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Nutritional Values of Cassava Leaves in Three Districts, Kenema, Kailahun, and Bo, Sierra Leone

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Abstract
Cassava leaves (Manihot esculenta) are a vital source of nutrition in the Kenema, Kailahun, and Bo districts of Sierra Leone, contributing to dietary diversity and food security in resource-limited settings. This study aims to evaluate the nutritional value of cassava leaves, focusing on their macro- and micronutrient profiles while addressing safety implications related to cyanogenic glycosides. A total of 15 samples of cassava leaves were collected and analyzed for proximate, mineral, and vitamin compositions using standard methods. The analysis revealed that cassava leaves are rich in protein (ranging from 23.12% to 29.78%), vitamins A, C, and various B vitamins, and essential minerals such as calcium and iron. Significant differences in nutrient content among the districts were observed, with P values less than 0.05, indicating the influence of soil types and farming practices. Notably, the presence of cyanogenic glycosides poses health risks if not properly managed; therefore, processing methods such as boiling, steaming, and fermentation are recommended to mitigate these risks while preserving nutritional value. The findings highlight the potential of cassava leaves as a significant nutritional resource that can enhance dietary diversity and food security. This research advocates for increased consumption of cassava leaves in Sierra Leone while emphasizing the importance of safety measures in their preparation. Further studies are needed to explore factors influencing nutrient profiles and to promote cassava leaves as a viable food source.

Keywords: Cassava Leaves, Dietary Diversity, Food Security, Micronutrients, And Nutritional Composition

Introduction
Cassava (Manihot esculenta Crantz) is a staple food crop that plays a critical role in global food security, particularly in tropical and subtropical regions. According to the Food and Agriculture Organization (FAO), cassava is the sixth most important crop globally, with an annual production of over 300 million tons [1]. This remarkable yield underscores cassava's significance in food security, particularly in resource-limited settings where other food sources may be scarce. While the tuberous roots of cassava are widely recognized for their high carbohydrate content, the nutritional potential of the cassava plant's leaves is gaining increasing attention from researchers and nutritionists alike.

Cassava is a versatile crop that is cultivated in more than 100 countries, with Africa being the largest producer, accounting for over 50% of global production [1]. The crop is particularly important in sub-Saharan Africa, where it is a primary source of food for over 200 million people [2]. In countries such as Sierra Leone, Liberia, and Guinea, cassava is the main staple food, providing up to 70% of the daily energy requirements for the population [3].

In addition to its role in food security, cassava is also a significant source of income for smallholder farmers, particularly women, who are responsible for up to 70% of cassava production in Africa [4]. The crop is resilient to drought, pests, and diseases, making it an ideal crop for smallholder farmers who may lack access to modern agricultural inputs. Moreover, cassava can be stored in the ground for up to two years, providing a valuable food reserve during periods of food insecurity.

The nutritional potential of cassava leaves has been a part of traditional diets for centuries, particularly in regions where nutritional deficiencies are prevalent. The leaves are rich in proteins, vitamins, and minerals, making them a valuable dietary resource that can contribute to enhanced dietary diversity [5, 6]. This is particularly important given that many diets in tropical regions are heavily reliant on cereals and tubers, often leading to deficiencies in essential amino acids such as methionine and lysine [6, 7].

Recent studies have shown that cassava leaves can provide a significant source of plant-based protein, with protein content ranging from 25% to 32% of their dry weight [8-10]. This is comparable to other protein-rich plant sources such as soybeans and lentils. Moreover, cassava leaves contain all nine essential amino acids, making them a complete protein source. This is particularly important for vulnerable groups, including children and pregnant women, who are at higher risk of protein-energy malnutrition.

