Mineral Composition of Neglected and Underutilized Food Crops and Their Role in Nutrition Security in Sierra Leone

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Abstract

Background

Sierra Leone's food system faces persistent nutritional challenges, largely due to limited crop diversity and reliance on imported staples. Neglected and Underutilized Food Crops (NUFCs), though culturally embedded and ecologically resilient, remain underexplored in formal nutrition and agricultural strategies. This study evaluates the mineral composition of selected NUFCs cultivated in Bo and Kenema districts regions known for their agricultural activity and vulnerability to micronutrient deficiencies.

Methodology

A mixed-methods approach was employed, combining ethnobotanical surveys with laboratory-based nutritional analysis. Plant samples were collected through guided field walks and community engagement, then identified and authenticated at the National Herbarium, Njala University. Mineral profiling was conducted using standardized procedures: Kjeldahl digestion for nitrogen (converted to protein), Bray I extraction for phosphorus, and Atomic Absorption Spectrophotometry (AAS) and flame photometry for trace elements including iron (Fe), zinc (Zn), copper (Cu), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), and phosphorus (P). All concentrations were standardized to mg/100g for comparability.

Result

The results revealed that *Piper unbellatum* exhibited the most diverse mineral profile, with high concentrations of zinc (12.49 mg/100g), phosphorus (103.1 mg/100g), magnesium (8.94 mg/100g), calcium (11.62 mg/100g), and sodium (1.93 mg/100g). *Celosia argentea* and *Luffa aegyptiaca* were iron-rich, while *Ipomoea aquatica* showed the highest protein content (7.00%) and notable potassium levels. These findings affirm the nutritional relevance of NUFCs and their potential to address micronutrient deficiencies, particularly in rural communities with limited access to fortified foods.

Conclusion

This study confirms the nutritional value of selected indigenous NUFCs, providing empirical evidence to support their role in nutrition-sensitive agriculture. *Crops such as Piper unbellatum, Celosia argentea*, and *Ipomoea aquatica* show strong potential to improve dietary diversity, public health, and food system resilience in Sierra Leone. The findings lay a foundation for future research, policy action, and community-level nutrition initiatives.

INTRODUCTION

Sierra Leone's agricultural landscape is rich in biodiversity, yet its food system remains heavily reliant on a narrow range of staple crops primarily rice, cassava, and maize that offer limited nutritional diversity and are increasingly vulnerable to climate shocks. Despite having over 5.36 million hectares of cultivable land (FAO et al., 2022; World Bank, 2023), the country continues to import approximately 80% of its food (WFP & FAO, 2024), underscoring a systemic gap between agricultural potential and nutritional outcomes. This reliance on imported staples and low-diversity cropping systems has contributed to widespread micronutrient deficiencies, particularly among women and children, with iron-deficiency anemia, zinc deficiency, and protein-energy malnutrition remaining prevalent (UNICEF, 2017).

Neglected and Underutilized Food Crops (NUFCs) represent a promising yet overlooked solution to these challenges. These crops often indigenous, climate-resilient, and culturally embedded have historically contributed to local diets and traditional medicine but remain marginalized in formal agricultural and nutrition programs (Jain & Dutta Gupta, 2013). In Sierra Leone, species such as *Piper unbellatum, Celosia argentea, Ipomoea aquatica*, and *Vernonia amygdalina* are widely known and consumed in rural communities, yet their nutritional profiles are poorly documented and underappreciated in policy and research circles.

The lack of empirical data on the mineral composition of NUFCs has hindered their integration into national food security strategies. While anecdotal and ethnobotanical evidence supports their nutritional value, systematic laboratory-based assessments are scarce. Comparative studies with global benchmarks reveal inconsistencies in nutrient values due to environmental, genetic, and methodological factors (Adeyemi & Babatunde, 2014; Saikia et al., 2023). Without standardized data and validated nutritional profiles, NUFCs remain excluded from agricultural extension services, dietary guidelines, and public health interventions.

This study addresses that gap by evaluating the mineral composition of selected NUFCs cultivated in Bo and Kenema districts regions known for their agricultural engagement and vulnerability to nutritional deficiencies. By quantifying key minerals such as iron (Fe), zinc (Zn), copper (Cu), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na), the research aims to scientifically validate the nutritional potential of these crops.

The study aligns with national development priorities, including the Feed Salone initiative, which seeks to reduce dependency on imported staples and promote indigenous crops for food sovereignty. It also contributes to global efforts to mainstream underutilized crops in sustainable food systems(Nhamo et al., 2022; van Zonneveld et al., 2023). By bridging scientific analysis with traditional knowledge, this research positions NUFCs as vital assets in the fight against hidden hunger and agricultural vulnerability in Sierra Leone.

We aim to evaluate the mineral composition of selected NUFCs cultivated in Bo and Kenema districts to assess their potential contribution to food and nutrition security in Sierra Leone. In this study, we hypothesize that these crops possess mineral profiles capable of addressing micronutrient deficiencies prevalent in the region.

METHODOLOGY

Study Area

The study was conducted in Bo and Kenema districts of Sierra Leone, two agriculturally active regions located in the Southern and Eastern Provinces, respectively. Bo District spans approximately 5,473 km² and is characterized by a tropical climate with fertile soils suitable for rice, cassava, maize, and leafy vegetables (OCHA, 2015a). Kenema District, covering about 6,053 km², shares similar agro-ecological features but is also known for its inland valley swamp (IVS) systems and cash crops like cocoa and coffee (OCHA, 2015b). Both districts experience a monsoon-type humid tropical climate, with annual rainfall ranging from 2,000 mm in the north to 4,000 mm in the south (OCHA, 2015b, 2015a). These conditions support diverse cropping systems and make the regions ideal for studying NUFCs, which are often cultivated in marginal or mixed farming environments.

