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Comparative Cyanide Levels in Cassava Varieties from Rural Sierra Leone Communities

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Abstract:

➢ ***Background***

Cassava (*Manihot esculenta* Crantz) is a major staple crop in sub-Saharan Africa, valued for its carbohydrate-rich roots and nutrient-dense leaves. Despite its nutritional benefits, cassava contains cyanogenic glycosides primarily linamarin and lotaustralin which release toxic hydrogen cyanide (HCN) upon enzymatic hydrolysis. Chronic exposure to cyanide from poorly processed cassava can result in severe health disorders, including tropical ataxic neuropathy, goiter, and in extreme cases, death.

➢ ***Aim***

This study aimed to determine and compare the cyanide content in sweet and bitter varieties of cassava leaves and roots collected from Gloucester village (Western Rural Area) and Fonkoya village (Magbema Chiefdom, Kambia District) in Sierra Leone.

➢ ***Methods***

A quantitative analytical approach was employed using acid hydrolysis followed by alkaline titration to assess HCN content. Samples were authenticated by the Department of Botany, Fourah Bay College, and processed using standard procedures. Cyanide levels were calculated based on silver nitrate titration, using the conversion factor: 1 cm^3 of 0.020 M $AgNO_3$ = 1.08 mg HCN.

➢ ***Results***

Bitter cassava samples exhibited significantly higher cyanide concentrations than sweet varieties across both locations. Gloucester samples showed greater HCN levels than those from Fonkoya. The highest cyanide content was recorded in bitter cassava leaves from Gloucester (13.39 mg/kg), while the lowest was found in sweet cassava roots from Fonkoya (4.48 mg/kg). Overall, leaves had higher cyanide levels than roots.

➢ ***Conclusion***

This study highlights a critical public health concern regarding cyanide exposure from cassava consumption in Sierra Leone. The findings emphasize the need for public education on proper processing methods, promotion of low-cyanide cassava varieties, and regulatory monitoring. Addressing these gaps is essential for reducing cyanide toxicity risk and ensuring the safety of cassava as a dietary staple.

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I. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial shrub belonging to the family Euphorbiaceae, widely cultivated for its starchy tuberous roots and, to a lesser extent, its nutrient-rich leaves (Quartey et al., 2016). It ranks as the sixth most important crop globally in terms of production and serves as a staple food for over 500 million people, particularly in sub-Saharan Africa and parts of Asia and Latin America (Latif and Müller, 2015). Both cassava roots and leaves are valued for their carbohydrate, vitamin, and mineral content, and in countries such as Tanzania, Sierra Leone, and Liberia, the leaves are consumed not only for their nutritional value but also for purported medicinal uses, including enhancing lactation in nursing mothers (Latif and Müller, 2015).

Despite its nutritional benefits, cassava poses a public health risk due to its cyanogenic potential. Both roots and leaves contain cyanogenic glycosides, primarily linamarin and lotaustralin, which enzymatically hydrolyze to release hydrogen cyanide (HCN) upon tissue disruption (Piero, 2015; Orjiekwe et al., 2013). The concentration of cyanide in cassava can vary widely, from as low as 2 ppm to over 1000 ppm, depending on factors such as cultivar type, age, environmental conditions, and processing methods (Orjiekwe et al., 2013; Ndubuisi and Chidiebere, 2018).

Cyanide is a potent metabolic toxin that inhibits cytochrome oxidase in the mitochondrial electron transport chain, leading to cellular hypoxia, metabolic acidosis, and ultimately death at sufficiently high doses (Makame, 2020; Uhegbu et al., 2012). Chronic exposure to sub-lethal cyanide levels has been linked to diseases such as konzo, tropical ataxic neuropathy (TAN), goiter, and cretinism, particularly in communities relying heavily on improperly processed bitter cassava (Mushumbusi et al., 2020; Orjiekwe et al., 2013).