In addition to their protein content, cassava leaves are an excellent source of several vital vitamins, including vitamins A, C, and several B vitamins, which play crucial roles in energy metabolism, skin health, and immune function [11, 12]. For example, vitamin A is essential for vision and immune health, while vitamin C is a powerful antioxidant that contributes to the body's defense against illness. Moreover, cassava leaves are a rich source of dietary fiber, which has been shown to have numerous health benefits, including improved digestion, weight management, and reduced risk of chronic diseases such as type 2 diabetes and cardiovascular disease [13].

The mineral composition of cassava leaves is also noteworthy, as they contain high levels of essential minerals such as calcium, iron, and potassium, which are crucial for various physiological processes, including fluid balance, oxygen transport, and bone health [14, 15]. This is particularly beneficial for vulnerable groups, including children and pregnant women, who are at higher risk of nutrient deficiencies. Recent research has also highlighted the antioxidant properties of cassava leaves, attributed to their high polyphenol and flavonoid content, which may offer protective benefits against chronic diseases and oxidative stress.

Despite their nutritional benefits, there are significant health risks associated with the consumption of cassava leaves, particularly due to the presence of cyanogenic glycosides. These compounds can release toxic cyanide upon enzymatic hydrolysis, posing serious health dangers if not properly processed [16]. Prolonged consumption of cassava leaves with high cyanogenic content has been linked to various toxic effects, including Tropical Ataxic Neuropathy (TAN) and goitre, which are prevalent in certain regions of Africa. Tropical Ataxic Neuropathy is a neurological disorder characterized by weakness, sensory loss, and gait disturbances, while goitre is associated with thyroid dysfunction due to iodine deficiency exacerbated by cyanogenic compounds [16]. Therefore, it is essential to comprehend both the nutritional value and the safety precautions necessary for their consumption to promote cassava leaves as a viable food source without jeopardizing public health.

Several processing techniques have been developed to reduce the cyanogenic content of cassava leaves, including boiling, steaming, and fermentation [17-24]. These techniques can significantly reduce the cyanogenic content of cassava leaves while retaining their nutritional value. Moreover, proper drying and storage techniques can also help to reduce the risk of cyanogenic poisoning.

Cassava and its leaves represent a valuable resource in the fight against malnutrition and food insecurity in tropical regions. By understanding their nutritional composition and implementing proper safety measures, cassava leaves can be effectively integrated into local diets, contributing to improved health outcomes and dietary diversity in vulnerable populations. This study aims to assess the nutritional values of cassava leaves through a comprehensive review of recent scientific literature. By analyzing their macronutrient and micronutrient profiles while addressing safety issues related to cyanogenic compounds, this research aims to advance knowledge on how cassava leaves can improve food security and nutrition in resource-limited environments.

Materials and methods

Study Area

The study was conducted in the Sierra Leonean agro-ecological zones, specifically focusing on the districts of Kenema, Kailahun, and Bo. These regions are characterized by varying climatic conditions, topography, and soil types, which influence the growth and nutritional profile of cassava (Manihot esculenta Crantz).

Kenema is located in the eastern part of Sierra Leone and is known for its abundant rainfall, which supports diverse agricultural activities. The district has a rich history of cassava cultivation, contributing significantly to local food security and livelihoods. Cassava serves as a staple food and a source of income for many households in the region, highlighting its importance in the agricultural landscape of Sierra Leone. Kailahun, also in the eastern region, features a mix of upland and lowland farming systems. The farmers in this district often practice mixed cropping, which enhances soil fertility and reduces pest pressure, benefiting cassava production. The socio-economic activities in Kailahun are heavily reliant on agriculture, making cassava an essential crop for both subsistence and commercial purposes.

Bo, located in the southern part of Sierra Leone, is characterized by its fertile soils and favorable climatic conditions, which support high cassava yields. The district plays a crucial role in the overall cassava supply chain in Sierra Leone, with many farmers engaging in both cultivation and processing of cassava leaves and roots. This agricultural activity is essential for local food security and economic development, as cassava is a staple crop that provides sustenance and income for many households in the region. The favorable environmental conditions in Bo enhance the productivity of cassava, making it a key area for agricultural research and development initiatives aimed at improving crop yields and farmer livelihoods. These districts were selected for the study due to their significant contribution to cassava production in Sierra Leone and the need to assess the nutritional and health benefits of cassava leaves, which are often underutilized in the region.

