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Nutritional composition and biomass valorization potential of *Terminalia catappa* leaf litter

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This study evaluated the proximate composition and assessed the nutritional potential of *Terminalia catappa* leaf litter as a sustainable biomass resource for feed and agro-industrial applications. Proximate analysis revealed that carbohydrates (43.24 ± 0.06%) was the most abundant component, followed by crude fiber (26.90 ± 0.06%), crude fat (12.39 ± 0.06%), moisture (12.32 ± 0.04%), and ash (11.27 ± 0.05%), while crude protein (7.21 ± 0.02%) was the least abundant. The high carbohydrate and fiber contents indicate that the biomass can serve as an energy source and support digestive function, particularly in ruminant animals. Mineral analysis confirmed the presence of essential macro- and micro-elements, including calcium, magnesium, potassium, iron, and zinc, highlighting its potential contribution to micronutrient supply, although the values obtained were solvent-dependent and do not represent absolute composition. Anti-nutritional factor analysis showed that tannins (2.85 ± 0.12 mg/g), phytate (1.92 ± 0.08 mg/g), and oxalate (1.35 ± 0.06 mg/g) were present at low to moderate levels, suggesting minimal interference with nutrient bioavailability. The findings demonstrate that *T. catappa* leaf litter possesses significant nutritional value and can be utilized as a low-cost supplementary feed resource. This study establishes a viable pathway for biomass valorization by converting an underutilized plant residue into a functional material, thereby supporting sustainable agriculture and the development of a circular bioeconomy.

Key words: *Terminalia catappa* leaf litter, proximate composition, biomass valorization, nutritional analysis, agricultural waste utilization.

INTRODUCTION

The increasing demand for sustainable and cost-effective sources of nutrients has intensified research into alternative biomass resources, particularly agricultural residues and plant waste materials. Plant-derived biomass is recognized as a valuable source of macronutrients and micronutrients, including carbohydrates, proteins, lipids, minerals, and dietary fiber, which are essential for both human and animal nutrition (Siva and Anderson, 2023; Sharma et al., 2025). The utilization of such resources contributes significantly to sustainable agriculture and supports the development of circular bioeconomy systems through efficient waste valorization. Leaf litter, a major component of plant biomass, is often regarded as waste despite its potential

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nutritional and functional value. However, unlike fresh plant material, leaf litter represents a senescent stage of plant development characterized by distinct biochemical transformations, including nutrient remobilization, increased accumulation of structural carbohydrates, and modifications in phytochemical composition (Asim et al., 2023). These changes may alter its nutritional profile and functional properties, making it fundamentally different from green leaves and warranting independent evaluation. The conversion of such underutilized biomass into value-added products represents an effective strategy for waste minimization, resource recovery, and sustainable bioresource management (Begum et al., 2024).

Terminalia catappa is a tropical plant widely distributed across Africa and other tropical regions. While its fresh leaves and fruits have been extensively studied for their medicinal, nutritional, and phytochemical properties, its senescent leaf litter remains largely underexplored (Utiome et al., 2025; Utiome and Achuba, 2025). Previous studies have reported the presence of bioactive compounds and essential nutrients in fresh *T. catappa* leaves (Chukwuma et al., 2024), but there is a paucity of information regarding the proximate composition and mineral profile of its leaf litter. Importantly, no comprehensive study has evaluated how the biochemical changes associated with leaf senescence influence the nutritional quality and potential applications of *T. catappa* leaf litter in feed or agro-industrial systems. This represents a clear research gap in biomass valorization.

Proximate analysis is a fundamental tool for evaluating the nutritional quality of plant materials, providing essential information on moisture, crude protein, crude fat, crude fiber, ash, and carbohydrate content (Racero-Galaraga et al., 2024). In addition, mineral elements such as calcium, iron, magnesium, and potassium play critical roles in physiological and metabolic processes and are important indicators of nutritional value (Alghamdi et al., 2024). Assessing these parameters is essential for determining the suitability of plant biomass, particularly unconventional resources such as leaf litter, for feed formulation and agro-industrial utilization.

