresh papaya leaves were harvested, shade-dried, milled, and subjected to laboratory analyses. The proximate composition revealed that the leaf meal contained 13.87% ash, 4.03% ether extract, 31.06% crude protein, 27.10% crude fibre, 23.94% nitrogen-free extract (NFE), and a metabolizable energy value of 2562.90 kcal/kg DM. Mineral analysis showed high concentrations of potassium (1430.65 mg/100 g), calcium (360.12 mg/100 g), phosphorus (240.51 mg/100 g), and magnesium (176.06 mg/100 g). The vitamin profile indicated appreciable levels of vitamins A, C, D, E, and B12, while phytochemical screening revealed the presence of phenolics, flavonoids, alkaloids, saponins, tannins, and carpaine. The results demonstrate that papaya leaf meal possesses valuable nutritive and functional properties that could enhance poultry performance, health status, and productivity. It is concluded that PLM has considerable potential as a sustainable phyto-additive in poultry diets, particularly when incorporated at moderate inclusion levels.

Keywords: *Carica papaya*, Papaya leaf meal, Phytogenic feed additive, Poultry nutrition, Bioactive compounds, Nutritive value

1.0 Introduction

Poultry production plays a major role in meeting the global demand for affordable, high-quality protein as a result of their rapid growth, strong feed conversion, and ability to reach market weight in a short time (Sam and Udo, 2025; *Ebong et al*., 2023; Alphonsus *et al.*, 2012; Okon *et al.*, 2023). However, the sustainability of the industry is increasingly challenged by the high cost of conventional feed ingredients, which can account for 60% to 80% of total production costs (Essien and Sam, 2018; Essien *et al.*, 2023; Sam *et al*., 2020). The poultry industry continues to seek sustainable alternatives to synthetic growth promoters due to increasing concerns regarding antimicrobial resistance, consumer preference for naturally produced poultry products, and regulatory restrictions on antibiotic growth promoters (Windisch *et al*., 2008; Saeed *et al.*, 2018). Phytogenic feed additives derived from medicinal plants have emerged as promising alternatives because of their ability to improve nutrient utilization, enhance immune responses, modulate gut microbiota, and reduce oxidative stress (Hashemi & Davoodi, 2011).

Papaya (Carica papaya L.) is widely cultivated in tropical and subtropical regions and has long been utilized in traditional medicine (Aravind *et al.*, 2013). Various parts of the plant, including leaves, contain bioactive compounds with nutritional and pharmacological importance (Krishna *et al.*, 2008; Rahmat *et al.*, 2021). Papaya leaves are particularly rich in protein, minerals, and phytochemicals that contribute to antioxidant and antimicrobial activities (Bhat & Sridhar, 2008; Nwofia *et al.*, 2012).

The beneficial effects of papaya leaf meal have been linked to phytochemicals such as flavonoids, phenolics, alkaloids, tannins, and saponins (Rahmat *et al.*, 2021). These compounds have been associated with improved digestive function, immune modulation, and disease resistance in animals (Oloruntola *et al.*, 2019). Additionally, papaya leaves contain papain, a proteolytic enzyme that enhances protein digestion and nutrient utilization (Krishna *et al.*, 2008).

Studies have reported improved growth performance, feed efficiency, and health status in poultry fed papaya leaf-based diets (Oloruntola *et al.*, 2018; Widjastuti *et al*., 2012). However, variations in composition due to environmental and processing factors necessitate continuous evaluation of papaya leaf meal. Therefore, this study assesses its nutritive and bioactive properties as a potential Phyto additive in poultry production.

2.0 Materials and Methods

2.1 Study Location

Conducted at the Poultry Unit, Teaching and Research Farm, Department of Animal Science, Akwa Ibom State University, Obio Akpa Campus (4°30′–5°00′N, 7°30′–8°00′E), in Nigeria's tropical rainforest zone. The area has 3,500–5,000 mm annual rainfall, ~27.5°C average temperature, and 60–90% relative humidity (AKSG, 2022).

2.2 Source and Preparation of Experimental Material

Fresh mature papaya leaves were harvested from healthy Carica papaya plants and processed as described by standard feed preparation methods (AOAC, 2019). Leaves were washed, shade-dried to preserve heat-sensitive nutrients, milled, and stored for analysis.