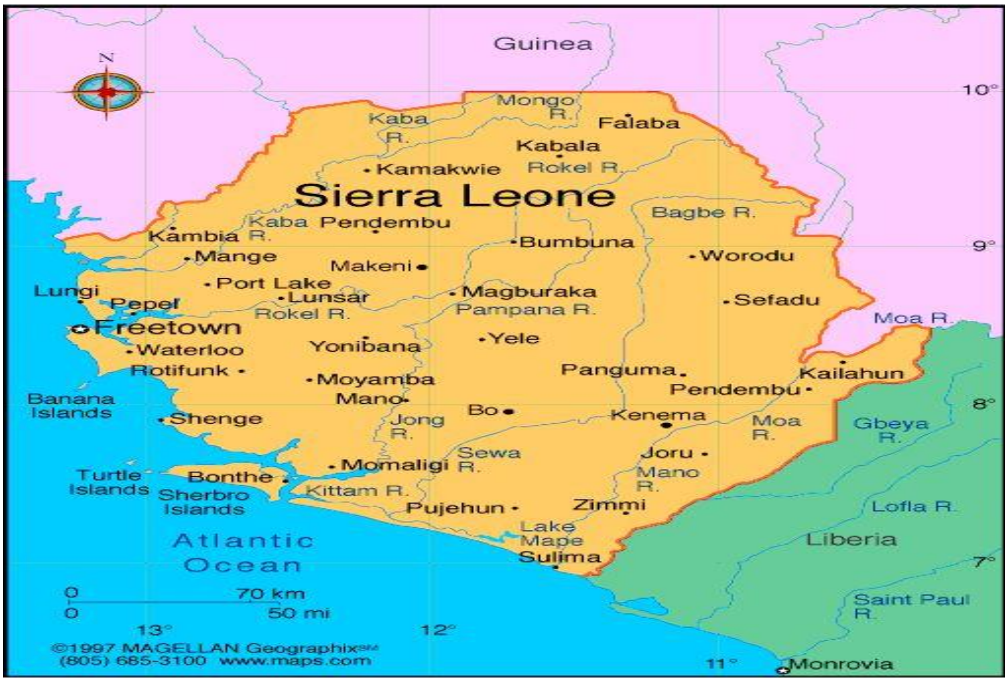

Figure 1: Map of Sierra Leone

Sample Collection

Selection of Sites: A total of six farms were identified across the three districts for sample collection.

Harvesting: Fresh cassava leaves were harvested from the selected farms during the peak harvest season to ensure optimal nutritional quality.

Traditional Use of Cassava Leaves

Cassava leaves have been a staple in the diets of communities in Sierra Leone for generations. Traditionally, they are used in various local dishes, often cooked with spices or incorporated into stews. This cultural backdrop emphasizes the leaves' importance not just as a nutritional resource but also as a part of the community's culinary heritage.

Sample Size: A total of 15 samples were gathered, with three samples from each farm to reduce environmental biases.

District	Number of Farms	Samples per Farm	Total Samples
Kenema	2	3	6
Kailahun	2	3	6
Bo	1	3	3
Total	**5**	**-**	**15**

Table 1: Sample Distribution

Storage and Transport: The samples were placed in clean, labeled plastic bags to avoid contamination. They were transported to the laboratory in a cooler to maintain freshness and prevent spoilage.

Proximate Composition Analysis

Moisture Content

Each sample was weighed and dried in the oven at 105°C until a constant weight was achieved. The moisture content was calculated based on the weight loss.

Crude Protein

A known weight of sample was digested in sulfuric acid, converting nitrogen to ammonium sulfate [25]. The nitrogen content was then determined by distillation and titration. Protein content was calculated by multiplying the nitrogen content by 6.25.