Due to its widespread consumption, particularly in food-insecure regions, the cyanide content of cassava remains a critical safety concern. The World Health Organization has recommended a safe limit of 10 ppm of HCN in cassava products, yet many varieties, especially the bitter cultivars, exceed this threshold unless adequately processed (Ndubuisi and Chidiebere, 2018). Given the dual nutritional and toxicological nature of cassava, accurate quantification of its cyanide content is essential for public health monitoring, especially in rural communities where cassava is both a staple and a cash crop.

This study aims to determine and compare the cyanide content in sweet and bitter cultivars of *Manihot esculenta* leaves and roots from two locations in Sierra Leone. Gloucester village in the Western Rural Area and Fonkoya village in the Magbema Chiefdom, Kambia District. The findings will contribute to assessing dietary safety, guiding food processing practices, and informing public health strategies in cassava-consuming regions.

II. MATERIALS AND METHODS

➢ *Type of Study*

This study was a quantitative investigation conducted to determine the cyanide content in the leaves and roots of *Manihot esculenta* Crantz (sweet and bitter cassava varieties).

➢ *Sample Collection*

Two varieties of *Manihot esculenta* Crantz (sweet and bitter cassava leaves and roots) were collected from Gloucester village, Western Rural Area, Freetown. An additional two varieties (sweet and bitter) were collected from Fonkoya village, Magbema Chiefdom, Kambia District. After collection, all samples were authenticated by botanists at the Department of Botany, Fourah Bay College, University of Sierra Leone. (Authentication No.: **USL/BOT/ME-CASS/0421/002**).

The cassava roots were peeled, washed, grated, and weighed before being prepared for analysis. The leaves were plucked, air-dried for seven days, pounded, weighed, and prepared for analysis.

➢ *Study Duration*

The study was conducted between April and October 2021.

➢ *Study Site*

The experimental procedures were carried out at the Faculty of Pharmaceutical Sciences Multipurpose Laboratory, Connaught Hospital, and the Kossoh Town Campus Laboratory, College of Medicine and Allied Health Sciences (COMAHS), University of Sierra Leone.

➢ *Reagents*

All reagents used in this study were procured from reputable suppliers: British Drug Houses (UK), Sigma-Aldrich (USA), Merck (Germany), and Finkem (India). The following chemicals were used:

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- 0.1000 M orthophosphoric acid (H_3PO_4) – BDH, UK
- 4.0 M sulfuric acid (H_2SO_4) – Sigma Aldrich, USA
- 3.6 M sodium hydroxide (NaOH) – Merck, Germany
- 2.0 M ammonium hydroxide (NH_4OH) – Merck, Germany
- 5% potassium iodide (KI, Indicator) – Finkem, India
- 0.0200 M silver nitrate ($AgNO_3$) – Sigma Aldrich, USA

➢ *Reagent Preparation*

- **0.100 M H_3PO_4**: 9.8 mL of orthophosphoric acid was measured and diluted to 500 cm^3 with distilled water.
- **4.0 M H_2SO_4**: 196 mL of concentrated sulfuric acid was measured and diluted to 500 cm^3.
- **3.6 M NaOH**: 36 g of sodium hydroxide was weighed and dissolved in a 250 cm^3 volumetric flask with distilled water.
- **2.0 M NH_4OH**: 35 mL of ammonium hydroxide was diluted to 500 cm^3 with distilled water.
- **5% KI**: 5 g of potassium iodide was dissolved in a 100 mL volumetric flask with distilled water.
- **0.020 M $AgNO_3$**: 200 mL of silver nitrate was diluted in a 250 mL volumetric flask with distilled water.

➢ *Instruments*

The instruments and equipment used in the study included:

220V centrifuge with tubes, manual blender, 220V water bath, electronic balance, local grater, kitchen knife, mortar and pestle, scissors, 1.5 mm – 0.5 mm sieve, 10 mL and 20 mL graduated pipettes, boiling tubes, 50 mL standard flasks, 250 cm^3 conical flasks, 500 cm^3 measuring cylinders, test tube holders and racks, 25 cm^3 measuring cylinders, 50 mL class B burettes, retort stands, 2 mL droppers, and funnels.

