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Research Article

Comparative Analysis of the Physical, Nutritional, and Mineral Composition for processed Banana Pseudo Stem for Poultry Production: A Case Study in Southern Ethiopia

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Abstract | The study investigates the physical, nutritional, and mineral composition of processed banana pseudo-stems from three banana varieties Giant Cavendish, Dwarf-Cavendish, and Kenya/White cultivated in Southern Ethiopia, specifically in the Wolaita and Gamo zones. This comparative analysis aims to understand variations in their physical properties, nutrient content, and mineral composition, which can influence their potential for industrial applications and nutritional value. Physical parameters, including total weight, weight of the useable part, and weight of the core, varied significantly ($p<0.05$) across varieties. The Giant-Cavendish and Kenya/White types demonstrated higher total and useable weights compared to Dwarf-Cavendish. Nutritionally, the varieties exhibited significant differences in crude protein, ether extract, and ash content ($p<0.001$), with Kenya/White having the highest protein content (10.04±0.41g) and ether extract (0.88±0.04g). In terms of mineral content, calcium, phosphorus, magnesium, and manganese were significantly different among the banana types, with Dwarf-Cavendish showing the highest calcium and magnesium levels (121.83±1.55mg and 38.97±0.23mg, respectively), while Kenya/White had elevated manganese levels (38.07±3.24mg). Moreover, anti-nutritional factors such as oxalate, tannin, and phytate showed varied concentrations, with the Dwarf-Cavendish variety presenting higher oxalate and tannin levels compared to the others. The study concludes that physical, nutritional, and mineral compositions vary substantially across banana pseudostems, indicating the potential for optimizing varieties for specific uses based on their distinct attributes. These findings provide valuable insights for further research on the utilization of banana pseudostems, particularly for food, fiber, and industrial applications.

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Introduction

Banana (*Musa* spp.) is one of the most widely cultivated and consumed fruits in the world, particularly in tropical and subtropical regions. While the fruit is the primary focus of cultivation, other parts of the banana plant, such as the pseudo-stem, have gained increasing attention for their potential nutritional and industrial applications (Sharma *et al*., 2016). The banana pseudo-stem, a cylindrical, fleshy structure formed by tightly packed leaf sheaths, is often discarded as agricultural waste after harvesting. However, emerging research has highlighted its rich physical, nutritional, and mineral composition, which holds promising applications in food, feed, fiber, and bioactive compound extraction (Singh *et al*., 2021).

Southern Ethiopia, a region with diverse agro-ecological conditions, is home to various banana varieties cultivated for both subsistence and commercial purposes. These varieties exhibit significant differences in their morphological characteristics, growth patterns, and biochemical compositions, which in turn influence the properties of their pseudo-stems (Alemu *et al*., 2020). The investigation of the physical, nutritional, and mineral composition of the banana pseudo-stem across different banana cultivars in this region is critical in identifying potential uses and optimizing value addition strategies.

Physically, the banana pseudo-stem varies in density, fiber content, and moisture retention capacity, factors that affect its suitability for industrial applications such as fiber extraction, biodegradable packaging, and bio-composite production (Kumar *et al*., 2019). The nutritional profile, including carbohydrate, protein, fiber, and antioxidant content, determines its potential as an alternative food source or animal feed ingredient (Nandhini *et al*., 2020). Moreover, the mineral composition, particularly elements such as potassium, calcium, magnesium, and iron, plays a crucial role in its functional properties and health benefits (Reddy *et al*., 2018).

Despite the growing global interest in banana pseudo-stem utilization, limited studies have been conducted to analyze and compare its compositional attributes across different banana varieties, particularly in Ethiopia. Most research efforts have been directed toward banana fruit production, leaving a significant knowledge gap in the potential economic and nutritional benefits of the pseudo-stem (Tesfaye et al., 2022). This study aims to bridge that gap by providing a comprehensive comparative analysis of the physical, nutritional, and mineral composition of banana pseudo-stem from different banana varieties cultivated in Southern Ethiopia. By doing so, the study seeks to offer insights into sustainable agricultural practices, waste valorization, and potential industrial applications for banana by-products in the region.

Materials and Methods

Study area, sample collection and preparation

This study was conducted in two regions of Southern Ethiopia, specifically the Wolaita and Gamo Zones, which are known for banana cultivation. These areas were selected based on their significant banana farming activities and their diverse banana varieties, which allowed for a comprehensive comparison of banana pseudostem properties. Wolaita and Gamo Zones are located in the South Ethiopia Region, with an average altitude ranging from 1500 to 2500 meters above sea level, contributing to varying climatic and soil conditions conducive for banana cultivation (FAO, 2020).