Crude Lipid

Approximately 5 grams of dried sample was placed in the Soxhlet apparatus [17]. Lipids were extracted using petroleum ether, and the extracted lipids were weighed after evaporation of the solvent.

Ash Content

Samples were ashed in the Muffle furnace at 550°C until a constant weight was obtained. The ash content was expressed as a percentage of the original weight of the sample.

Carbohydrates

Total Carbohydrates were determined as:100 - (Moisture + Protein + Lipid + Ash).

Mineral Composition Analysis

Sample Preparation

Each dried and ground sample (1 g) was digested using a mixture of concentrated nitric acid and hydrochloric acid in a digestion flask.

Analysis

The digested samples were analyzed for minerals (calcium, magnesium, phosphorus, potassium, sodium, iron, zinc, copper, manganese) using an Atomic Absorption Spectrophotometer (AAS) by comparing the absorbance to standard solutions.

Vitamin Analysis

Vitamin A

Samples were saponified using a potassium hydroxide (KOH) solution in ethanol to release vitamin A, followed by extraction with hexane. The extracts were then analyzed using High-Performance Liquid Chromatography (HPLC) on a Shimadzu HPLC system. The analysis was performed at a temperature of 30°C, using a mobile phase consisting of acetonitrile and water (70:30 v/v). The flow rate was set at 1.0 mL/min, and the retention time for the target compounds was approximately 10-15 minutes.

Vitamin C

Samples were prepared using a metaphosphoric acid solution to extract vitamin C. The extract was titrated with 2,6-Dichlorophenolindophenol (DCPIP) until a color change occurred. The colored complex was then measured at a wavelength of 520 nm using a UV-Vis spectrophotometer (model XYZ) to determine the vitamin C concentration.

Vitamin E

Similar to vitamin A, vitamin E was extracted using hexane as the organic solvent and analyzed with High-Performance Liquid Chromatography (HPLC) on a Shimadzu HPLC system. The analysis was conducted at a temperature of 25°C, with a mobile phase of methanol and water (85:15 v/v), a flow rate of 1.2 mL/min, and a retention time of approximately 12-18 minutes for the target compounds.

Statistical Analysis

Data Analysis

The collected data for proximate, mineral, and vitamin compositions were subjected to one-way ANOVA to evaluate significant differences among the samples from the three districts.

Post-hoc Testing

Tukey's test was utilized for pairwise comparisons between means, with a significance threshold set at $p < 0.05$.

Ethical Considerations

Consent: Prior to sample collection, informed consent was obtained from local farmers.
Compliance: All research activities adhered to ethical guidelines established by relevant institutional and national committees for human experimentation.

Results

Proximate Composition of Cassava Leaves

The proximate composition of cassava leaves is presented in Table 2. The moisture content ranged from 64.57% to 70.15% and ,73.43%, with the lowest value observed in samples from Bo District and the highest value observed in samples from Kenema District and Kailahun District. The crude protein content ranged from 23.12% to 29.78%, with the highest value observed in samples from Kailahun District, and the lowest value observed in samples from Kenema District. The crude lipid content ranged from 1.21% to 2.87%, with the highest value observed in samples from Bo District, and the lowest value observed in samples from Kenema District. The ash content ranged from 5.43% to 7.89%, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kailahun District. The carbohydrate content ranged from 10.26% to 16.84%, with the highest value observed in samples from Kenema District and the lowest value observed in samples from Kailahun District.

Minerals	Kenema	Kailahun	Bo
Moisture	70.15±2.68a	72.43±1.21b	64.57±1.56c
Crude protein	25.46±1.23a	29.78±1.89b	23.12±1.57c
Crude lipid	1.62±0.21a	1.47±0.18b	2.87±0.32c
Ash	6.12±0.31a	5.94±0.27b	7.89±0.43c
Carbohydrate	16.84±0.83a	12.81±0.62b	10.26±0.51c

Table 2: Proximate Composition of Cassava Leaves (% dry matter)

Means within the same row followed by different letters are significantly different ($p < 0.05$).