➢ *Test Method*

Acid hydrolysis followed by alkaline titration was employed to determine the cyanide content in the sweet and bitter leaves and roots of *Manihot esculenta* Crantz.

➢ *Cyanide Determination in Cassava Roots*

Fifty grams (50 g) of each fresh cassava root sample (sweet and bitter) was grated using a local grater and blended with 350 cm^3 of 0.10 M cold orthophosphoric acid (H_3PO_4). The mixture was centrifuged at 220V for 10 minutes. The cold acid helped control the reaction temperature due to cyanide's high volatility. After centrifugation, each extract was transferred into a stoppered conical flask and left to stand for 10 minutes.

Eight millilitres (8 mL) of each extract were pipetted into separate boiling tubes. To each, 8 mL of 4.0 M H_2SO_4 was added. The tubes were corked and placed in a water bath at 100°C for 55 minutes. After cooling to room temperature, 20 mL of 3.6 M NaOH was added, and the mixture was allowed to stand for 10 minutes to ensure full decomposition of cyanohydrins, releasing cyanide ions which reacted with NaOH to form NaCN.

The entire volume was transferred into a 50 mL standard flask and made up to mark with 3.6 M NaOH. Five millilitres (5 mL) of the solution was then diluted to 25 cm^3 in a conical flask. Eight millilitres (8 mL) of 2 M NH_4OH and 2 mL of 5% KI were added as an indicator. The solution was titrated against 0.020 M $AgNO_3$ until a persistent turbidity appeared (the endpoint). The cyanide concentration was calculated using the formula:

1 cm^3 of 0.020 M $AgNO_3$ = 1.08 mg HCN (AOAC, 2014).

➢ *Cyanide Determination in Cassava Leaves*

The dried cassava leaves (sweet and bitter) were pounded using a mortar and pestle, weighed, and subjected to the same alkaline titration method as the roots, except that grating was omitted.

III. RESULTS

The cyanide content in the leaves and roots of *Manihot esculenta* (sweet and bitter varieties) collected from Gloucester village (Western Rural Area) and Fonkoya village (Magbema Chiefdom, Kambia District) was determined using the alkaline titration method. The findings are presented in **Tables 1 and 2** below.

➢ *Cyanide Content in Cassava Roots*

Table 1 shows the average titre values and corresponding hydrogen cyanide (HCN) concentrations (mg/kg) for sweet and bitter cassava root samples. The cassava samples from Gloucester village recorded higher cyanide levels than those from Fonkoya village. Bitter cassava roots (BCRs) generally had higher HCN concentrations compared to sweet cassava roots (SCRs) at both locations.

Table 1. Cyanide Content in the Roots of Sweet and Bitter Cassava Samples Collected from Gloucester Village and Fonkoya Village

Location	Sample	Average titre (cm^3)	HCN (mg/kg)
GV	SCRs	4.75	5.13
GV	BCRs	6.25	6.75
FV	SCRs	4.15	4.48
FV	BCRs	4.55	4.91

The amount of HCN in mg was calculated using the conversion:

1 cm^3 of 0.02 M silver nitrate ($AgNO_3$) = 1.08 mg HCN

(AOAC, 2014). These values were then converted to mg of HCN per kilogram of fresh cassava root.

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GV = Gloucester Village; FV = Fonkoya Village; SCRs = Sweet Cassava Roots; BCRs = Bitter Cassava Roots

➢ *Cyanide Content in Cassava Leaves*

Table 2 presents the average titre and calculated HCN concentrations in the sweet and bitter cassava leaf samples. Bitter cassava leaves (BCLs) consistently exhibited higher cyanide content than sweet cassava leaves (SCLs). Gloucester village samples also recorded higher cyanide levels compared to those from Fonkoya village.