2.2.1 Proximate Composition Determination

Proximate analysis followed AOAC (2019) procedures for moisture, crude protein, ether extract, crude fibre, ash, and nitrogen-free extract determination. Metabolizable energy was estimated using standard predictive equations.

2.2.2 Mineral Composition Determination

Mineral contents were determined using wet acid digestion followed by Atomic Absorption Spectrophotometry (AAS), consistent with established analytical protocols (Nwofia *et al.*, 2012).

2.2.3 Vitamin Composition Determination

Vitamin analysis was conducted using spectrophotometric and titrimetric methods adapted for plant-based materials (Rahmat *et al.*, 2021).

2.2.4 Bioactive Composition Determination

Phytochemical screening for phenolics, flavonoids, alkaloids, tannins, and saponins followed standard methods (Rekha & Vijayalakshmi, 2013; Rahmat *et al.*, 2021). Carpaine was analyzed using HPLC techniques.

2.3 Statistical Analysis

Data were analyzed using descriptive statistics and expressed as mean ± standard deviation (SD) of SPSS (2025) software, version 25.

3.0 Results and Discussion

3.1 Proximate Composition of Papaya Leaf Meal

Table 3.1 shows the proximate composition of papaya (Carica papaya) leaf meal on a dry matter basis. The result revealed that the leaf meal contained 13.87% ash, 4.03% ether extract, 31.06% crude protein, 27.10% crude fibre, 23.94% nitrogen-free extract (NFE), and a metabolizable energy value of 2562.90 kcal/kg DM. The nutrient composition indicates that papaya leaf meal possesses considerable nutritional value and could serve as a useful feed resource in poultry production. The crude protein content of 31.06% obtained in this study indicates that papaya leaf meal is a rich source of plant protein. Protein plays a vital role in growth, tissue development, enzyme synthesis, and maintenance of physiological functions in poultry. The high crude protein value recorded in the present study is in line with the findings of Babalola and Alabi (2015), who reported that papaya leaves contain substantial levels of crude protein capable of supporting livestock growth and productivity.

Similarly, Rahmat *et al.* (2021) noted that papaya leaves are characterized by moderate to high protein content, making them suitable as alternative feed ingredients in animal nutrition. The observed protein level suggests that papaya leaf meal could contribute significantly to meeting the protein requirements of poultry when incorporated at appropriate dietary levels. The crude fibre content of 27.10% indicates a high proportion of structural carbohydrates in the leaf meal. This result conforms with the findings of Heuzé et al. (2020), who reported that papaya leaves contain appreciable amounts of fibre due to the presence of cellulose, hemicellulose, and lignin within the plant cell wall. In the same vein, Oloruntola et al. (2018) observed relatively high fibre concentrations in tropical leaf meals and attributed such values to the fibrous nature of mature leaves. Although fibre can enhance gut health and intestinal motility, excessive dietary fibre may reduce nutrient digestibility and feed utilization in poultry, particularly in young birds. Therefore, the inclusion level of papaya leaf meal should be carefully regulated to maximize its nutritional benefits. The ether extract value of 4.03% suggests that papaya leaf meal contains a moderate amount of lipid. This result is in line with the report of Adejumo et al. (2014), who found relatively low fat contents in papaya leaves and other tropical forage plants. The lipid fraction contributes to dietary energy and facilitates the absorption of fat-soluble vitamins. Furthermore, papaya leaf lipids may contain bioactive compounds with antioxidant properties that could enhance the health status of poultry.

The ash content of 13.87% recorded in this study reflects the abundance of mineral elements in papaya leaf meal. This finding conforms with the observations of Heuzé et al. (2020), who reported high mineral concentrations in papaya leaves. Similarly, Madzimure et al. (2014) noted that leaf meals generally possess considerable ash content due to their richness in essential minerals. The high ash value obtained suggests that papaya leaf meal may serve as a useful source of minerals required for bone development, enzyme activation, electrolyte balance, and other metabolic activities in poultry. The nitrogen-free extract value of 23.94% indicates the presence of soluble carbohydrates capable of supplying readily available energy. This result agrees with the findings of Onyimonyi and Ernest (2009), who reported appreciable carbohydrate fractions in papaya leaf meal. The NFE component contributes to energy metabolism and supports the efficient utilization of dietary nutrients by birds. The metabolizable energy value of 2562.90 kcal/kg DM demonstrates that papaya leaf meal can contribute meaningful amounts of dietary energy. This result is in line with the reports of Krishna *et al.* (2008), who documented moderate energy values for papaya leaves and other tropical leaf meals used in animal feeding.