Study Design

This research employed a mixed-methods design, integrating both quantitative laboratory analysis and qualitative ethnobotanical inquiry. The study focused on assessing the mineral composition of selected NUFCs to determine their nutritional potential. A purposive sampling strategy was used to select plant species based on local consumption patterns, traditional knowledge, and availability in the study area. The design included structured questionnaires with an in-dept interview, guided field walks, and laboratory-based chemical assays. This triangulated approach ensured a comprehensive understanding of both the biochemical properties and socio-cultural relevance of NUFCs.

Sample Size and Species Selection

From an initial pool of 45 neglected and underutilized food crops (NUFCs) documented across Bo and Kenema districts in Sierra Leone, 23 species with more than five recorded observations were subjected to binomial statistical analysis to determine utilization trends. These were categorized as significantly increasing, declining, or exhibiting no statistically significant change in consumption. For the present study on proximal mineral composition, eight NUFC species were purposively selected from the latter two categories those with declining usage or no significant change ($p > 0.05$). Selection was guided not only by statistical classification but also by practical considerations including local availability, adaptability to extreme environmental conditions, cultural values, and potential nutritional relevance. The final sample included species such as *Luffa aegyptic, Justicia insularis, Triumfetta cordifolia, Piper unbellatum*, *Asystasia gangetica*, *Celosia argentinae, Vernoniamy cordiafolia*, and *Ipomoea aquatica*. These crops were identified through community consultations with experienced local farmers, women, hunters, and farm traders, and represent a subset of NUFCs at risk of underutilization despite their nutritional promise.

Data Collection

i. Fieldwork and Ethnobotanical Survey

Data collection began with the training of research assistants in digital tools such as Kobo Toolbox, followed by a pilot survey to refine the questionnaire. Semi-structured interviews were conducted with farmers, market vendors, and community elders to document indigenous knowledge, cultivation practices, and perceptions of NUFCs. FGDs provided deeper insights into the cultural and nutritional roles of these crops, while guided field walks enabled direct observation and documentation of NUFCs in their natural and cultivated environments.

ii. Plant Specimen Collection and Identification

Plant samples were collected from home gardens, farms, and forest margins. Priority was given to fertile specimens bearing flowers or fruits to ensure accurate identification. Young leaves were harvested using knives or cutlasses and stored in sealed transparent plastic bags to preserve freshness. With guidance from herbarium experts, samples were treated to prevent early dehydration and transported to the Quality Control Laboratory at Njala University for analysis.

Voucher specimens were prepared and authenticated by experts at the National Herbarium, Njala University, using standard botanical literature and morphological keys. Photographs and local names were recorded for each species, and samples were preserved using alcohol and pressing techniques for reference and laboratory analysis. The plant parts analyzed (proximal mineral composition) in this study were the young leaves sourced from the following locations and institutions:

1. *Piper unbellatum*: Collected from Kasewe Forest Reserve (coordinates: 8.336248–12.170405), under guidance of District Forest Officer, Moyamba District.

2. *Triumfetta cordifolia*: Collected from Kasewe Forest Reserve (coordinates: 8.342758–12.180665), under guidance of District Forest Officer, Moyamba District.

3. *Vernoniamy cordiafolia*: Obtained from Small Bo chiefdom, Kenema District under the guidance of the town chiefd (coordinates: 7.8502519–11.2486597).

4. *Justicia insularis*: Obtained from Tikonko chiefdom, Bo District under the guidance of the town chief (coordinates: 7.8877352–11.7858397).

5. *Asystasia gangetica*: Collected from Gbo chiefdom, Bo District under the guidance of the town chief (coordinates: 8.070604210636244, -11.826134556167704).

6. *Luffa aegyptic*: Collected from Gbo chiefdom, Bo District under the guidance of the town chief (coordinates: 8.070604210636244, -11.826134556167704).

7. *Celosia argentinae*: Collected from Kandu Leppiam chiefdom, Kenema District under the guidance of the town chief (coordinates: 8.070604210636244, -11.826134556167704).

8. *Ipomoea aquatica*: Obtained from Small Bo chiefdom, Kenema District under the guidance of the town chief (coordinates: 7.8502519–11.2486597).

iii. Laboratory Analysis

Proximal mineral analysis was conducted on eight selected neglected and underutilized food crops (NUFCs) identified through prior statistical and ethnobotanical screening. Fresh leaf samples of each species were collected from Bo and Kenema districts, air-dried at ambient temperature, and subsequently oven-dried at 60°C to constant weight. The dried samples were ground into fine powder using a stainless-steel mill and stored in airtight containers prior to analysis. The chemical analysis was conducted at the Environmental Chemistry Laboratory, Njala University. The Kjeldahl method was used to estimate nitrogen content, which was converted to protein using the AOAC, (1990) standard factor of 6.25.

Sample Preparation and Digestion

Each powdered sample was subjected to acid digestion using a mixture of nitric acid (HNO_3) and perchloric acid ($HClO_4$) in a 2:1 ratio. Approximately 0.5 g of sample was digested in a fume hood until a clear solution was obtained. The digested samples were filtered and diluted to a final volume of 50 mL with deionized water.

Mineral elements were quantified using:

• Nitrogen content was determined using the Kjeldahl method, which involves digestion with concentrated sulfuric acid (H_2SO_4) in the presence of a catalyst, followed by distillation and titration. Crude protein was calculated by multiplying the total nitrogen content by a conversion factor of 6.25, based on the assumption that protein contains approximately 16% nitrogen (AOAC, 1990).

• Iron (Fe), cooper (Cu), and Zinc (Zn) were determined using Atomic Absorption Spectrophotometry (AAS), following the Ammonium Bicarbonate DTPA method (Soltanpour, 1984)

• Phosphorus (P) was quantified using the Bray I extraction method, followed by colorimetric determination with a spectrophotometer (Bray & Kurtz, 1945)

• Flame photometry for potassium (K), sodium (Na), calcium (Ca), and magnesium (Mg).