Despite the growing interest in biomass valorization, limited attention has been given specifically to senescent leaf biomass such as *T. catappa* leaf litter. Therefore, this study uniquely focuses on evaluating the proximate composition and mineral profile of this underutilized biomass, providing novel insights into its potential as a sustainable resource within circular bioeconomy frameworks.

MATERIALS AND METHODS

Collection and preparation of plant material

Senescent leaves of *T. catappa* were collected from the premises of Delta State University, Abraka, Nigeria. The collected leaves were thoroughly washed with clean water to remove adhering dust and debris and then air-dried under ambient laboratory conditions at a temperature of 27 ± 2°C and relative humidity of 65 to 70% for two weeks until a constant weight was obtained. The dried leaves were pulverized into fine powder using a laboratory grinder and stored in airtight containers at room temperature pending analysis.

Proximate analysis

The proximate composition of the leaf litter, including moisture content, crude protein, crude fat, crude fiber, and ash content, was determined according to standard procedures described by the Association of Official Analytical Chemists (AOAC, 2019).

Carbohydrate content was calculated by difference using the formula:

Carbohydrate (%) = 100 − (Moisture (%) + Crude Protein (%) + Crude Fat (%) + Crude Fiber (%) + Ash (%))

Mineral analysis

Mineral elements including calcium, iron, magnesium, manganese, copper, and zinc were determined using Atomic Absorption Spectrophotometry (AAS) following standard procedures described by AOAC (1984). For mineral determination, 2 g of the powdered sample was dry-ashed in a muffle furnace at 550°C for 4 h. The ash obtained was dissolved in 5 mL of 1 M nitric acid, filtered, and diluted to a known volume with deionized water prior to analysis. Potassium and sodium were determined using a flame photometer.

Anti-nutritional factor analysis

Determination of tannins

Tannin content was determined using the method described by Deshpande et al. (1986). Briefly, the sample was extracted using an appropriate solvent, and the tannin concentration was quantified spectrophotometrically based on standard procedures outlined for food products. Results were expressed as tannic acid equivalents per gram of sample.

Determination of phytate

Phytate content was determined based on the method described by Bogar et al. (2003). The procedure involved measuring the amount of inorganic phosphorus released from sodium phytate following enzymatic hydrolysis. The liberated phosphorus was quantified spectrophotometrically, and phytate concentration was calculated accordingly.

Determination of oxalate

Oxalate content was determined according to the method described by Libert and Franceschi (1987).

The sample was subjected to acid extraction, and the oxalate content was quantified using standard analytical procedures suitable for plant materials.

Table 1. Proximate composition of *T. catappa* leaf litter.

Parameter	% Composition
Moisture	12.32 ± 0.04
Crude fat	12.39 ± 0.06
Crude protein	7.21 ± 0.02
Crude fiber	26.90 ± 0.06
Ash	11.27 ± 0.05
Carbohydrate	43.24 ± 0.06

Values are mean ± standard deviation of triplicate determinations.

Table 2. Anti-nutritional factors of *T. catappa* leaf litter.

Parameter	Value (mg/g)
Tannins	2.85 ± 0.12
Phytate	1.92 ± 0.08
Oxalate	1.35 ± 0.06

Values are mean ± standard deviation of triplicate determinations.

Statistical analysis

All analyses were carried out in triplicate, and results were expressed as mean ± standard deviation. Data were subjected to one-way analysis of variance (ANOVA) using SPSS version 25.0. Where significant differences existed, means were separated using Tukey's post-hoc test. Statistical significance was accepted at $p < 0.05$.

RESULTS

Proximate composition

The proximate composition of *T. catappa* leaf litter is shown in Table 1. Carbohydrate was the most abundant component (43.24 ± 0.06%), followed by crude fiber (26.90 ± 0.06%). Moderate levels of crude fat (12.39 ± 0.06%), moisture (12.32 ± 0.04%), and ash (11.27 ± 0.05%) were observed, while crude protein (7.21 ± 0.02%) were the least abundant component.