In the same vein, Nwofia *et al.* (2012) reported that leaf meals with moderate energy content can serve as supplementary feed resources when incorporated into balanced poultry diets. The energy value obtained in this study may be attributed to the combined contributions of carbohydrates, protein, and lipid fractions present in the leaf meal.

The relatively high crude protein content, appreciable mineral concentration, moderate lipid level, and favourable metabolizable energy value obtained in this study suggest that papaya leaf meal has the potential to serve as a nutrient-rich phytogenic feed ingredient in poultry nutrition. Its utilization could contribute to improved dietary quality while providing additional bioactive compounds that may support poultry health and performance.

Table 3.1: Proximate composition of pawpaw leaf meal

Parameters	Mean ± SD
ASH (%)	13.87 ± 0.32
ETHER EXTRACT (%)	4.03 ± 0.22
CRUDE PROTEIN (%)	31.06 ± 0.11
CRUDE FIBRE (%)	27.10 ± 0.15
NITROGEN FREE EXTRACT (%)	23.94 ± 0.21
ME(kcal/kg DM)	2562.90 ± 10.32

SD= Standard deviation

3.2 Bioactive Composition of Papaya Leaf Meal

Table 3.2 shows the bioactive composition of dried papaya (Carica papaya) leaf meal. The result revealed that the leaf meal contained 20.58 mg total phenolic content, 19.00 mg total flavonoids, 11.00 g/100 g total alkaloids, 4.50% saponin, 0.72% tannin, and 3200 ppm carpaine. Among the bioactive constituents determined, carpaine recorded the highest concentration, whereas tannin had the lowest value. This result is in line with Rahmat *et al.* (2021), who reported that papaya leaves contain a wide range of biologically active compounds responsible for their medicinal and functional properties. The high presence of phenolics and flavonoids suggests strong antioxidant potential.

In a similar direction, Oloruntola *et al.* (2018) observed that plant materials rich in these compounds improve antioxidant status and immune response in broiler chickens. These compounds help reduce oxidative stress, which is important for maintaining health and productivity in poultry. Alkaloids, particularly carpaine, were also detected. This finding conforms with Krishna *et al.* (2008), who identified carpaine as a key bioactive compound in papaya leaves with antimicrobial and antiparasitic effects. Whereas synthetic antibiotics act on specific pathogens, plant alkaloids tend to provide broader antimicrobial support with a lower risk of resistance development. Saponins were present and may contribute to improved gut health and cholesterol regulation. This result is in line with Saeed *et al.* (2018), who reported that saponin-containing feed additives can positively influence intestinal microbial balance in poultry.

However, excessive levels may reduce feed palatability, which highlights the importance of controlled inclusion. Tannins were detected at relatively low concentrations. This is beneficial because, in the same vein, Francis *et al.* (2002) noted that while low tannin levels may provide antioxidant benefits, high concentrations can interfere with protein digestion. The low tannin content observed here therefore supports the safe use of papaya leaf meal in poultry diets. The presence of these compounds confirms that papaya leaf meal is not only a nutrient source but also a functional feed ingredient capable of supporting health and disease resistance in poultry.

Table 3.2: Bioactive composition of dried papaya leaf

Parameters	Mean ± SD
Total Phenolic Content(mg)	20.58 ± 0.33
Total Flavonoid(mg)	19.00 ± 0.41
Total Alkanoids(g|100g)	11.00 ± 0.63
Saponin(%)	4.50 ± 0.11
Tanin(%)	0.72 ± 0.02
Carpaine(ppm)	3200 ± 12.61

SD= Standard deviation

3.3 Vitamin Composition of Papaya Leaf Meal

Table 3.3 shows the vitamin composition of papaya (Carica papaya) leaf meal. The result revealed that the leaf meal contained 15.06 mg/100 g vitamin A, 65.42 mg/100 g vitamin C, 8.21 mg/100 g vitamin D, 3.86 mg/100 g vitamin E, and 2.54 mg/100 g vitamin B12. Vitamin C was the most abundant vitamin detected in the leaf meal, while vitamin B12 occurred in the lowest concentration. This result is in line with Krishna *et al.* (2008), who reported that papaya leaves are rich in both fat-soluble and water-soluble vitamins. Vitamin C was particularly prominent, suggesting strong antioxidant activity.