All concentrations were initially recorded in mg/kg and converted to mg/100g using the Nutraceuticals Group’s online conversion scale (Nutraceuticals Group, 2025) to ensure consistency with global nutritional reporting standards.

Statistical Analysis

Quantitative data from laboratory assays were analyzed using Microsoft Excel, SPSS v26, and R. Descriptive statistics were used to summarize mineral concentrations across NUFC species. Comparative analysis was performed against global literature to assess alignment and variability in nutrient profiles.

Qualitative data from interviews and FGDs were thematically analyzed to contextualize the nutritional findings within traditional knowledge systems and community practices. This dual analysis provided a holistic understanding of the nutritional value and cultural relevance of NUFCs in Sierra Leone’s food system.

Ethical considerations

Although the study was primarily based in Bo and Kenema districts, two plant species were also collected from the Kasewe Forest Reserve in Moyamba District. Prior to data collection, participants were informed about the purpose and nature of the research. Ethical approval was obtained from the Directorate of Research and Development, Njala University, Sierra Leone, and the study adhered to the ethical principles of the Declaration of Helsinki. Informed consent was obtained from all participants, including consent for the publication of anonymized data. The study does not involve a clinical trial; hence, a clinical trial number is not applicable.

In addition to human subject protocols, ethical clearance also covered the collection of plant specimens. All plant materials were collected in accordance with national guidelines and institutional protocols. No endangered or protected species were involved. Permissions were obtained from the Sierra Leone Ministry of Agriculture and Forestry and local authorities, including district forest officers and town chiefs. While no formal reference number was issued, written consent and permission letters were provided by Njala University to the Ministry of Agriculture and local authorities prior to specimen collection. Documentation of these permissions is available upon request.

RESULTS

Proximal Mineral Composition of Selected NUFCs

The mineral analysis revealed considerable variation in nutrient profiles across the eight selected neglected and underutilized food crops (NUFCs). Table 1 summarizes the concentrations of key minerals calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), phosphorus (P), iron (Fe), zinc (Zn) as well as crude protein content, expressed as a percentage of dry weight.

i. Iron (Fe)

The crops with the highest iron content are *Celosia argentea* (15.226 mg/100g) and *Luffa Aegyptica* (12.962 mg/100g) making them an excellent candidate for addressing iron deficiency anemia, a significant public health issue in Sierra Leone. Iron is crucial for oxygen transport and energy production, and its deficiency can lead to fatigue, weakened immunity, and developmental delays in children. *Celosia argentea* and *Luffa Aegyptica* rich iron content highlights its potential to improve dietary iron intake, particularly in populations with limited access to fortified or animal-based iron sources. This crop could be integrated into local diets to enhance iron availability and overall nutritional status.

ii. Copper (Cu)

Vernonia amygdalina stands out with the highest copper content (22.13 mg/100g), followed by *Ipomoea acquatica* (17.99 mg/100g), far exceeding other crops in the study. Copper is essential for red blood cell formation, immune system function, and the maintenance of healthy nerves and bones. Its high concentration in *Vernonia amygdalina* and *Ipomoea acquatica* underscores the crop's potential role in preventing copper deficiency, which can cause anemia and cardiovascular issues. This exceptional copper content makes it an ideal addition to diets in areas where trace mineral deficiencies are prevalent.

iii. Zinc (Zn)

Piper unbellatum leads in zinc content with 12.49 mg/100g, making it a valuable source for supporting immune health, wound healing, and cellular metabolism. Zinc deficiencies are associated with stunted growth, increased susceptibility to infections, and delayed wound healing. By incorporating *Piper unbellatum* into local diets, particularly in regions with zinc-deficient soils, communities can address this critical nutrient gap and improve overall health outcomes, especially in children and pregnant women.

iv. Protein

The crop with the highest protein content is *Ipomoea aquatica* (7.00%), positioning it as a critical resource for addressing protein-energy malnutrition. Protein is vital for growth, tissue repair, and enzymatic functions, making it a cornerstone of human nutrition. *Ipomoea aquatica* has relatively high protein levels offers an affordable plant-based option for supplementing protein intake, particularly in low-resource settings where animal protein sources are scarce. This crop's role in improving dietary diversity and nutrition is significant, especially for vulnerable populations.

v. Phosphorus (P)

Piper unbellatum exhibits the highest phosphorus content (103.1 mg/100g), making it an essential crop for supporting bone health, energy production, and cellular repair. Phosphorus is a key component of DNA, RNA, and ATP, underscoring its importance in both structural and metabolic functions. By integrating *Piper unbellatum* into diets, communities can enhance their phosphorus intake and support overall growth and development, particularly in children and adolescents.

vi. Sodium (Na)

Among the crops analyzed, *Piper unbellatum* also leads in sodium content (1.93 mg/100g), followed by *Triumfetta cordiafolia* (1.32 mg/100g). While sodium is commonly present in diets, its moderate levels in this crop suggest it can contribute to maintaining electrolyte balance without posing risks of excessive sodium intake. This makes *Piper unbellatum* and *Triumfetta cordiafolia* suitable for complementing low-sodium diets while still supporting essential functions such as nerve transmission and muscle contraction.

vii. Potassium (K)

The highest potassium levels are found in *Vernonia amygdalina* (22.13 mg/100g) followed by *Ipomoea acquatica* (17.99 mg/100g), highlighting its role in supporting cardiovascular health and maintaining fluid balance. Potassium helps regulate blood pressure, making it a key nutrient for preventing hypertension and reducing the risk of heart disease. By incorporating *Vernonia amygdalina* and *Ipomoea acquatica* into daily diets, individuals can improve their potassium intake and promote overall cardiovascular health, especially in regions with a high prevalence of hypertension.

viii. Magnesium (Mg)

With a magnesium content of 8.94375 mg/100g, *Piper unbellatum* is the most magnesium-rich crop in this study. Magnesium is critical for nerve and muscle function, bone strength, and energy production. Its presence in Piper unbellatum enhances the crop's value as a dietary supplement for addressing magnesium deficiencies, which can lead to muscle cramps, fatigue, and cardiovascular issues. This nutrient-rich crop could play a significant role in improving health outcomes in communities with limited access to magnesium-rich foods.

ix. Calcium (Ca)

Piper unbellatum also ranks highest in calcium content (11.62 mg/100g), Ver*nonia amygdalina* (5.5445 mg/100g) making it an excellent source for supporting bone and dental health. Calcium is essential for skeletal strength and various metabolic processes, including muscle contraction and nerve signaling. The crop's high calcium content positions it as a natural alternative to dairy products, especially in populations with lactose intolerance or limited access to dairy. Promoting the consumption of *Piper unbellatum* could help address calcium deficiencies and enhance overall health in Sierra Leone.