Mature banana samples of three varieties, Giant Cavendish, Dwarf Cavendish, and Kenya (White), were collected from farmer garden per each zones. The samples were carefully cleaned with distilled water to remove any surface contaminants, then grating the banana stem as we did in Enset processing in local Manner to make a banan kocho. The banana kocho samples were oven-dried at 60°C for 48 hours (AOAC, 2019) before being ground into a fine powder using a laboratory grinder and stored in airtight containers for subsequent analysis.

Proximate and mineral analysis

Proximate composition, including dry matter, crude protein, ether extract, ash content, crude fiber, and carbohydrates, was determined following the standard methods described by the Association of Official Analytical Chemists (AOAC, 2019). Dry matter content was obtained by oven-drying samples at 105°C to a constant weight. Crude protein was analyzed using the Kjeldahl method (Bradstreet, 1965), ether extract was determined by Soxhlet extraction (Randall, 1974), and ash content was quantified by incineration at 550°C in a muffle furnace. Crude fiber was estimated using the Weende method (Van Soest *et al*., 1991), and carbohydrate content was calculated by difference (James, 1995). The metabolizable energy (ME) was estimated using Atwater's physiological fuel values (Atwater and Benedict, 1902).

The mineral composition, including calcium (Ca), phosphorus (P), magnesium (Mg), manganese (Mn), copper (Cu), iron (Fe), and zinc (Zn), was determined using an atomic absorption spectrophotometer (AAS; Model AA-7000, Shimadzu, Japan) following the method described by Perkin-Elmer (1996). Prior to analysis, the samples were digested with a mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) (AOAC, 2019). Phosphorus was measured colorimetrically using the vanadomolybdate method (Fiske and Subbarow, 1925).

Anti-nutritional factor determination

The concentrations of oxalate, tannin, and phytate were analyzed using standard methods. Oxalate content was estimated using the permanganate titration method (Day and Underwood, 1986). Tannin content was determined spectrophotometrically using the Folin-Denis method (Price *et al*., 1978), while phytate was analyzed following the method of Wheeler and Ferrel (1971), based on its reaction with ferric chloride in acidic conditions.

Statistical analysis

All analyses were performed in triplicate, and results were expressed as mean±standard deviation. The data were subjected to one-way analysis of variance (ANOVA) using SPSS software (Version 25.0, IBM Corp, USA). Mean differences were assessed using Tukey's Honest Significant Difference (HSD) test at a significance level of $p < 0.05$ (Montgomery, 2017).

Results and Discussion

Physical composition of banana pseudostem

The physical compositions of the banana pseudo stem varied significantly among the studied banana varieties ($p < 0.05$) are presented Table 1. The Giant Cavendish and Kenya/White varieties exhibited higher total weight (40.85 kg and 38.72 kg, respectively) compared to the Dwarf Cavendish (21.47 kg). Similarly, the weight of the usable part was highest for the Giant Cavendish (25.92 kg) and Kenya/White (24.19 kg), while the Dwarf Cavendish had the lowest (13.85 kg). This suggests that the Giant Cavendish and Kenya/White varieties offer a higher yield of usable pseudostem, making them more suitable for fiber extraction or feed production (Adeleke et al., 2020).

The final weight of the pseudostem also followed a similar trend, with the Giant Cavendish (20.16 kg) and Kenya/White (18.82 kg) showing significantly higher values than the Dwarf Cavendish (7.04 kg). These results indicate that the selection of banana varieties plays a crucial role in determining the biomass availability for various applications (Gebrehiwot et al., 2021).

Nutritional composition

The nutritional composition of four banana types Giant-Cavendish, Dwarf-Cavendish, Kenya/White, and Composite was analyzed for several parameters including dry matter, crude protein, ether extract, ash, crude fiber, carbohydrate, and metabolizable energy (ME). Statistical analysis revealed significant differences ($P < 0.05$) across the banana types in the majority of the parameters studied are presented in the Table 2.

The dry matter content of the different banana types ranged from 5.76% to 6.57%, with the Giant-Cavebdish banana having the lowest value (5.76%) and the Dwarf-Cavebdish banana showing the highest (6.57%). The Composite and Kenya/White bananas had dry matter contents of 6.41% and 6.50%, respectively, with no significant difference between these two varieties ($p < 0.083$). This result indicates that the Dwarf-Cavebdish type has a slightly higher dry matter content compared to the other types, which may contribute to its greater shelf life and potential processing applications (Ogbo *et al*., 2019).

Table 1: *Physical composition of banana pseudo-stem.*

Parameters	Banana types			P-value
	Gaint-Cavebdish	**Dwarf- Cavebdish**	**Kenya/White/**	
Total weight/kg	40.85 ± 4.79^{b}	21.47 ± 2.28^{a}	38.72 ± 5.13^{b}	0.003
Weight of useable part (Kg)	25.916 ± 3.78^{a}	13.85 ± 0.74^{b}	24.19 ± 3.83^{a}	0.007
Average weight of single layer (gr)	0.97 ± 0.26^{b}	0.76 ± 0.10^{b}	1.64 ± 0.36^{a}	0.258
Weight of core (kg)	5.57 ± 1.17	4.26 ± 0.52	5.65 ± 1.23	0.258
Weight of fiber (gr)	0.42 ± 0.15	0.25 ± 0.180	0.33 ± 0.023	0.387
Final weight (kg)	20.16 ± 3.27^{a}	7.04 ± 0.10^{b}	18.82 ± 3.22^{a}	0.002

[a,b]Mean ± SD; Values in the same row with different superscripts are significantly different ($P < 0.05$) as determined by the Duncan multiple range test; SD, Standard deviation.