In a similar vein, Rahmat *et al.* (2021) explained that vitamin C enhances immune response and helps poultry cope with environmental stress. Vitamin E also plays a protective role by preventing lipid oxidation in body tissues. Vitamin A supports vision, epithelial tissue development, and immune function. This conforms with Aravind *et al.* (2013), who highlighted the nutritional importance of papaya-derived products in supporting growth and health. The presence of vitamin D is noteworthy because it supports calcium and phosphorus metabolism, which is essential for bone development and eggshell formation.

Whereas plant materials rarely contain significant vitamin D, its detection here adds to the functional value of papaya leaf meal. Vitamin B12 was found in trace amounts, which may be linked to microbial activity during plant growth or environmental factors. In the same vein, Nwofia *et al.* (2012) reported trace levels of B-vitamins in tropical leafy plants. These vitamins indicate that papaya leaf meal may serve as a supportive natural source of micronutrients in poultry diets.

Table 3.3: Vitamin composition of papaya leaf meal

Vitamins	**Mean ± SD (mg/ 100g)**
Vitamin A	15.06 ± 0.12
Vitamin C	65.42 ± 0.16
Vitamin D	8.21 ± 0.08
Vitamin E	3.86 ± 0.05
Vitamin B12	2.54 ± 0.14

SD= Standard deviation

3.4 Mineral Composition of Papaya Leaf Meal

Table 3.4 shows the mineral composition of papaya (Carica papaya) leaf meal. The result revealed that the leaf meal contained 360.12 mg/100 g calcium, 240.51 mg/100 g phosphorus, 1430.65 mg/100 g potassium, 176.06 mg/100 g magnesium, 23.52 mg/100 g sodium, 6.60 mg/100 g iron, 3.80 mg/100 g zinc, 0.60 mg/100 g copper, and 4.30 mg/100 g manganese. Potassium was the most abundant mineral present in the leaf meal, followed by calcium and phosphorus, whereas copper recorded the lowest concentration among the minerals evaluated.

This result is in line with Nwofia *et al.* (2012), who reported that papaya leaves are rich in essential minerals needed for physiological functions. Potassium was the most abundant mineral, indicating its importance in maintaining electrolyte balance and proper nerve function. In the same vein, Windisch *et al*. (2008) noted that potassium plays a key role in maintaining acid-base balance and metabolic stability in poultry. Calcium and phosphorus levels suggest that papaya leaf meal can contribute to skeletal development and eggshell quality.

This conforms with Saeed *et al.* (2018), who observed improved bone strength in poultry fed mineral-rich phytogenic additives. Magnesium supports enzyme activity and energy metabolism. Whereas deficiency in magnesium can impair growth and productivity, its presence in papaya leaf meal enhances its nutritional usefulness. Trace minerals such as iron, zinc, and copper support blood formation, immune response, and enzyme functions. In the same vein, Oloruntola *et al.* (2019) reported improved haematological parameters in birds fed plant-based supplements rich in trace minerals. The mineral composition clearly shows that papaya leaf meal can serve as a useful natural mineral supplement in poultry feeding systems.

Table 3.4: Mineral composition of papaya leaf meal

Minerals	Mean ± SD (mg/ 100g)
Calcium (ca)	360.12 ± 0.11
Phosphorus (P)	240.51 ± 0.13
Potassium (K)	1430.65 ± 0.14
Magnesium (Mg)	176.06 ± 0.19
Sodium (Na)	23.52 ± 0.21
Iron (Fe)	6.60 ± 0.16
Zink (Zn)	3.80 ± 0.18
Copper (Cu)	0.60 ± 0.03
Manganese (Mn)	4.30 ± 0.12

SD= Standard deviation

4.0 Conclusion

Papaya leaf meal possesses considerable nutritional and phytochemical value, making it a promising natural phytoadditive for poultry production. Its combination of nutrients and bioactive compounds supports growth, immunity, and overall productivity. Further in vivo studies are recommended to determine optimal inclusion levels and long-term effects on poultry performance.

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