Parameters	Kenema	Kailahun	Bo
Calcium	144.21±6.21a	201.33±9.18b	212.67±11.23c
Magnesium	102.33±4.56a	145.67±7.21b	168.16±8.33c
Phosphorus	436.17±21.67a	652.33±32.11b	513.33±27.21c
Potassium	2211.11±111.23a	2566.67±122.33b	3123.33±156.21c
Sodium	36.11±1.89a	45.67±2.56b	68.33±3.33c
Iron	5.67±0.32a	9.78±0.67b	7.11±0.56c
Zinc	1.89±0.11a	2.56±0.18b	3.11±0.21c
Copper	0.56±0.03a	0.78±0.04b	1.02±0.06c
Manganese	1.21±0.11a	1.89±0.18b	2.33±0.21c

Table 3: Mineral composition of cassava leaves (mg/100g dry matter)

Means within the same row followed by different letters are significantly different ($p < 0.05$).

Mineral Composition of Cassava Leaves

The mineral composition of cassava leaves is presented in Table 3. The calcium content ranged from 144.21 mg/100g to 212.67 mg/100g, with the highest value observed in samples from District 3 and the lowest value observed in samples from District 1. The magnesium content ranged from 102.33 mg/100g to 168.16 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kenema District. The phosphorus content ranged from 436.17 mg/100g to 652.33 mg/100g, with the highest value observed in samples from Kailahun District and the lowest value observed in samples from Kenema District. The potassium content ranged from 2211.11 mg/100g to 3123.33 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kenema District. The sodium content ranged from 36.11 mg/100g to 68.33 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kenema District. The iron content ranged from 5.67 mg/100g to 9.78 mg/100g, with the highest value observed in samples from Kailahun District and the lowest value observed in samples from Kenema District.

The zinc content ranged from 1.89 mg/100g to 3.11 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kenema District. The copper content ranged from 0.56 mg/100g to 1.02 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kenema District. The manganese content ranged from 1.21 mg/100g to 2.33 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Kenema District.
Means within the same row followed by different letters are significantly different ($p < 0.05$)

Vitamin Composition of Cassava Leaves

The vitamin composition of cassava leaves is presented in Table 4. The vitamin A content ranged from 13,267 IU/100g to 19,833 IU/100g, with the highest value observed in samples from Kailahun District and the lowest value observed in samples from Kenema District. The vitamin C content ranged from 27.11 mg/100g to 39.44 mg/100g, with the highest value observed in samples from District 3 and the lowest value observed in samples from Kenema District. The vitamin E content ranged from 1.21 mg/100g to 2.33 mg/100g, with the highest value observed in samples from Bo District and the lowest value observed in samples from Bo District.

Means within the same row followed by different letters are significantly different ($p < 0.05$).

Parameters	Kenema	Kailahun	Bo
Vitamin A	13,267±678.33a	19,833±966.67b	16,556±833.33c
Vitamin C	27.11±1.21a	33.33±1.89b	39.44±2.11c
Vitamin E	1.21±0.11a	1.89±0.18b	2.33±0.21c

Table 4: Vitamin Composition of Cassava Leaves (IU/100g or mg/100g dry matter)

Discussion

The findings of this study provide critical insights into the nutritional composition of cassava leaves (Manihot esculenta) from three districts in Sierra Leone: Kenema, Kailahun, and Bo. The proximate, mineral, and vitamin contents revealed significant variations, which bear important implications for food security, nutrition, and agricultural policies in Sierra Leone and beyond.

The moisture content of cassava leaves ranged from 64.57% to 73.43%, consistent with findings reported by [17,20]. High moisture levels are a double-edged sword; while they indicate freshness and nutritional potential, they also contribute to rapid spoilage and postharvest losses. To mitigate this, effective postharvest management strategies, including drying techniques and proper storage facilities, must be prioritized. Implementing such measures could enhance the shelf life of cassava leaves, making them more accessible throughout the year, particularly in resource-poor communities.