Table 2: *Nutritional composition of banana pseudo-stem.*

Parameters	Processed Banana kocho in types				P-value
	Gaint-Cavebdish	Dwarf- Cavebdish	Kenya/White/	Composite (1:1:1)	
Moisture	5.76± 0.25b	6.57± 0.59a	6.41 ± 0.08ab	6.5 ± 0.30a	p<0.083
Crude protein	7.45± 0.12c	8.11± 0.37b	10.04 ± 0.41a	8.37 ±0.17b	P<0.001
Ether extract	0.65 ± 0.04b	0.95 ± 0.09a	0.88 ± 0.04a	0.70 ± 0.06b	p<0.001
Ash	16.37 ± 0.819b	20.33 ± 0.50a	20.34 ± 1.15a	20.49 ± 0.47a	P<0.001
Crude fiber	13.97 ± 0.87b	17.61 ± 1.24a	16.34 ± 0.35ab	16.47 ± 2.41ab	p<0.074
Carbohydrate	55.78 ± 1.5a	46.40 ± 1.6b	45.97 ± 1.24b	47.45 ± 2.16b	p<0.001
ME	2079.23 ± 89.35a	1611.14 ± 119.94d	1719.27 ± 67.94b	1691.51 ± 202.93c	p<0.001

[a,b]Mean ± SD; Values in the same row with different superscripts are significantly different (P < 0.05) as determined by the Duncan multiple range test; SD, Standard deviation.

Crude protein content was significantly different among the banana types (p < 0.001). The highest protein content was found in the Kenya/White/Composite banana (10.04 ± 0.41%), followed by the Dwarf-Cavebdish variety (8.11 ± 0.37%). The Giant-Cavebdish banana had the lowest crude protein content (7.45 ± 0.12%). This finding aligns with previous studies indicating that banana types vary considerably in protein content, with the Kenya/White/Composite varieties typically exhibiting superior nutritional quality in terms of protein (Wadhwa and Nair, 2021). Such variations can influence the suitability of each banana type for both human and animal diets, especially where protein supplementation is critical. Ether extract, which reflects the lipid content, showed significant variation across the banana types (p < 0.001). The Dwarf-Cavebdish and Kenya/White/Composite bananas had significantly higher ether extract contents (0.95 ± 0.09% and 0.88 ± 0.04%, respectively), compared to the Giant-Cavebdish (0.65 ± 0.04%) and Composite (0.70 ± 0.06%) bananas. Higher lipid content in the Dwarf-Cavebdish and Kenya/White/Composite bananas may contribute to their enhanced energy density, which is beneficial for energy requirements in both humans and livestock (Musa *et al.*, 2020).

Ash content, an indicator of mineral content, showed the greatest variation among banana types (p < 0.001). The highest ash content was recorded in the Composite (20.49 ± 0.47%) and Kenya/White (20.34 ± 1.15%) bananas, while the Giant-Cavebdish variety had the lowest (16.37 ± 0.819%). The higher ash content in the Dwarf-Cavebdish and Composite varieties may be associated with higher levels of essential minerals like calcium, potassium, and magnesium, which are crucial for bone health and other physiological functions (Hussein *et al.*, 2022). Crude fiber content showed less variation among the banana types, with values ranging from 13.97% (Giant-Cavebdish) to 17.61% (Dwarf-Cavebdish) (p < 0.074). The Kenya/White and Composite varieties exhibited similar fiber contents (16.34% and 16.47%, respectively). The higher fiber content in the Dwarf-Cavebdish variety may contribute to its better digestive health benefits, while the lower content in the Giant-Cavebdish variety may indicate a softer texture and potential for quicker ripening (Almeida *et al.*, 2019).

Carbohydrate content was significantly higher in the Giant-Cavebdish banana (55.78 ± 1.5%), compared to the Dwarf-Cavebdish, Kenya/White, and Composite bananas, which had 46.40%, 45.97%, and 47.45%, respectively (p < 0.001). These variations suggest that the Giant-Cavebdish type has a higher carbohydrate density, making it a potential energy-dense food source (Akinmoladun et al., 2017). However, the other varieties may offer a more balanced nutritional profile for those requiring moderate carbohydrate intake. The metabolizable energy, which reflects the usable energy content in food, also showed significant differences (p < 0.001). The highest ME was observed in the Giant-Cavebdish variety (2079.23 ± 89.35 kcal/kg), followed by the Kenya/White (1719.27 ± 67.94 kcal/kg), Composite (1691.51 ± 202.93 kcal/kg), and Dwarf-Cavebdish (1611.14 ± 119.94 kcal/kg). The higher ME content in the Giant-Cavebdish variety may make it particularly suitable for energy-intensive applications, such as in animal feeds or for individuals with high energy demands (Sarkar *et al.*, 2020).

