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Research Article

Nutritional Composition and Cyanide Content of Cassava (*Manihot esculenta* Crantz) Tuberous Roots from Selected Cultivars in the Pool Department, Republic of Congo

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Abstract

Cassava (*Manihot esculenta* Crantz) is a tuberous root crop widely cultivated in tropical and subtropical regions, however, cassava roots also contain cyanogenic glycosides. This study aims to characterize the nutritional composition and cyanide content of cassava (*Manihot esculenta* Crantz) tuberous roots from cultivars selected in three localities of the Pool department, Republic of Congo: Loukoko, Mbanza Nkolo and Ntoula. Analyses focused on water, ash, protein, lipid, total free sugars and hydrocyanic acid (HCN) content. The results reveal a high biochemical variability between cultivars and localities. Water contents range from 53.12% to 69.49%, directly influencing post-harvest conservation. Ash contents (1.02% to 3.8%) indicate a significant mineral richness, particularly in Mbanza Nkolo cultivars. Proteins reach up to 2.94% in some Ntoula cultivars, suggesting improved nutritional potential. Lipids, although low (0.2% to 0.81%), show interesting variations for energy intake. Total free sugars range from 0.2% to 14.9%, influencing palatability and processing possibilities. Regarding cyanide content, all cultivars exceed the safety threshold recommended by FAO/WHO (10 mg/kg), with values up to 93.3 mg/kg. These results highlight the need for appropriate processing practices to ensure food safety. All the data obtained make it possible to identify promising cultivars for direct consumption, agri-food processing or varietal selection, while taking into account the health risks associated with cyanogenic glycosides.

Keywords

Manihot esculenta Crantz, Nutritional Composition, Cyanide, Food Safety, Local Cultivars, Biochemical Variability

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a tuberous root crop widely cultivated in tropical and subtropical regions, where it is a major source of carbohydrates for millions of people [1-4]. Its adaptability to varied soil and climate conditions and its tolerance to drought make it a strategic crop for food security, particularly in sub-Saharan Africa [5, 6]. Beyond its energy role, cassava is of nutritional and technological interest related to its chemical composition, including macronutrients,

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free sugars, and certain secondary compounds [5-7].

However, cassava roots also contain cyanogenic glycosides, mainly linamarin and lotaustralin, which can release hydrocyanic acid (HCN) during enzymatic hydrolysis [8-10]. Excessive consumption of poorly processed cassava can lead to acute or chronic toxic effects, with implications for public health [11, 12]. HCN content varies among cultivars, agroecological conditions, and cultural practices, hence the need to evaluate this parameter in relation to nutritional characteristics [12-14].

In Congo-Brazzaville, and more specifically in the Pool department, cassava is the staple food for the majority of rural and urban households [15-17]. However, recent data on the chemical composition of local cultivars remain limited, particularly with regard to hydrocyanic acid content, macronutrients (lipids, proteins, water, dry matter, ash) and total free sugars. Such information is essential to guide varietal improvement strategies, optimize processing methods and strengthen food security.

This study aims to determine, for several cassava cultivars grown in three localities of the Pool department (Ntoula, Loukoko and Mbanza Nkolo), the contents of hydrocyanic acid, lipids, proteins, water and dry matter, ash and total free sugars. The results will make it possible to identify variations related to localities and cultivars, and to propose recommendations for a safe and nutritionally optimized use of local cassava.

2. Materials and Methods

2.1. Collection Sites and Description of Localities

Cassava (Manihot esculenta Crantz) samples were collected from three locations in the Pool department, in the south of the Republic of Congo: *Ntoula* (Goma Tsé tsé district), located 39.36 km from Brazzaville. Loukoko (Louingui district), 106 km from Brazzaville. *Mbanza-Nkolo* (Loumo district), 138 km from Brazzaville.

These localities were chosen for their importance in local cassava production, their representativeness of the diversity of local cultivars and the agro-ecological conditions of the department.

2.2. Sample Collection

Root collection was carried out using a sample survey of local producers, ensuring coverage of several cultivars and obtaining representative samples. Each sample consisted of fresh roots 10-16 months old, carefully selected for their integrity and absence of mechanical damage or rot. The collected roots were healthy, undamaged, and free of rot, and were transported to the laboratory in coolers at 4-6 ℃ for analysis within 48 hours of harvest.