Mineral composition

Mineral analysis of *T. catappa* leaf litter extracts confirmed the presence of essential macro- and micro-elements, including calcium, magnesium, potassium, iron, manganese, zinc, copper, selenium, cobalt, and molybdenum.
However, the values obtained were based on solvent-dependent extraction and therefore do not represent the absolute mineral composition of the leaf litter. Detailed solvent-specific mineral distribution is beyond the scope of this study and is reported elsewhere.

Anti-nutritional factors

The anti-nutritional factors present in *T. catappa* leaf litter are shown in Table 2 The results showed
that tannin content was the highest among the anti-nutritional components analyzed, with a value of 2.85 ± 0.12 mg/g. Phytate content was moderate at 1.92 ± 0.08 mg/g, while oxalate content was the lowest at 1.35 ± 0.06 mg/g.

DISCUSSION

The proximate composition of *T. catappa* leaf litter indicates that it is predominantly composed of carbohydrates and crude fiber, highlighting its potential as an energy-rich biomass. The high carbohydrate content (43.24%) suggests that leaf litter can serve as a viable energy source in animal feed formulations, particularly in regions where conventional feed ingredients are expensive or scarce. Similar observations have been reported for other plant-derived residues, where carbohydrate-rich biomass contributes significantly to caloric value and energy supply (Egbune et al., 2025).

The elevated crude fiber content (26.90%) further underscores its functional role in animal nutrition, especially for ruminants. Dietary fiber is known to enhance rumen function, improve gut motility, and support microbial fermentation processes (Chen et al., 2022). However, high fiber levels may reduce digestibility in monogastric animals, indicating that processing techniques such as fermentation or enzyme supplementation may be required to improve nutrient availability (Sureshkumar et al., 2023).

The moderate crude fat content (12.39%) observed in this study suggests that *T. catappa* leaf litter may contribute to the energy density of feed formulations. Lipids are essential for energy provision and play important roles in cellular structure and metabolic processes (Ali and Szabó, 2023). Additionally, the ash content (11.27%) reflects the presence of mineral elements, which are required for various physiological functions.

Although crude protein content (7.21%) was relatively low, it is comparable to values reported for other leaf-based biomass used as supplementary feed ingredients (Nazir et al., 2022). This indicates that *T. catappa* leaf litter may not serve as a primary protein source but can be incorporated into feed formulations alongside protein-rich materials to achieve balanced nutrition.

The detection of essential minerals such as calcium, magnesium, iron, potassium, zinc, and selenium further supports the nutritional relevance of the biomass. These elements are known to play critical roles in bone development, enzymatic activity, oxygen transport, immune response, and antioxidant defense systems (Weyh et al., 2022; Stefanache et al., 2023; Razzaque and Wimalawansa, 2025). Although quantitative mineral composition was not established in this study due to solvent-dependent variability, the presence of these elements indicates that *T. catappa* leaf litter can contribute to micronutrient supply in animal diets.

From a broader perspective, the findings of this study highlight the potential for biomass valorization of *T. catappa* leaf litter. The conversion of this underutilized plant residue into a nutritionally relevant resource aligns with global efforts toward sustainable agriculture, waste reduction, and circular bioeconomy (Mehdizadeh et al., 2025). Its utilization as a low-cost feed ingredient could reduce reliance on conventional feed materials while promoting environmentally sustainable practices.

The anti-nutritional factors detected in *T. catappa* leaf litter were present at relatively low to moderate levels, with tannins (2.85 ± 0.12 mg/g) being the most abundant, followed by phytate (1.92 ± 0.08 mg/g) and oxalate (1.35 ± 0.06 mg/g). The predominance of tannins in the present study is consistent with reports that many tropical leaves accumulate phenolic compounds, particularly during senescence, as part of plant defense and structural stabilization mechanisms (Pratyusha, 2022). Although tannins are often regarded as anti-nutritional due to their ability to bind proteins and reduce digestibility, their presence at moderate levels may confer beneficial antioxidant and antimicrobial properties, which can enhance feed quality when properly managed (Sultanayeva et al., 2023).

The phytate content observed in this study was relatively low compared to values reported for many plant-based feed materials such as legumes and cereals (Auer et al., 2024). Phytate is known to chelate essential minerals, thereby reducing their bioavailability; however, at the levels reported here, its inhibitory effects are likely minimal (Zhang et al., 2022). Furthermore, phytate can be effectively reduced through processing techniques such as fermentation, soaking, or enzymatic treatment, which enhances nutrient accessibility and utilization (Sarkhel and Roy, 2022).