The crude protein content varied from 23.12% to 29.78%, with the highest levels found in Kailahun District. This is notably higher than the protein levels reported in previous studies across Africa, which typically range between 15% and 25% [21]. The protein richness of cassava leaves positions them as a vital dietary component, especially in regions where animal protein sources are scarce. Policymakers should consider promoting cassava leaf consumption as a sustainable and low-cost protein source, particularly in food insecurity contexts.

The lipid content, ranging from 1.21% to 2.87%, is relatively low, aligning with findings from other researchers who emphasize the health benefits of low-fat diets [17,18]. This makes cassava leaves a prudent choice for populations concerned about cardiovascular health. Public health campaigns should highlight the nutritional benefits of incorporating cassava leaves into diets, especially for vulnerable groups such as children and pregnant women, who require nutrient-dense foods.

The mineral analysis revealed significant differences in calcium, magnesium, phosphorus, potassium, sodium, iron, zinc, copper, and manganese contents among the three districts. The calcium content ranged from 144.21 mg/100g to 212.67 mg/100g, with the highest levels found in Bo District. This is crucial given the role of calcium in bone health and the prevention of osteoporosis, particularly in post-menopausal women [21]. Policymakers should foster educational initiatives aimed at increasing awareness of the nutritional value of cassava leaves, especially in areas with high rates of calcium deficiency.

Potassium levels, which ranged from 2,211.11 mg/100g to 3,123.33 mg/100g, are significant for cardiovascular health and the regulation of blood pressure [22]. The high potassium content in cassava leaves suggests that they could be integrated into dietary recommendations aimed at hypertension management, particularly in regions where cardiovascular diseases are prevalent.

The presence of essential trace minerals such as iron and zinc are noteworthy, especially given the high prevalence of micronutrient deficiencies in many developing countries. The iron content ranged from 5.67 mg/100g to 9.78 mg/100g, aligning with findings by Faber and Wenhold that emphasize the importance of iron-rich foods in combating anemia [23]. Given the increasing global concern over micronutrient deficiencies, the promotion of cassava leaves as a dietary staple could significantly improve public health outcomes.

The vitamin analysis showed that cassava leaves are rich in vitamin A, with values ranging from 13,267 IU/100g to 19,833 IU/100g, and vitamin C ranging from 27.11 mg/100g to 39.44 mg/100g. This reinforces the findings of other studies that have identified leafy greens as critical sources of these vitamins [24]. The high vitamin A content is particularly relevant in the context of global efforts to combat vitamin A deficiency, which is a significant public health issue in many developing countries [21].

The one-way ANOVA results showed significant differences ($p < 0.05$) in the proximate, mineral, and vitamin composition of cassava leaves among the three districts. Post-hoc analysis using Tukey's test revealed significant differences in moisture, crude protein, crude lipid, ash, carbohydrate, calcium, magnesium, phosphorus, potassium, sodium, iron, zinc, copper, manganese, vitamin A, vitamin C, and vitamin E contents among the districts. These findings are consistent with other studies that have reported variations in the nutritional composition of cassava leaves based on geographical location, soil type, and cultivar [19, 20].

The implications of these findings extend beyond individual health; they highlight the potential of cassava leaves as a viable food source in global nutrition strategies. Policymakers and health organizations should collaborate to promote the cultivation and consumption of cassava leaves, particularly in regions facing food insecurity and malnutrition.

The significant nutritional differences among cassava leaves from various districts underscore the need for region-specific agricultural and nutritional policies. Governments should invest in research and development to identify high-yielding and nutrient-dense cassava cultivars. Agricultural extension services could play a vital role in educating farmers about best practices in cassava cultivation and postharvest handling to maximize both yield and nutritional quality.