The cultivars and their characteristics by location are as follows*:* Loukoko (4 cultivars): "Mbala", "Boulabipaki", "Ndombi", "Dinkondi"; Mbanza-Nkolo (15 cultivars): Savannah cultivars: "6 months", "Yellow Variety". Forest cultivars: "6 months", "Yellow Variety", "Père Longi", "Mpembe Project", "Ma Batsiaka", "Mpembe Mangama", "Mpembe", "Ta Balossa 3", "Ta Balossa 2", "Ta Balossa 1", "Mbouaki", "Ndombi", "Improved Project"; *Ntoula* (9 cultivars): Ndombi (14 months), "6 months", Ntouloubandoumba, Violet, Mandoussou, Mboutounkari, Kidamou.

For each cultivar, fresh tuberous roots were collected and homogenized to create a representative sample.

2.3. Sample Preparation

The roots were washed with potable water to remove impurities, peeled using clean knives, grated, and homogenized to obtain a representative mixture.

A portion of the samples was used fresh for analyses requiring free water, while other aliquots were dried at 40-45 ℃ to constant mass and ground (<500 µm) for analyses of dry matter, ash, protein, lipids, and total free sugars.

2.4. Chemical Analyses

Water and dry matter content: determined according to AOAC method 925.10 (oven at 105 ℃ until constant mass).

$$\text{Humidity (\%)} = \frac{M_i - M_s}{M_i} \times 100 \tag{1}$$

$$Dry\ matter\ (\%) = 100 - Humidity\ (\%) \tag{2}$$

where: Mi: initial mass of the sample (before drying); Ms: mass of the dry sample (after drying in an oven, generally at 105 ℃ to constant mass)

Ashes: incineration of 2 g of dry sample at 550 ℃ for 6 h (AOAC 923.03):

$$Ashes\ (\%) = \frac{m_{Ashes}}{m_{Dry\ sample}} \times 100 \tag{3}$$

Proteins: determined by the Kjeldahl method (AOAC 990.03), with conversion of total nitrogen to protein via the factor 6.25:

$$Protéines\ (\%) = N\ (\%) \times 6{,}25 \tag{4}$$

Lipids: Soxhlet extract with hexane, according to AOAC 920.39.

Total free sugars: hydroalcoholic extraction and determination by the anthrone-sulfuric method, with glucose as standard, expressed in g/100 g of fresh matter.

Hydrogen cyanide (HCN): determined according to AOAC 915.03 (alkaline method suitable for cassava roots), with quantification by titration or spectrophotometry, expressed in mg/kg of fresh matter.

2.5. Quality Control

All analyses were performed in duplicate for each sample. Blanks, standards, and replicates were used to verify precision and accuracy. Outliers were identified and excluded after verification.

2.6. Statistical Analysis

Data were processed using SPSS 25. After checking for normality (Shapiro-Wilk test) and homogeneity of variance (Levene test), a one-way ANOVA (locality or cultivar depending on the parameter) was performed. Significant differences were assessed using Tukey's post-hoc test with a threshold of $p < 0.05$.

3. Results

3.1. Cyanide Content of Cassava Tuberous Roots

Figure 1 shows the cyanide content (expressed in mg/kg) of cassava tubers from four cultivars selected in the locality of Loukoko, Pool department, Republic of Congo: Mbala, Boula bipaki, Dinkondi and Ndombi.

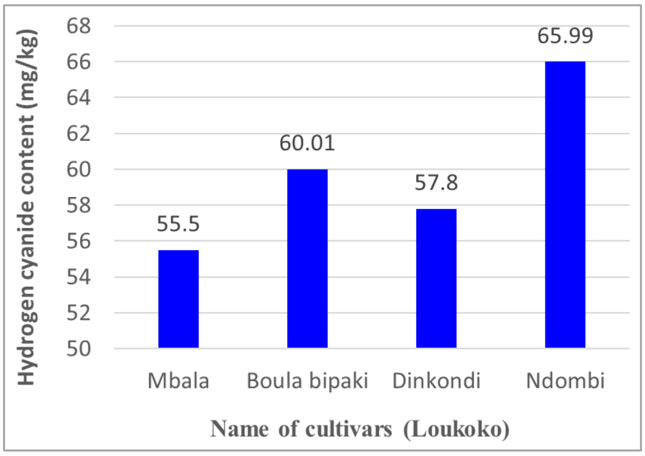

Figure 1. Cyanide content of cassava tuberous roots of four cultivars from the Loukoko locality.