Table 1
N/Protein and mineral composition of the selected NUFC

Sci name	Fe	Cu	Zn	N	P	Na	K	Mg	Ca
Luffa aegyptic	129.620	2.590	9.590	0.658	105.400	3.470	12.460	14.513	20.880
Justicia insularis	99.820	2.000	13.090	0.280	62.800	8.930	3.930	16.065	53.610
Triumfetta cordifolia	15.210	0.300	12.300	0.098	70.900	13.200	3.200	6.683	25.200
Piper unbellatum	24.740	0.490	12.490	0.308	103.100	1.930	24.930	8.944	11.620
Asystasia gangetica	77.180	1.540	5.540	0.241	105.400	5.630	28.670	12.555	34.000
Celosia argentinae	152.260	3.050	15.050	0.375	111.500	3.410	86.410	8.404	20.800
Vernoniamy cordiafolia	7.650	221.300	17.550	2.840	11.800	7.650	221.300	55.445	76.890
Ipomoea aquatica	0.140	179.900	6.550	1.120	23.520	0.140	179.900	33.196	45.590

Nutritional Highlights and Comparative Strengths

Based on overall mineral composition and nutritional purpose, *Piper unbellatum* is the most nutritionally versatile crop, addressing a broad spectrum of deficiencies. *Vernonia amygdalina, Ipomoea aquatica, Celosia argentea*, and *Luffa aegyptiaca* are significant contributors to iron, protein, potassium, and copper intake. Promoting the cultivation and dietary use of these NUFC can significantly enhance food security and public health outcomes in Sierra Leone.

i. **Piper unbellatum**, **contains (Zinc, Phosphorus, Magnesium, Calcium, Sodium)**

Piper unbellatum emerges as a highly versatile crop, leading in zinc (12.49 mg/100g), phosphorus (103.1 mg/100g), magnesium (8.94375 mg/100g), calcium (11.62 mg/100g), and sodium (1.93 mg/100g). These nutrients collectively support immune health, bone strength, cellular metabolism, and nerve function. Its exceptional mineral composition makes it a cornerstone crop for improving nutritional outcomes in resource-constrained communities.

ii. **Celosia argentea and Luffa aegyptiaca**, **contain (Iron)**

These crops are exceptionally high in iron, with Celosia argentea at 15.226 mg/100g and *Luffa aegyptiaca* at 12.962 mg/100g. Their rich iron content makes them critical for addressing iron deficiency anemia, particularly in populations with limited access to iron-rich foods. Their integration into local diets can improve oxygen transport and energy production, directly combating fatigue, weakened immunity, and developmental delays.

iii. **Vernonia amygdalina and Ipomoea aquatica**, **contain (Copper and Potassium)**

Vernonia amygdalina leads in copper (22.13 mg/100g) and potassium (22.13 mg/100g), with Ipomoea aquatica following closely in both categories (17.99 mg/100g for copper and potassium). These crops are essential for maintaining cardiovascular health, fluid balance, and the development of red blood cells. Their high potassium content makes them especially beneficial in preventing hypertension and supporting nerve function.

iv. **Ipomoea aquatica**, **contain (Protein)**

With the highest protein content at 7.00%, *Ipomoea aquatica* serves as a critical resource for combating protein-energy malnutrition. It provides an affordable plant-based protein source, particularly valuable for populations with limited access to animal proteins. This crop's contribution to dietary diversity and nutrition is particularly significant for vulnerable groups such as children and pregnant women.

v. **Triumfetta cordiafolia**, **contain (Sodium)**

While not leading in multiple nutrients, *Triumfetta cordiafolia* ranks second in sodium (1.32 mg/100g). It can complement low-sodium diets and support electrolyte balance, contributing to nerve transmission and muscle function.

Comparative analysis of mineral composition of NUFC with other literature

The study presents the protein and mineral compositions of various neglected and underutilized food crops (NUFC) identified within the study area. These crops were analyzed for their nutritional content, including key minerals such as iron, zinc, calcium, potassium, magnesium, and phosphorus and their protein levels. The findings were compared to similar studies conducted globally (see Tables 2 to 6 below), providing a broader context for understanding the nutritional potential of these crops. This comparison highlights both the unique nutrient profiles of the local NUFC and their alignment or deviation from values reported in other regions. By examining their nutrient compositions and comparing them with global benchmarks, the research offers valuable insights into their potential contribution to diversified diets and improved health outcomes. This comparative approach also aids in identifying crops with exceptional nutrient density, paving the way for targeted interventions and policy recommendations to promote their cultivation and consumption.

i. **Luffa aegyptiaca**: [local name: Bordorlyny (Mende)]

The nutrient analysis of *Luffa aegyptiaca* (from Table 2) reveals considerable variability in its mineral and protein content across the different sources. Iron (Fe) content, for instance, ranges from 41.05 mg/100g (Ani et al., 2020) to 12.962 mg/100g (This Study). This disparity could be attributed to environmental conditions such as soil composition, climatic differences, or differences in cultivation practices. Soil richness in specific minerals may enhance the uptake of iron, which might explain the higher values in the Ani et al., (2020) study. Zinc (Zn) content also shows significant variation between the two sources, Ani et al., (2020) reporting higher values. Copper (Cu), on the other hand, shows more consistent but lower values across both sources, suggesting a stable uptake mechanism or less environmental influence on this mineral. The protein content is higher, with values of 4.90% (Ani et al., 2020) and 0.411% in This Study.