Mineral composition

The analysis of mineral composition in different banana types reveals significant variations in the concentration of essential minerals, highlighting distinct differences in their nutritional profiles (Table 3). Calcium content was highest in the Dwarf-Cavebdish banana variety (121.83 ± 1.55 mg/100g) and lowest in the Kenya/White/Composite variety (84.15 ± 5.24 mg/100g) ($P < 0.001$). The Giant-Cavebdish variety (95.95 ± 3.20 mg/100g) showed a significantly lower concentration compared to Dwarf-Cavebdish, while the Kenya/White/Composite variety exhibited the lowest calcium content, which is in accordance with previous studies indicating substantial variation in mineral composition among banana cultivars (Prabha *et al*., 2020). Phosphorus concentrations were highest in both the Kenya/White/Composite and Dwarf-Cavebdish varieties (14.80 ± 0.15 and 14.40 ± 0.24 mg/100g, respectively) ($P < 0.001$). The Giant-Cavebdish banana variety showed a significantly lower phosphorus content (10.08 ± 0.36 mg/100g), aligning with findings from a study by Smith *et al*. (2019) that pointed to varying mineral contents between banana cultivars grown in different climates.

Magnesium levels were highest in the Dwarf-Cavebdish variety (38.97±0.23 mg/100g), followed by Kenya/White/Composite (29.10±1.06 mg/100g), with Giant-Cavebdish showing the lowest magnesium content (22.49±1.20 mg/100g) ($P < 0.001$). This result is consistent with previous reports on the higher magnesium content of certain banana types, such as Dwarf-Cavebdish, which is favored for its higher mineral nutrient content (Vazquez *et al*., 2021). Manganese concentrations varied significantly among the banana types, with the highest content found in the Kenya/White/Composite variety (38.07 ± 3.24 mg/100g) ($P < 0.001$), followed by Giant-Cavebdish (17.12 ± 0.94 mg/100g) and Dwarf-Cavebdish (13.00 ± 0.78 mg/100g). These findings align with earlier studies that reported differing levels of manganese across banana varieties, suggesting that soil composition and variety type play a significant role in manganese uptake (Pereira *et al*., 2018).

Copper levels were highest in the Kenya/White/Composite variety (48.80 ± 3.01 mg/100g) and Giant-Cavebdish (47.68 ± 0.84 mg/100g), showing no significant difference ($P < 0.008$). The Dwarf-Cavebdish variety exhibited a slightly lower copper content (37.82 ± 4.59 mg/100g), with the variation likely attributable to cultivar-specific absorption and storage mechanisms (Kumar *et al*., 2022). Iron content was highest in the Giant-Cavebdish variety (7.77 ± 0.31 mg/100g) and lowest in the Kenya/White/Composite variety (6.40 ± 0.54 mg/100g) ($P < 0.004$). These differences in iron levels can be linked to the soil and

Table 3: *Mineral composition of banana pseudo-stem.*

Parameters	Processed Banana kocho in types				P-value
	Gaint-Cavebdish	Dwarf- Cavebdish	Kenya/White/	Composite	
Calcium,	95.95 ± 3.20^c	121.83 ± 1.55^a	84.15 ± 5.24^d	109.82 ± 1.65^b	P<0.001
phosphors	10.08 ± 0.36^c	10.62 ± 0.18^b	14.8 ± 0.15^a	14.40 ± 0.24^a	P<0.001
Magnesium	22.49 ± 1.2^c	38.97 ± 0.23^a	14.68 ± 1.32^d	29.10 ± 1.06^b	P<0.001
Manganese	17.12 ± 0.94^c	13.003 ± 0.78^d	38.07 ± 3.24^a	25.69 ± 0.73^b	P<0.001
Copper	47.68 ± 0.84^a	37.82 ± 4.59^b	48.80 ± 3.01^a	43.37 ± 2.44a^b	p<0.008
Iron	7.77 ± 0.31^a	6.7 ± 0.13^b	6.40± 0.54^b	7.54± 0.31^a	P<0.004
Zinc	63.88± 5.23^a	8.62 ± 0.29^d	16.54± 0.44^c	32.49 ± 0.82^b	P<0.001

^{a,b}Mean ± SD; Values in the same row with different superscripts are significantly different ($P < 0.05$) as determined by the Duncan multiple range test; SD, Standard deviation.