Oxalate content was the lowest among the anti-nutritional factors analyzed. This is nutritionally significant, as high oxalate levels are associated with reduced calcium absorption and potential formation of kidney stones (Zayed et al., 2025). The low oxalate concentration in *T. catappa* leaf litter suggests that it poses minimal risk in terms of mineral interference and supports its suitability as a feed ingredient. Similar low oxalate levels have been reported in processed leaf-based biomass, further supporting the role of senescence and drying in reducing anti-nutritional compounds (Mahaveerchand and Abdul Salam, 2024).

CONCLUSION

This study demonstrates that *T. catappa* leaf litter is a nutritionally valuable biomass characterized by high carbohydrate and crude fiber contents, moderate lipid levels, and appreciable ash content. The proximate composition indicates its suitability as an energy source and highlights its potential role in supporting digestive health, particularly in ruminant animals. Although the protein content is relatively low, biomass can be effectively utilized as a supplementary feed component when combined with protein-rich ingredients.

The presence of essential mineral elements further supports its nutritional relevance, although detailed quantitative mineral composition was not fully established in this study due to solvent-dependent variability. Nevertheless, the detection of these elements suggests its potential contribution to micronutrient supply. Importantly, the anti-nutritional factors evaluated, including tannins, phytate, and oxalate, were present at relatively low to moderate levels. These concentrations are unlikely to significantly impair nutrient bioavailability and may be further reduced through processing methods such as fermentation or heat treatment. This indicates that *T. catappa* leaf litter can be safely utilized with minimal anti-nutritional constraints.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Alghamdi M, Gutierrez J, Komarnytsky S (2022) Essential minerals and metabolic adaptation of immune cells. Nutrients 15(1):123.

Ali O, Szabó A (2023) Review of eukaryote cellular membrane lipid composition, with special attention to the fatty acids. Int. J. Mol. Sci International Journal of Molecular Sciences. 24(21):15693.

Association of Official Analytical Chemists (AOAC) (1984) Official methods of analysis. Association of Official Analytical Chemists, Washington DC.

Association of Official Analytical Chemists (AOAC) (2019) Official methods of analysis of the Association of Official Analytical Chemists. 21st edition. AOAC, Washington DC.

Asim M, Zhang Y, Sun Y, Guo M, Khan R, Wang XL, Shi Y (2023) Leaf senescence attributes: the novel and emerging role of sugars as signaling molecules and the overlap of sugars and hormones signaling nodes. Critical Reviews in Biotechnology 43(7):1092-1110.

Auer J, Alminger M, Marinea M, Johansson M, Zamaratskaia G, Högberg A, Langton M (2024) Assessing the digestibility and estimated bioavailability/bioaccessibility of plant-based proteins and