Table 2
Comparative assessment of mineral composition of *Luffa Aegyptica* leaf

Mineral Composition	This Study	(Ani et al., 2020)
Fe (mg/100g)	12.962	41.05
Cu (mg/100g)	0.26	1.3
Zn (mg/100g)	0.96	21.3
Protein (%)	0.41	4.9
P (mg/100g)	10.54	-
Na (mg/100g)	0.347	73.05
K (mg/100g)	1.246	89.45
Mg (mg/100g)	1.4513	58.05
Ca (mg/100g)	2.088	192.1

ii. **Justicia insularis**: [local name: Lamie (Mende)]

The mineral content of *Justicia insularis* (from Table 3) exhibits a striking degree of variability, particularly for iron (Fe) and zinc (Zn). This Study reports iron at 9.982 mg/100g, while (Adeyemi & Babatunde, (2014) report an extraordinary 449.0 mg/100g. Such a vast difference raises questions about analytical methodologies and whether the higher value might be an outlier or reflective of unique environmental conditions. Similarly, zinc content varies from 1.309 mg/100g (This Study) to 4,972.0 mg/100g (Adeyemi & Babatunde, 2014). Copper (Cu) levels also show extreme variability, with This Study reporting 0.20 mg/100g compared to 631.0 mg/100g from (Adeyemi & Babatunde, 2014). These differences suggest that either environmental factors (soil, climate, time of year, etc), the age of the part sampled (young or mature), how it was preserved and stored, varietal differences, processing may significantly affect the assessment or there may be inconsistencies in measurement techniques between studies.

Protein content in *Justicia insularis* is another area of wide variation, with the This study reporting a modest 1.75% compared to an extraordinarily high 448% by (Adeyemi & Babatunde, 2014). The latter figure is likely due to a misrepresentation or error in reporting and emphasizes the importance of cross-referencing data from multiple studies. Despite these discrepancies, *Justicia insularis* demonstrates potential as a source of essential nutrients and protein. Efforts to standardize cultivation and analysis methods are critical to fully understanding its nutritional value.

Table 3
Comparative assessment of the mineral composition of *Justicia insularis* leaf

Mineral Composition	This Study	(Adeyemi & Babatunde, 2014)
Fe (mg/100g)	9.982	449.0
Cu (mg/100g)	0.2	631
Zn (mg/100g)	1.31	4972
Protein (%)	0.15	448
P (mg/100g)	6.28	11
Na (mg/100g)	0.8931	631.04
K (mg/100g)	0.393	168
Mg (mg/100g)	1.6065	76
Ca (mg/100g)	5.0361	330

iii. **Piper umbellatum**: [local name: Popodar (Mende)]

The nutrient profile of *Piper umbellatum* (from Table 4) shows both consistency and variability across studies. Iron content, for instance, is reported as 2.47 mg/100g (in this study) and 1.32 mg/100g (Baradum et al., 2021) while Kalu and Osuji (Kalu & Osuji, 2018) report a significantly higher 70.56 mg/100g. These discrepancies may stem from differences in environmental factors, such as soil mineral availability, or genetic variations between samples. Zinc (Zn) content also varies widely, with this study reporting 12.49 mg/100g, Baradum et al., (2021) reporting 0.09 mg/100g, and (Kalu & Osuji, 2(018) reporting 3.19 mg/100g. Copper (Cu) levels are more consistent between this study (0.49 mg/100g) and Baradum et al., (2021) (0.43 mg/100g) but are notably higher in Kalu & Osuji, (2018) findings (3.96 mg/100g), suggesting possible location-specific enrichment.

Protein content, on the other hand, shows significant fluctuation, with This study reporting 1.93% and Baradum et al., (2021) 19.90%, while Kalu & Osuji, (2018) report a low 0.88%. These variations might reflect differences in plant maturity, sample preparation, or analytical approaches. Despite these inconsistencies, *Piper umbellatum* remains a promising candidate for food and nutrition security due to its high potassium content, which supports cardiovascular health.

Table 4
Comparative assessment of the mineral composition of *Piper umbellatum* leaf

Mineral Composition	This study	Baradum et al., (2021)	Kalu & Osuji, (2018)
Fe (mg/100g)	2.474	1.322	70.56
Cu (mg/100g)	0.49	0.433	3.958
Zn (mg/100g)	12.49	0.092	3.187
Protein (%)	1.925	19.9	0.88
P (mg/100g)	103.1	1.912	-
Na (mg/100g)	1.93	0.092	46.43
K (mg/100g)	24.93	5.817	336.619
Mg (mg/100g)	8.94375	0.252	1370.99
Ca (mg/100g)	11.62	2.38	71.3

iv. **Vernonia amygdalina**: [Local name: Bitter leaf (Creole)]

The nutrient composition of *Vernonia amygdalina* (from Table 5) is marked by notable variations, particularly in its mineral content. Iron levels, for instance, range from 0.765 mg/100g (This study) to 32.2 mg/100g (Usunobun & Okolie, 2015). This variation might be attributed to differences in soil conditions, environmental factors, or plant processing methods. Copper (Cu) content is another area of divergence, with this study reporting a high value of 22.130 mg/100g compared to 19.50 mg/100g by (Usunobun & Okolie, 2015). Zinc (Zn) levels are also inconsistent between studies, with values of 1.755 mg/100g (this study) and 14.23 mg/100g (Usunobun & Okolie, 2015).

Protein content reported in this study is 17.75%, highlighting *Vernonia amygdalina* as a valuable dietary protein source. Although protein data is absent from the (Usunobun & Okolie, 2015) study, the high mineral content supports the crop's nutritional importance. Given its nutrient density, *Vernonia amygdalina* could significantly address micronutrient deficiencies, particularly iron and protein-related malnutrition.