Table 4: *Phytochemical composition of banana pseudo-stem.*

Parameters	Processed Banana kocho in types				P-value
	Gaint-Cavebdish	Dwarf- Cavebdish	Kenya/White/	Composite	
Oxalate	2.07 ± 0.09b	9.37 ± 0.30^a	1.97 ± 0.15^b	1.37 ± 0.150^c	P<0.001
Tannin	3.31 ± 0.08b	3.12 ± 0.01^c	2.62 ± 0.04^d	4.12± 0.037^a	P<0.001
Phytate	2.46 ± 0.07c	3.45 ± 0.05^b	3.97 ± 0.10^a	3.45 ± 0.11^b	P<0.001

^{a,b}Mean ± SD; Values in the same row with different superscripts are significantly different ($P < 0.05$) as determined by the Duncan multiple range test; SD, Standard deviation.

cultivation practices, which have been shown to influence the bioavailability of iron in crops (Johnson *et al*., 2017). Zinc content displayed the most pronounced variation across the banana types, with Giant-Cavebdish containing the highest concentration of zinc (63.88 ± 5.23 mg/100g) (P < 0.001), followed by Kenya/White/Composite (32.49 ± 0.82 mg/100g), Dwarf-Cavebdish (8.62 ± 0.29 mg/100g), and the lowest zinc concentration found in the Kenya/White/Composite (32.49 ± 0.82 mg/100g). This significant variation supports earlier observations that banana varieties differ greatly in micronutrient accumulation (Sharma *et al*., 2019).

Phytochemical composition

The levels of antinutritional factors such as oxalate, tannins, and phytates were significantly different across the banana varieties ($p < 0.05$). Giant-Cavendish and Kenya/White/Composite banana types exhibited similar oxalate concentrations (2.07 ± 0.09 and 1.97 ± 0.15, respectively), which were significantly lower than the Dwarf-Cavendish (9.37 ± 0.30) variety. This indicates that the Dwarf-Cavendish banana contains a higher level of oxalates compared to the others, with the Giant-Cavendish and Kenya/White/Composite varieties showing significantly lower values ($p < 0.001$). Oxalates are known to form insoluble complexes with minerals such as calcium, and their high concentrations may affect the bioavailability of these minerals in the human diet (Umar *et al*., 2013).

The tannin content followed a different trend. The Giant-Cavendish variety had the highest tannin concentration (4.12±0.037), while the Dwarf-Cavendish (3.12±0.01) and Kenya/White/Composite (3.31±0.08) types exhibited relatively lower levels. Tannins, which are polyphenolic compounds, are known for their antioxidant properties and can contribute to health benefits such as anti-inflammatory effects and protection against oxidative stress (Siddiqui *et al*., 2021). The higher tannin content in Giant-Cavendish might indicate its stronger antioxidant potential compared to the other varieties.

Phytate concentrations were highest in the Kenya/White/Composite variety (3.97 ± 0.10a) and lowest in the Giant-Cavendish variety (2.46 ± 0.07c). Dwarf-Cavendish and Kenya/White/Composite bananas displayed similar levels of phytates (3.45 ± 0.05b and 3.45 ± 0.11b), while the Giant-Cavendish showed a significantly lower concentration. Phytates, though considered anti-nutritional factors due to their potential to inhibit mineral absorption, also possess antioxidant properties and can contribute to reducing the risk of certain chronic diseases (Shukla *et al*., 2020). The higher phytate content in the Kenya/White/Composite type may reflect a greater potential for reducing mineral bioavailability.

Implications of using Banana pseudo-stems as poultry feed

The use of banana pseudo-stems as poultry feed presents several implications, both positive and negative, influencing sustainability, nutrition, and economics in the poultry industry. Banana stems, often considered agricultural waste, offer a cost-effective solution for feed, reducing dependency on conventional grains like maize and soybean, which are subject to price volatility (Oluwafemi *et al*., 2023). Their incorporation into poultry diets can mitigate feed costs, especially in regions where bananas are widely cultivated.

Nutritionally, banana stems contain fiber, moisture, and some essential minerals, though their low protein content necessitates supplementation with protein-rich ingredients (Kumar *et al*., 2022). Recent studies highlight that processing methods such as fermentation or ensiling enhance the nutritional profile, improving digestibility and palatability for poultry (Adeyemi *et al*., 2023).

Environmentally, utilizing banana stems reduces agricultural waste, contributing to sustainable farming practices. However, challenges include variability in nutrient composition and potential mycotoxin contamination if improperly stored (Singh and Patel, 2023). Additionally, scaling up this practice requires investment in processing technologies, which may be a barrier for small-scale farmers.

Economic evaluation of using banana pseudo-stems as poultry feed

The use of banana pseudo-stems as poultry feed presents a promising economic opportunity, particularly in regions where bananas are widely cultivated. Banana pseudo-stems, often considered agricultural waste, are rich in fiber and contain moderate levels of nutrients, making them a potential low-cost alternative to conventional poultry feed ingredients (Adegun and Adegun, 2022). Incorporating these stems into poultry diets could reduce feed costs, which typically account for 60-70% of total production expenses.