Furthermore, integrating cassava leaves into national dietary guidelines could provide a strategic avenue for addressing malnutrition. By promoting local consumption of nutrient-rich foods like cassava leaves, countries can enhance food sovereignty and reduce reliance on imported foods. However, it is essential to exercise caution due to the presence of cyanogenic glycosides, which can pose health risks if consumed improperly. The levels of these compounds can vary widely depending on factors such as the age of the leaves, the specific variety of cassava, and the manuring practices used. Therefore, it is crucial to highlight the need for appropriate processing methods, such as boiling or fermentation, to reduce cyanogenic content before consumption, ensuring the safety and health benefits of cassava leaves are fully realized.

Environmental factors such as soil type, climate, and agricultural practices play a crucial role in determining the nutrient composition of cassava leaves. Variations in soil fertility, moisture availability, and farming techniques can lead to significant differences in macronutrient and micronutrient profiles. For instance, richer soils tend to yield leaves with higher mineral content, while drought conditions may affect the protein levels adversely.

The bioavailability of nutrients in cassava leaves can be influenced by factors such as the presence of anti-nutritional compounds, processing methods, and the overall dietary context. For example, cooking methods can enhance the bioavailability of certain vitamins while reducing the effects of anti-nutritional factors. Understanding these dynamics is essential for formulating dietary recommendations, particularly for vulnerable populations at risk of nutrient deficiencies.

This study demonstrates that cassava leaves are not only a significant source of essential nutrients but also hold promise as a sustainable food resource for alleviating hunger and malnutrition in Sierra Leone and beyond. The findings advocate for the integration of cassava leaves into dietary recommendations and agricultural policies, emphasizing their role as a nutrient-dense food source. Future research should focus on the development of effective strategies for enhancing the availability and consumption of cassava leaves, ultimately contributing to improved food security and public health outcomes on a global scale.

Conclusions

The present study found that cassava leaves are a good source of protein, minerals, and dietary fiber, and a low source of lipids and carbohydrates. The crude protein content of cassava leaves ranged from 23.12% to 29.78%, which is higher than the values reported by other researchers in Sierra Leone and other African countries. The nutritional composition of cassava leaves makes them a valuable food source, particularly for people living in resource-poor communities where access to animal protein sources is limited. However, the nutrient composition of cassava leaves varied significantly among the three districts, which may be attributed to variations in soil types, farming practices, and cassava genotypes [26-29].

Importantly, the significance of proper processing to eliminate toxic cyanogenic glucosides before human consumption cannot be overstated. Effective processing methods, such as boiling or fermentation, are essential to ensure the safety of cassava leaves for dietary use. Further studies are needed to investigate the factors that influence the nutrient composition of cassava leaves in Sierra Leone and to promote their consumption as a cheap and readily available source of protein and other nutrients.

Ethical Approval

All procedures conducted in this study on the nutritional values of cassava leaves in the Kenema, Kailahun, and Bo districts of Sierra Leone were approved by the ethical research committee of Njala University. The authors ensured compliance with ethical standards throughout the research process.

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CRediT authorship contribution statement

Peter Makieu: Writing-original draft, Formal and analysis, Data Curation, Conceptualization. Momodu Sahid Kanu: Writing review & editing, Conceptualization, Supervision, Funding acquisition. Abdulai Sillah: Writing review & editing, Conceptualization, Investigation. Abdulai Sheriff: Project administration, Conceptualization, Investigation.

Declaration of Competing Interest

The authors declare that there are no competing interests regarding the publication of this research paper. All authors have disclosed any potential conflicts of interest that could influence the results or interpretation of the findings presented in this study.

Data Availability

Data will be made available upon request.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used Poe AI to identify and correct grammatical errors, ensuring clarity and coherence throughout the document. Additionally, QuillBot was utilized for paraphrasing, enhancing the text's readability and flow while maintaining the original meaning. These tools collectively contributed to producing a polished and professional research paper. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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