Table 5
Comparative assessment of the mineral composition of *Vernonia amygdalina* leaf

Mineral Composition	This study	Usunobun & Okolie, (2015)
Fe (mg/100g)	0.765	32.2
Cu (mg/100g)	22.13	19.5
Zn (mg/100g)	1.755	14.23
Protein (%)	1.775	-
P (mg/100g)	1.18	-
Na (mg/100g)	0.765	48.31
K (mg/100g)	22.13	62.8
Mg (mg/100g)	5.5445	681.36
Ca (mg/100g)	7.689	1264.18

v. **Ipomoea aquatica**: [local name: Gogodee (Mende)]

Ipomoea aquatica (from Table 6) demonstrates substantial variability in its nutrient content across multiple sources. Iron levels range from as low as 0. 014 mg/100g (this study) to an extraordinarily high 146,710 mg/100g (Saikia et al., 2023). Such extreme values suggest either measurement inconsistencies or environmental factors affecting iron uptake. Copper (Cu) levels also vary widely, from 0.023 mg/100g (USDA, 2019) to 17.99 mg/100g (this study). Zinc (Zn) content shows inconsistency, with values from 0.655 mg/100g (this study) to 8,110 mg/100g (Saikia et al., 2023), affirming its potential as a zinc source. Potassium (K) content shows inconsistency, with values from 179.9 mg/100g (this study) to 11,171.35 mg/100g (Chitsa et al., 2014), and 129,4080 mg/100g (Saikia et al., 2023) These disparities highlight the need for more standardized and controlled studies to determine its nutrient profile accurately.

The least recorded protein composition in *Ipomoea aquatica* was by (Umar et al., 2007) with 1.008%, and the highest was 31.9% (Samkol, 2009). On the other hand, this study recorded 7.00% protein. This variability might reflect differences in plant maturity, growth conditions, or analysis methods. Despite these inconsistencies, *Ipomoea aquatica* remains a nutrient-dense crop, with high calcium, magnesium, and potassium levels contributing to its value as a dietary supplement. Given its adaptability to diverse conditions and potential for addressing nutrient deficiencies, further research should focus on optimizing cultivation practices and validating its nutrient composition. Such efforts could position Ipomoea aquatica as a cornerstone of food and nutrition security initiatives in Sierra Leone.

Table 6
Comparative assessment of the mineral composition of *Ipomoea aquatica* leaf

Sources	Fe (mg/100g)	Cu (mg/100g)	Zn (mg/100g)	Protein (%)	P (mg/100g)	Na (mg/100g)	K (mg/100g)	Mg (mg/100g)	Ca (mg/100g)
This study	0.014	179.9	0.655	7	2.352	0.014	17.99	3.31963	4.559
(Umar et al., 2007);	210.3	0.36	2.47	1.008	1,093.00	135.00	5,458.33	301.60	416.70
(Adedokun et al., 2019)	3.2	5.3	4.1	4.096	8.60	159.000	444.00	52.0	163.00
(Adelakun et al., 2016)	19.76	0.673	6.387	26.45	-	323	982	424.0	335.0
(Chitsa et al., 2014)	30.67	-	-	-	6,092.03	-	11,171.35	370.40	14087.97
(Ndamitso et al., 2015)	15.5	3.607	2.521	17.48	2.2569	40.0	0.04	230	3.725
(Saikia et al., 2023)	146.7	-	8,110	19.55	1,023,120	235,780	129,4080	196,270	254,150
(Nyein, 2019)	1.2	-	0.10	2.9	-	-	13.64	-	23.30
(USDA, 2019)	1.67	0.023	0.18	2.6	39.0	113.0	312.0	71.00	77.00
(Ngamsaeng et al., 2004)	-	-	-	22.3	-	-	-	-	-
(Maung et al., 2020)	-	-	-	28.0	-	-	-	-	-
(Samkol, 2009)	-	-	-	31.9	-	-	-	-	-
(Shariff et al., 2019)	-	-	-	2.87	-	-	-	-	-

NUFC plants that have scarce information about their mineral composition

i. **Triumfetta cordiafolia**: [local name: Tey-gweh (Mende)]

The analysis of *Triumfetta cordiafolia* (from Table 7) reveals its potential as a valuable source of essential minerals for addressing nutritional deficiencies. With an iron content of 1.521 mg/100g and zinc levels of 1.23 mg/100g, this crop offers significant benefits for combating anemia and supporting immune health. The crop's phosphorus (7.09 mg/100g) and calcium (2.52 mg/100g) and magnesium (0.668 mg/100g) content further highlight a useful supplement for general well-being. However, its low protein content (0.6125%) limits its ability to serve as a primary protein source. This indicates that while it is highly beneficial for enhancing mineral intake, its contribution to addressing protein-energy malnutrition is minimal.

ii. **Asystasia gangetica**: [local name: Gbolohui (Mende)]

Asystasia gangetica (from Table 7) demonstrates substantial nutritional potential, particularly due to its high iron content of 7.718 mg/100g. The crop also contains notable levels of potassium (2.867 mg/100g), which is essential for maintaining fluid balance and supporting heart health. Its moderate zinc content (0.554 mg/100g) adds to its benefits, as zinc plays a crucial role in immune function, wound healing, and potassium levels (2.867 mg/100g), ellular metabolism. Phosphorus (10.54 mg/100g) and calcium (3.4 mg/100g) contribute to bone health, making the crop particularly valuable for populations with low dairy consumption. In addition to its mineral content, Asystasia gangetica offers a modest protein contribution of 1.505%.

i. **Celosia argentea**: [local name: Gbolohui (Mende)]

Celosia argentea (from Table 7) stands out as an exceptionally nutrient-dense crop, particularly due to its high iron content of 15.226 mg/100g. Its zinc content of 1.505 mg/100g, potassium (8.641 mg/100g), phosphorus (11.15 mg/100g), and calcium (2.08 mg/100g) make it a well-rounded source of essential minerals. The protein content of Celosia argentea (2.345%) is higher than that of *Triumfetta cordiafolia* and *Asystasia gangetica*, making it a more robust option for addressing protein-energy deficiencies. The crop's high potassium content is particularly beneficial for populations at risk of hypertension, while its iron and zinc levels address key micronutrient deficiencies.