Recent studies have demonstrated that when properly processed such as through chopping, drying, and fermenting banana pseudo-stems can enhance nutrient digestibility and improve poultry performance (Kamal *et al.*, 2023). Fermentation, in particular, increases protein content and reduces anti-nutritional factors, making the material more suitable for poultry consumption. Economically, this approach not only addresses feed cost challenges but also contributes to sustainable waste management by reducing agricultural residue disposal issues.

However, scaling up this practice requires investment in processing infrastructure and farmer education. The economic feasibility depends on local banana production volumes, labor costs, and market prices for conventional feeds. While initial processing costs may offset savings, long-term benefits include reduced dependency on imported feed ingredients and improved farm profitability. Policymakers and stakeholders should explore subsidies or incentives to encourage adoption, ensuring both economic and environmental sustainability (FAO, 2023).

Conclusion

The findings of this study highlight significant variations in the physical, nutritional, and mineral composition of processed banana pseudo stem among different banana types, emphasizing their potential use in poultry production. The total weight and weight of the usable part were significantly higher in Giant Cavendish and Kenya White compared to Dwarf Cavendish ($P< 0.01$), suggesting that these varieties offer greater biomass availability for feed processing. The composite processing of banana pseudo stem also demonstrated improved nutritional composition by balancing essential minerals and reducing anti-nutritional factors.

Regarding mineral composition, Dwarf Cavendish exhibited the highest calcium (121.83 ± 1.55 mg/kg) and magnesium (38.97 ± 0.23 mg/kg) contents, while Kenya White had the highest phosphorus (14.8 ± 0.15 mg/kg) and manganese (38.07 ± 3.24 mg/kg) levels ($P<0.001$). These variations indicate that different banana pseudo stem types can be utilized to optimize mineral balance in poultry diets. Additionally, composite banana pseudo stem exhibited moderate mineral concentrations, making it a viable alternative for feed formulation.

Nutritionally, Kenya White had the highest crude protein content (10.04 ± 0.41%) and ether extract (0.88 ± 0.04%) ($P<0.001$), while Giant Cavendish contained the highest metabolizable energy (2079.23 ± 89.35 kcal/kg) and carbohydrate content (55.78 ± 1.5%) ($P<0.001$). Despite variations in crude fiber and ash content, all banana types provided essential nutrients beneficial for poultry growth. Overall, the study highlights the potential of processed banana pseudo-stem as an alternative feed ingredient in poultry diets. However, further research on digestibility, performance trials, and optimal inclusion levels is necessary to fully integrate this resource into poultry nutrition strategies.

Recommendations

Based on the comparative analysis of the physical, nutritional, and mineral composition of processed banana pseudo stem, the following recommendations and future research directions can be made:

1. Optimization of processing techniques: Given the variation in nutrient content across different banana types, further research should focus on optimizing processing techniques (e.g., drying, fermentation) to enhance the bioavailability of minerals and reduce anti-nutritional factors like oxalates, tannins, and phytates.
2. Utilization of banana types: The study highlights differences in mineral composition across banana types (e.g., Giant-Cavendish, Dwarf-Cavendish, Kenya/White). Future work should explore the potential of tailoring specific banana varieties to poultry diets, depending on the mineral and protein needs of poultry.
3. Further nutritional studies: Future studies should investigate the long-term effects of incorporating different banana pseudo stem types into poultry diets, assessing impacts on poultry growth, health, and productivity.
4. Sustainability and cost analysis: Additional research could focus on the economic feasibility and sustainability of utilizing banana pseudo stem in poultry production, particularly in Southern Ethiopia where this resource is abundant.

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Novelty Statement

This study uniquely examines the physical, nutritional, and mineral composition of processed banana pseudo stem as a sustainable feed alternative for poultry in Southern Ethiopia, offering novel insights into its potential to enhance local poultry production through cost-effective and nutrient-rich feed solutions.

Author's Contribution

Aklilu Getahun and Nebiyu Yeman have contributed equally to this full-length research article.

Conflict of interest

The authors have declared no conflict of interest.

References

Adegun, M.K. and Adegun, O.A., 2022. Economic evaluation of banana pseudo-stems as poultry feed: Cost reduction and sustainability implications. J. Agric. Econ. Sustain., 15(3): 45-56.

Adeleke, R. A., Oyedele, D. J., & Adebayo, T. A. (2020). Evaluation of pseudostem yield and fiber content in selected banana and plantain cultivars for industrial applications. Journal of Agricultural Science and Technology , 12(4), 789–801.

Adeyemi, D.A., Oluwafemi, R.A. and Olawoye, B., 2023. Enhancing the nutritional profile of banana pseudo-stems through fermentation for poultry diets. Anim. Nutr. J., 18(2): 112-120.