minerals from soy, pea, and faba bean ingredients. LWT 197:115893.
Begum YA, Kumari S, Jain SK, Garg MC (2024) A review on waste biomass-to-energy: integrated thermochemical and biochemical conversion for resource recovery. Environmental Science: Advances 3(9):1197-1216.
Bogar B, Szakaes G, Linden JC, Pandey A, Tengerdy RP (2003) Optimization of phytase production by solid-state fermentation. Journal of Microbiology and Biotechnology 30(3):183-189.
Chen X, Yan F, Liu T, Zhang Y, Li X, Wang M, Wu S (2022) Ruminal microbiota determines the high-fiber utilization of ruminants: evidence from the ruminal microbiota transplant. Microbiology Spectrum 10(4):e00446-22.
Chukwuma IF, Ossai EC, Nworah FN, Apeh VO, Abiaziem EO, Iheagwam FN, Korzeniowska M (2024) Changes in nutritional, health benefits, and pharmaceutical potential of raw and roasted tropical almond (Terminalia catappa Linn.) nuts from Nigeria. PLoS One 19(1):e0287840.
Deshpande SS, Cheryan M, Salunkhe DK, Luh BS (1986) Tannin analysis of food products. Critical Reviews in Food Science and Nutrition 24(4):401-449.
Egbune E, Ezedom T, Odeghe O, Egbune O, Eraga L, Avwioroko O, Anigboro AA, Tonukari N (2025) Sustainable bio-processing: Solid-state fermentation and agricultural waste. *African Research Reports*, *1*(2), 40-54.
Libert B, Franceschi VR (1987) Oxalate in crop plants. Journal of Agricultural and Food Chemistry 35(6):926-938.
Mahaveerchand H, Abdul Salam AA (2024) Environmental, industrial, and health benefits of Moringa oleifera. Phytochemistry Reviews 23(5):1497-1556.
Mehdizadeh M, Omidi A, Matindike R, Nigussie ZG, Ikegwu TM, Agu HO, Merghany RM (2025) Agri-waste valorization: pathways to sustainable bioenergy and biochemical innovation. Circular Economy and Sustainability pp.1-31.
Nazir MT, Soufiani AM, Ferreira JA, Sar T, Taherzadeh MJ (2022) Production of filamentous fungal biomass with increased oil content using olive oil as a carbon source. Journal of Chemical Technology and Biotechnology 97(9):2626-2635.
Pratyusha S (2022). Phenolic compounds in the plant development and defense. Plant Stress Physiology: Perspectives in Agriculture 125p.
Racero-Galaraga D, Rhenals-Julio JD, Sofan-German S, Mendoza JM, Bula-Silvera A (2024) Proximate analysis in biomass: standards, applications and key characteristics. Results in Chemistry 12:101886.
Razzaque MS, Wimalawansa SJ (2025) Minerals and human health: from deficiency to toxicity. Nutrients 17(3):454.
Sarkhel S, Roy A (2022) Phytic acid and its reduction in pulse matrix: structure–function relationship owing to bioavailability enhancement of micronutrients. Journal of Food Process Engineering 45(5):e14030.
Sharma K, Zhang W, Rawdkuen S (2025) Dietary plant-based protein supplements: sources, processing, nutritional value, and health benefits. Foods 14(18):3259.
Siva N, Anderson CT (2023) Assessing lignocellulosic biomass as a source of emergency foods. Journal of Current Research in Food Science 7:100586.
Stefanache A, Lungu II, Butnariu IA, Calin G, Gutu C, Marcu C, Damir D (2023) Understanding how minerals contribute to optimal immune function. Journal of Immunology Research 2023(1):3355733.
Sultanayeva L, Karkehabadi S, Zamaratskaia G, Balji Y (2023) Tannins and flavonoids as feed additives in the diet of ruminants to improve performance and quality of the derived products: a review. Bulgarian Journal of Agricultural Science 29(3).
Sureshkumar S, Song J, Sampath V, Kim I (2023) Exogenous enzymes as zootechnical additives in monogastric animal feed: a review. Agriculture 13(12):2195.
Utiome SM, Achuba FI (2025) Modulatory Effects of Almond (Terminalia catappa) Leaf Extract on Oxidative Stress in Wistar Rats Fed a Crude Oil-Contaminated Diet. Nigerian Journal of Science and Environment, *23*(2), 1-14.
Utiome SM, Egbune EO, Magbegor O, Achuba FI (2025) Biotechnological valorization of almond leaf litter: effect of solid-state fermentation with baker's yeast, palm wine yeast, and Rhizopus oligosporus on nutrient and anti-nutrient. African Research Reports 1(5):302-311.
Weyh C, Krüger K, Peeling P, Castell L (2022) The role of minerals in the optimal functioning of the immune system. Nutrients 14(3):644.
Zayed A, Adly GM, Farag MA (2025) Management strategies for the anti-nutrient oxalic acid in foods: a comprehensive overview of its dietary sources, roles, metabolism, and processing. Food and Bioprocess Technology 18(5):4280-4300.
Zhang YY, Stockmann R, Ng K, Ajlouni S (2022) Revisiting phytate-element interactions: implications for iron, zinc and calcium bioavailability, with emphasis on legumes. Critical Reviews in Food Science and Nutrition 62(6):1696-1712.