Table 7
N/Protein and mineral composition of the selected NUFC [without research literature]

Sample Type (leaf)	Fe (mg/100g)	Cu (mg/100g)	Zn (mg/100g)	Protein (%)	P (mg/100g)	Na (mg/100g)	K (mg/100g)	Mg (mg/100g)	Ca (mg/100g)	Sources
Triumfetta cordiafolia	1.521	0.03	1.23	0.613	7.09	1.32	0.32	0.6683	2.52	This study
Asystasia gangetica	7.718	0.154	0.554	1.505	10.54	0.563	2.867	1.256	3.40	This study
Celosia argentea	15.226	0.305	1.505	2.345	11.15	0.341	8.641	0.8404	2.08	This study

DISCUSSION

Among the crops analyzed, *Piper unbellatum* emerged as the most nutritionally versatile, exhibiting high concentrations of zinc (12.49 mg/100g), phosphorus (103.1 mg/100g), magnesium (8.94 mg/100g), calcium (11.62 mg/100g), and sodium (1.93 mg/100g). These minerals are essential for immune function, bone health, cellular metabolism, and electrolyte balance. The crop's broad-spectrum nutrient profile positions it as a strategic candidate for addressing multiple micronutrient deficiencies in Sierra Leone, particularly in rural communities with limited access to fortified foods (Baradum et al., 2021; Kalu & Osuji, 2018).

Celosia argentea and *Luffa aegyptiaca* were identified as iron-rich crops, with concentrations of 15.23 mg/100g and 12.96 mg/100g, respectively. Iron deficiency anemia remains a significant public health concern in Sierra Leone, especially among women and children (UNICEF, 2017). The integration of these crops into local diets could substantially improve iron intake, enhance oxygen transport, and reduce fatigue and developmental delays. Their cultivation also aligns with traditional knowledge systems, where leafy vegetables are commonly used in soups and sauces.

Vernonia amygdalina and *Ipomoea aquatica* showed exceptional levels of copper (22.13 mg/100g and 17.99 mg/100g) and potassium (22.13 mg/100g and 17.99 mg/100g). Copper supports red blood cell formation and neurological health, while potassium regulates blood pressure and fluid balance. These findings are particularly relevant given the rising incidence of hypertension and cardiovascular disease in Sierra Leone (WFP, 2024). Promoting these crops could offer a low-cost, plant-based intervention to improve cardiovascular outcomes.

In terms of protein content, *Ipomoea aquatica* stood out with 7.00%, making it a valuable resource for combating protein-energy malnutrition. Protein is critical for growth, tissue repair, and enzymatic functions. In low-income settings where animal protein is scarce, plant-based sources like Ipomoea aquatica offer an affordable alternative. Its adaptability to swampy environments and rapid growth cycle further enhances its viability for smallholder farmers.

The study also highlighted *Triumfetta cordiafolia* and *Asystasia gangetica* as crops with moderate mineral profiles but limited protein content. While *Triumfetta cordiafolia* ranked second in sodium (1.32 mg/100g), its protein content was only 0.61%, suggesting its role may be more complementary than foundational in addressing malnutrition. *Asystasia gangetica*, with 7.72 mg/100g iron and 2.87 mg/100g potassium, offers targeted benefits for anemia and heart health, though its overall nutrient density is lower than other NUFCs.

Comparative analysis with global literature revealed significant variability in nutrient values, underscoring the influence of environmental conditions, genetic diversity, and methodological differences. For instance, iron content in *Luffa aegyptiaca* ranged from 12.96 mg/100g (This study) to 41.05 mg/100g (Ani et al., 2020), while zinc in *Justicia insularis* varied from 1.31 mg/100g (this study) to 4972 mg/100g (Adeyemi & Babatunde, 2014). These discrepancies highlight the need for standardized protocols and localized nutrient profiling to inform policy and dietary recommendations.

The findings also intersect with traditional knowledge systems. Many of the NUFCs studied such as *Vernonia amygdalina, Celosia argentea*, and *Triumfetta cordiafolia* are used in indigenous medicine and cultural rituals. Their nutritional validation reinforces the value of traditional food systems and supports the thesis goal of integrating NUFCs into sustainable food strategies. Moreover, the gendered nature of NUFC cultivation and processing often managed by women suggests that promoting these crops could enhance women's economic empowerment and household nutrition.

CONCLUSION

While country is agriculturally active, but still continues to face persistent challenges in food and nutrition security, particularly due to limited dietary diversity and micronutrient deficiencies. Through standardized laboratory analysis, the research quantified essential minerals including iron, zinc, copper, calcium, magnesium, phosphorus, potassium, and sodium across multiple NUFC species, offering empirical evidence of their nutritional value.

The findings revealed that crops such as *Piper unbellatum, Celosia argentea, Ipomoea aquatica, Vernonia amygdalina*, and *Luffa aegyptiaca* possess rich and varied mineral profiles, with several species demonstrating concentrations that rival or exceed global benchmarks. Notably, *Piper unbellatum* emerged as the most nutritionally versatile crop, exhibiting high levels of zinc, phosphorus, magnesium, calcium, and sodium. *Celosia argentea* and *Luffa aegyptiaca* were identified as iron-rich, while *Ipomoea aquatica* stood out for its protein content and cardiovascular-supporting potassium levels.

These results underscore the strategic potential of NUFCs in addressing micronutrient deficiencies endemic to rural Sierra Leone. Their integration into local diets could significantly improve nutritional outcomes, particularly among vulnerable populations with limited access to fortified foods or animal-based sources. Moreover, the cultivation of these crops aligns with traditional knowledge systems and agro-ecological conditions, reinforcing their cultural relevance and adaptability.