Hydrogen cyanide (HCN) levels in Loukoko cultivars range from 55.5 mg/kg for Mbala to 65.99 mg/kg for Ndombi. Boula bipaki and Dinkondi cultivars have intermediate values (60.01 and 57.8 mg/kg, respectively). These results indicate that Ndombi is the most cyanogenic cultivar in the locality, while Mbala is the least toxic.

Figure 2 presents the hydrocyanic acid (HCN) contents of cassava tubers from fifteen cultivars grown in Mbanza Nkolo, Pool Department, Republic of Congo. Cyanide concentrations ranged from 22.9 mg/kg to 93.3 mg/kg, revealing high variability among cultivars.

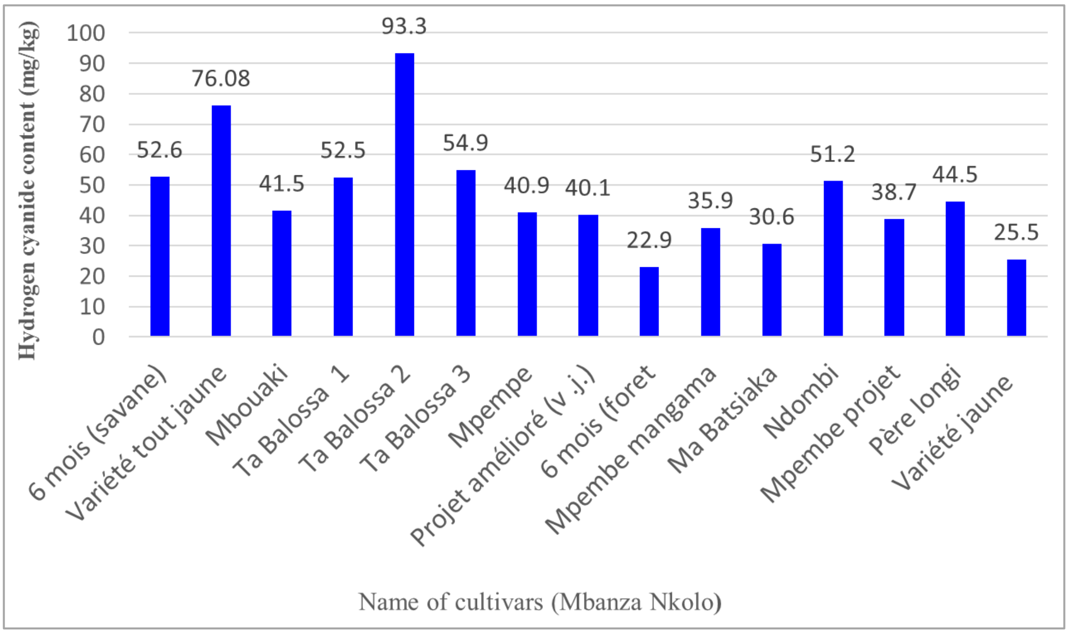

Figure 2. Cyanide content of cassava tuberous roots of fifteen cultivars from the locality of Mbanza Nkolo.

The levels observed in Mbanza Nkolo show a more marked variation, ranging from 22.9 mg/kg (Improved Project - forest) to 93.3 mg/kg (Ta Balossa 2 - forest). Savannah cultivars show intermediate levels, such as 6 months (52.6 mg/kg) and All Yellow Variety (76.08 mg/kg). This diversity reflects a strong influence of agroecological conditions and genetic variability. Cultivars with high levels (e.g. Ta Balossa 2, Mpembe mangama) require extensive processing before consumption, while others (Improved Project, Yellow Variety) appear safer and better suited to domestic consumption.

Figure 3 illustrates the hydrocyanic acid (HCN) contents of cassava tuberous roots from nine cultivars grown in the Ntoula locality. Cyanide concentrations ranged from 20.25 mg/kg to 78.3 mg/kg, highlighting significant chemical diversity among the genotypes studied.