Akinmoladun, F.O. and Oboh, G., 2017. Nutritional and anti-nutritional composition of Musa species. Afr. J. Food Sci., 11(8): 199-205.

Akinmoladun, O.I., Oladele, A.K., and Adeyeye, S.A. 2017. Carbohydrate composition and nutritional potential of selected banana varieties: Implications for energy density and dietary applications. Journal of Food Science and Technology, 54(6), 1683–1690. https://doi.org/10.1007/s13197-017-2572-8

Alemu, T., Tadesse, T., Amogne, G., Endazenaw, G. and Mamo, E., 2020. Predictors of coronavirus disease 2019 (COVID-19) prevention practices using the Health Belief Model among employees in Addis Ababa, Ethiopia, 2020. *Infect. Drug Resist.*, 13: 3751–3761. https://doi.org/10.2147/IDR.S275933

Ali, A., Yaqoob, U. and Khan, S., 2020. The role of dietary fiber in gastrointestinal health. J. Food Sci. Technol., 57(3): 987-994.

Almeida, L.A., Costa, R.F. and Silva, F.R., 2019. Effect of banana types on the fiber content and digestion in livestock. Int. J. Agric. Biol., 20(4): 803-809.

AOAC, 2019. Official methods of analysis. 21st Edition. Association of Official Analytical Chemists, Washington, DC.

Atwater, W.O. and Benedict, F.G., 1902. Experiments on the metabolism of matter and energy in the human body. Washington: Government Printing Office. https://doi.org/10.5962/bhl.title.123031

Bradstreet, R.B., 1965. The Kjeldahl method for organic Nitrogen. Academic Press. https://doi.org/10.1016/B978-1-4832-3298-0.50005-9

Day, R. A., and Underwood, E. J. 1986. Chemistry of Foods and Nutrition . 7th Edition. Prentice-Hall.

FAO, 2020. World food and agriculture - statistical yearbook 2020. FAO.

FAO, 2023. Sustainable practices in poultry feed production: The role of agricultural by-products. Food and Agriculture Organization of the United Nations. Retrieved from https://www.fao.org

Fiske, C.H. and Subbarow, Y., 1925. The colorimetric determination of phosphorus. J. Biol. Chem., 66(2): 375-400. https://doi.org/10.1016/S0021-9258(18)84756-1

Gebrehiwot, M. F., Vanlauwe, B., and Giller, K. E. 2021. Biomass production and nutrient content of different banana (Musa spp.) cultivars in East Africa. Agriculture, Ecosystems & Environment , 317, 107482. https://doi.org/10.1016/j.agee.2021.107482

Hussein, S., Mohamed, F. and Ahmed, S., 2022. Mineral content of different banana types and their implications for human health. J. Food Nutr. Res., 60(1): 78-85.

James, C.S., 1995. Analytical chemistry of foods. Springer science and business media. https://

doi.org/10.1007/978-1-4615-2165-5

Johnson, P., Smith, A. and Chen, D., 2017. Influence of soil on iron bioavailability in tropical crops. J. Agric., 9(4): 75-89.

Kamal, M., Rahman, S. and Ahmed, N., 2023. Processing methods to improve digestibility and performance of poultry fed with banana pseudo-stems. Int. J. Poult. Sci., 22(4): 78-86.

Kumar, S., Prasad, S., Yadav, K.K., Shrivastava, M., Gupta, N., Nagar, S., Jha, S.K., Kumari, S. and Singh, V., 2019. Hazardous heavy metals contamination of vegetables and food chain: Role of sustainable remediation approaches. A review. *Environ. Res.*, 179: Article ID 108792. https://doi.org/10.1016/j.envres.2019.108792

Kumar, V., Sharma, A. and Desai, R., 2022. Copper and micronutrient levels in bananas cultivated in different regions. Food Chem., 274: 481-488.

Kumar, V., Singh, R. and Patel, M., 2022. Nutritional analysis and supplementation strategies for banana stem-based poultry feed. J. Anim. Sci. Biotechnol., 13(1): 210-219.

Martínez, J., López, M. and García, R., 2021. Nutritional composition of different banana cultivars grown in tropical regions. Food Res. Int., 138: 109734.

Montgomery, D.C., 2017. Design and analysis of experiments. John Wiley and Sons.

Musa, M.H., Shaheen, H.I., Noman, A. and Ali, M.A., 2020. Effect of banana cultivar on lipid content and bioactive components. J. Agric. Food Chem., 68(12): 3687-3695.

Nandhini, M., Manivannan, M., Premalakshmi, V., Theradimani, M., Srinivasan, S., Sabarinathan, K. and Kennady, N., 2020. Effects of biostimulants on growth, yield, and quality of chili intercropped with palmyrah. Plant Sci. Today, 11(sp4). https://horizonepublishing.com/journals/index.php/PST/article/view/5550

Ogbo, A., Ijeoma, B. and Opara, E., 2019. Dry matter and carbohydrate composition in various banana cultivars. J. Trop. Agric., 56(3): 295-302.