By scientifically validating the mineral composition of NUFCs, this research lays the groundwork for their inclusion in national food security strategies, nutrition programming, and agricultural extension services. Promoting these crops not only diversifies the food system but also enhances resilience against climate variability and market dependency. Future research should explore bioavailability, seasonal variation, and consumer acceptability to further support the mainstreaming of NUFCs into Sierra Leone's sustainable development agenda.

Recommendations for Future Laboratory Analysis

While the present study provides valuable insights into the mineral composition of selected NUFCs, several external factors may influence laboratory outcomes and should be considered in future research. Environmental conditions such as soil type, rainfall, and seasonality can significantly affect nutrient uptake and accumulation in plants. Similarly, variations in plant maturity and the specific part analyzed (e.g., leaf vs. seed) may lead to differences in mineral concentrations. Standardizing harvest stages and clearly documenting plant parts used will improve comparability across studies. Post-harvest handling, particularly drying temperature, exposure to sunlight, and ambient humidity can also impact nutrient stability, especially for heat-sensitive compounds.

Analytical precision depends on the sensitivity of the methods employed. While techniques such as AAS and flame photometry are widely accepted, cross-validation with more sensitive instruments (e.g., ICP-MS) and the use of certified reference materials are recommended to enhance reliability. Incorporating soil nutrient analysis alongside plant tissue profiling would provide a more holistic understanding of mineral dynamics. Finally, increasing biological replicates and sampling across multiple agroecological zones can strengthen statistical power and generalizability, especially for crops with localized cultivation patterns or emerging nutritional relevance.

Declarations

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

SF, RW, TSS, and SMTW contributed to the manuscript's writing, literature review and interpretation, and data analysis. All authors read and approved the final manuscript.

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Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

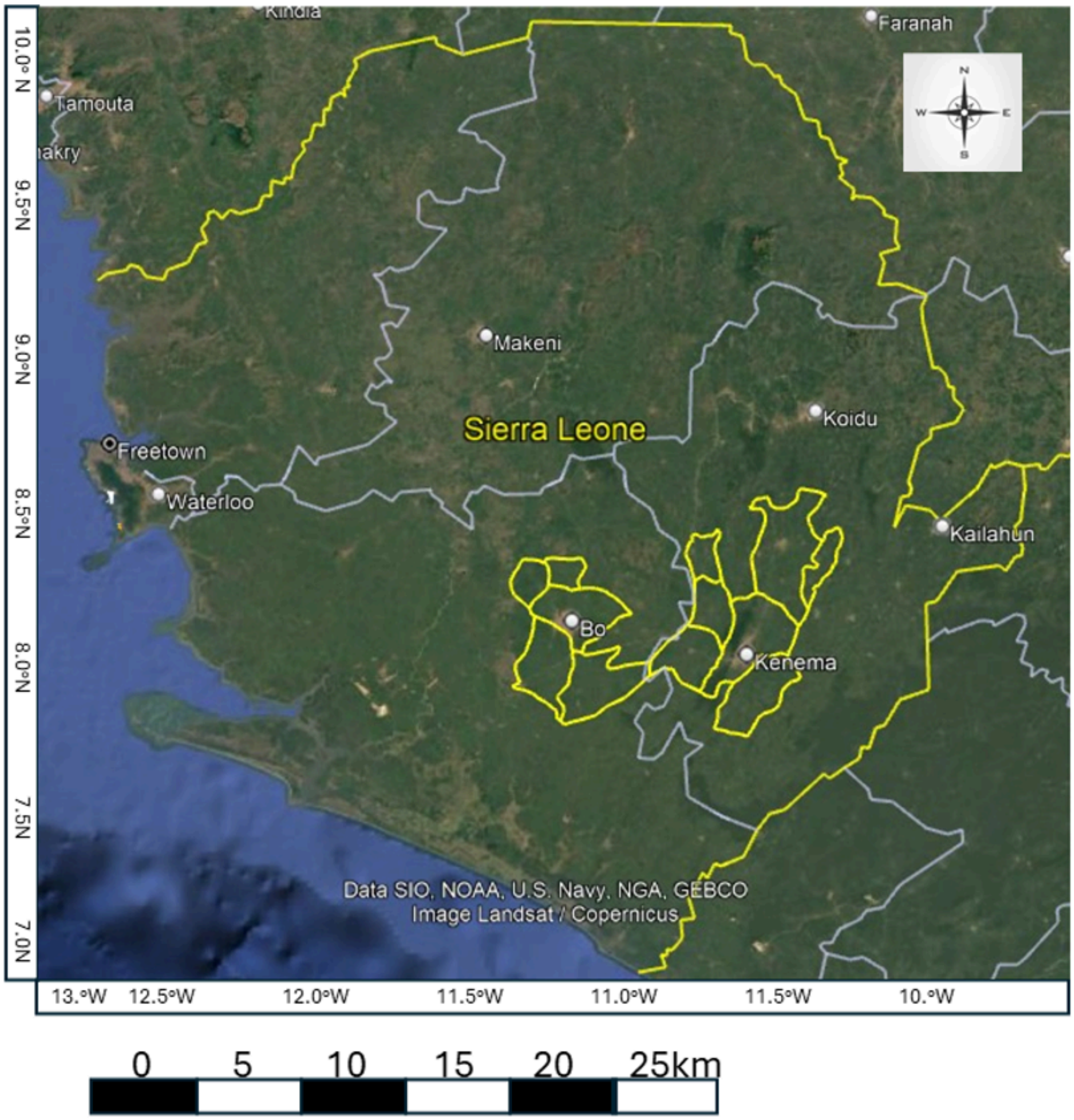

Figure 1

Satellite map of Sierra Leone showing the study districts of Bo and Kenema, highlighted in yellow. Major cities and district boundaries are labeled for geographic reference.