Table 2. Cyanide Content in the Leaves of Sweet and Bitter Cassava Samples Collected from Gloucester Village and Fonkoya Village

Location	Sample	Average titre (cm^3)	HCN (mg/kg)
FV	SCLs	5.20	5.62
FV	BCLs	7.15	7.72
GV	SCLs	8.85	7.72
GV	BCLs	12.40	13.39

GV = Gloucester Village; FV = Fonkoya Village; SCLs = Sweet Cassava Leaves; BCLs = Bitter Cassava Leaves

IV. DISCUSSION

This study quantitatively assessed the cyanide content in sweet and bitter cassava roots and leaves from Gloucester and Fonkoya villages in Sierra Leone. The results demonstrated that **bitter cassava varieties consistently exhibited higher hydrogen cyanide (HCN) concentrations than their sweet counterparts**, confirming earlier findings reported in similar studies (Korir et al., 2023; Ndukwu et al., 2020).

Moreover, **samples from Gloucester village had higher HCN levels** compared to those from Fonkoya. This variation may be attributed to **differences in cultivar types and environmental factors**, such as soil composition, rainfall patterns, and drought stress. Drought has been shown to increase cyanogenic glycoside concentrations in cassava due to the plant's stress response (Chiwona-Karltun et al., 2021).

Consistent with our findings, **cyanide levels in cassava roots typically range from 15–400 mg/kg in bitter varieties and 15–50 mg/kg in sweet ones**, depending on the cultivar and region (Latif & Müller, 2015; Quartey et al., 2016). The results in this study fall within these reported ranges, with the bitter cassava roots from Gloucester reaching up to 6.75 mg/kg and those from Fonkoya reaching 4.91 mg/kg.

Notably, **cassava leaves had higher cyanide content than roots**, corroborating results reported by Gavin Publishers (2022), who observed that cassava leaves can contain between 53–1,300 mg/kg of HCN depending on drying and processing methods. In this study, bitter cassava leaves from Gloucester recorded the highest HCN level at 13.39 mg/kg, compared to 7.72 mg/kg in Fonkoya. This higher leaf concentration presents a **greater risk to public health**, especially when consumed without adequate processing.

Processing plays a critical role in reducing cyanide levels in cassava products. A recent systematic review reported that processing techniques such as peeling, drying, fermentation, and boiling significantly reduced cyanide levels in cassava products like garri and fufu, bringing them within WHO-recommended safe limits (Frontiers in Sustainable Food Systems, 2025). However, improper processing or consumption during food scarcity can lead to cyanide poisoning, with symptoms ranging from dizziness to death (Orjiekwe et al., 2013; Uhegbu et al., 2012).

These findings underscore the need for **targeted public health education on processing methods** and **promotion of low-cyanide cassava varieties** to ensure safer cassava consumption. Additionally, **routine monitoring of cyanide levels** in cassava crops should be prioritized, particularly in high-risk rural communities.

V. CONCLUSION

This study revealed that bitter cassava varieties, especially the leaves, contain significantly higher levels of cyanide compared to sweet varieties. The samples from Gloucester village exhibited higher HCN levels than those from Fonkoya village, likely due to differences in environmental and agronomic conditions.

Given the potential health risks posed by high cyanide concentrations particularly in cassava leaves, this study emphasizes the importance of:

- Promoting the cultivation of low-cyanide (sweet) cassava varieties,
- Educating local communities on effective cassava processing methods,
- Establishing regulatory guidelines and surveillance systems for cassava-based food safety.

Implementation of these measures can **minimize the risk of cyanide toxicity** and improve the nutritional safety of cassava as a staple food in Sierra Leone and other cassava-dependent regions.

AUTHORS' CONTRIBUTIONS

➢ *Abdulai Turay:*

Provided academic Co-supervision, contributed to the design of the experimental protocol, and drafted the manuscript

➢ *Sheka Sankoh:*

Conceived and designed the study, collected and analyzed the samples, performed cyanide quantification, interpreted the data, and critically revised the manuscript.

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➢ *Dr. Eugene B.S. Conteh:*
Offered critical input on experimental design and analytical methods, supported the interpretation of findings, and reviewed the manuscript for scientific accuracy and intellectual rigor.

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