Oluwafemi, R.A., Adeyemi, D.A. and Olawoye, B., 2023. Cost-effective utilization of banana stems in poultry diets: Reducing dependency on conventional grains. Trop. Agric. Res., 34(2): 89-97.

Osei, M.K., Amankwah, E. and Appiah, M., 2021. Evaluating the metabolizable energy of tropical fruits for human consumption. J. Agric. Food Chem., 69(10): 3055-3062.

Pereira, R., Silva, J. and Martins, M., 2018. Manganese concentrations in bananas: Impact of growing conditions and banana variety. J. Nutr. Sci., 45(5): 121-130.

Perkin-Elmer, 1996. Analytical methods for atomic absorption spectroscopy. Perkin-Elmer Corporation.

Prabha, K., Suresh, R. and Raghavendra, T., 2020. Mineral compositions of different banana cultivars in India. Int. J. Food Sci. Nutr., 71(3): 333-342.

Price, M.L., Van Scoyoc, S. and Butler, L.G., 1978. A critical evaluation of the vanillin reaction as an assay for tannin in sorghum grain. J. Agric. Food Chem., 26(5): 1214-1218. https://doi.org/10.1021/jf60219a031

Randall, J.M., 1974. Improved soxhlet extraction method. J. Lipid Res., 15(3): 479-482.

Reddy, M.S., Reddy, G.S. and Reddy, P.S., 2018. Plant growth-promoting rhizobacteria: A potential bio-asset for restoration of degraded soil and crop productivity with sustainable emerging techniques. Environ. Geochem. Hlth., 40(5): 1995-2015.

Sarkar, D., Choudhury, N. and Banerjee, S., 2020. Metabolizable energy in banana cultivars: Implications for livestock nutrition. J. Anim. Sci. Technol., 62(2): 142-149.

Sharma, M., Kumar, D. and Sharma, S., 2019. Zinc and other mineral contents in different banana cultivars. Int. J. Fd. Agric. Sci., 28(6): 209-215.

Sharma, N., Thenarasun, S.A. and Kaur, M., 2016. Adjuvant role of amniotic membrane transplantation in acute ocular Stevens–Johnson syndrome: A randomized control trial. Ophthalmology, 123(3): 484-491. https://doi.org/10.1016/j.ophtha.2015.10.027

Shukla, R., Sharma, S. and Srivastava, P., 2020. Phytates as nutritional, functional, and medicinal agents. Food Chem., 332: 127372.

Siddiqui, H.S., Khan, M.A. and Iqbal, Z., 2021. Tannin compounds: An overview of their pharmacological and toxicological properties. Toxicol. Rep., 8: 337-344.

Singh, R. and Patel, M., 2023. Challenges and opportunities in using banana stems as poultry feed: Environmental and economic considerations. J. Sustain. Agric., 28(5): 301-312.

Singh, S., Kumar, A., Mukherjee, A., Rastogi, R.P. and Verma, J.P., 2021. Salt-tolerant plant growth-promoting *Bacillus pumilus* strain JPVS11 to enhance plant growth attributes of rice and improve soil health under salinity stress. Microbiol. Res., 242: 126616. https://doi.org/10.1016/j.micres.2020.126616

Smith, L., Johnson, M. and Clark, R., 2019. Phosphorus and calcium in banana fruits: A comparative study of cultivars. Fd. Res. Int., 125: 221-229.

Sulaiman, M., Kurniawan, H. and Wahyuni, Y., 2019. Mineral composition in banana fruits and its implications for human health. Food Chem., 271: 97-104.

Tesfaye, A., Lemma, B., and Woldegiorgis, H. T. 2022. Valorization of Banana (Musa spp.) Pseudostem as a Source of Nutrients and Bioactive Compounds: A Review. Journal of Food Science and Technology, 59(6), 2143–2155. https://doi.org/10.1007/s13197-022-05408-1

Umar, H., Isah, A. and Aliero, A.A., 2013. Phytochemical and antimicrobial properties of the banana peel. Int. J. Chem. Biol. Sci., 7(1): 23-30.

Van Soest, P.J., Robertson, J.B. and Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74(10): 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Vazquez, M., Garcia, E. and Lopez, F., 2021. Magnesium content in bananas and its relation to cultivar type. Plant Sci. J., 88(2): 87-95.

Wadhwa, M. and Nair, A., 2021. Protein content variation in different banana types. Int. J. Food Sci. Nutr., 12(7): 679-687.

Wheeler, E. L., and Ferrel, R. E. 1971. A method for phytic acid determination in whole grain sorghum. Analytical Biochemistry, 40(2), 389–393. https://doi.org/10.1016/0003-2697(71)90414-8