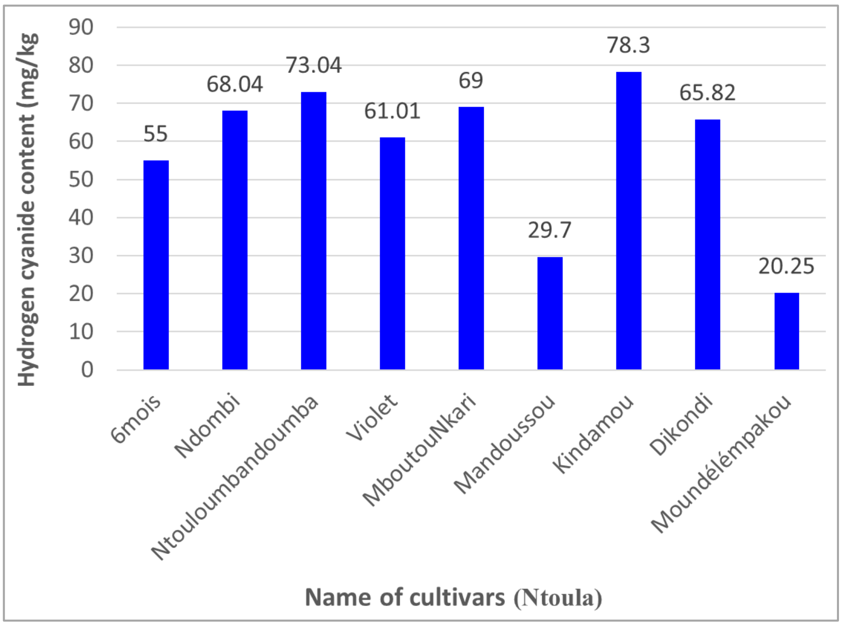

Figure 3. *Cyanide content of cassava tuberous roots of nine cultivars from the Ntoula locality.*

The Kindamou cultivar had the highest cyanide content (78.3 mg/kg), followed by Ntouloumbandoumba (73.04 mg/kg) and MoutoutouNkari (69 mg/kg). These levels far exceed recommended food safety thresholds, indicating a potential risk to human health if consumed unprocessed.

In contrast, Moundélémpakou (20.25 mg/kg) and Mandoussou (29.7 mg/kg) had the lowest levels, suggesting greater suitability for direct consumption or simplified processing. The 6 mois cultivar, with a content of 55 mg/kg, fell into an intermediate range but remained above the critical threshold of 10 mg/kg set by FAO/WHO for processed products.

The variation in HCN levels observed between localities reflects the interaction between genetic and environmental factors. Forest cultivars, particularly in Mbanza Nkolo, show greater variability and higher levels. These results corroborate those in the literature, which report levels ranging from 20 to 150 mg/kg depending on the cultivar and growing conditions [18, 19].

Thus, food safety related to cassava consumption relies both on the choice of cultivars with low HCN levels and on the implementation of traditional detoxification processes (soaking, fermentation, cooking). The identification of safer cultivars, such as Mbala in Loukoko or Projet Enhanced in Mbanza Nkolo, constitutes an important lever for reducing the risk of chronic poisoning in the Pool department.

3.2. Biochemical Composition of Tuberous Roots

Biochemical analysis of cassava roots grown in the localities of Loukoko, Mbanza Nkolo and Ntoula reveals significant variability between cultivars and agroecological zones. Parameters assessed include water, ash, protein, lipid and total free sugar content.

3.2.1. Water Content of Cultivars

The water content of tuberous roots varies considerably depending on the location and cultivar. Observed values range from 53.12% (Moundélémpakou, Ntoula) to 69.49% (Mboutou Nkari, Ntoula), with a higher average in the Ntoula area.

This variability can be attributed to agroecological (soil type, ambient humidity) and genetic (cultivar cell structure) factors. High water content is generally associated with poor storage capacity [20] while low-moisture cultivars, such as Mbouaki 54.48%, (Mbanza Nkolo), are more suitable for processing into flour or prolonged storage.

The water content of Loukoko tuberous roots (Figure 4) ranges from 55.22% (Boula bipaki) to 61.56% (Ndombi), with an average of 57.43% ± 2.83 (standard deviation). The values are generally moderate, with a maximum difference of ~6 percentage points between cultivars. In terms of dry matter

(DM), this corresponds to 42.6% DM on average, suggesting good potential yields of dry products (flour, gari) and moderate drying requirements.

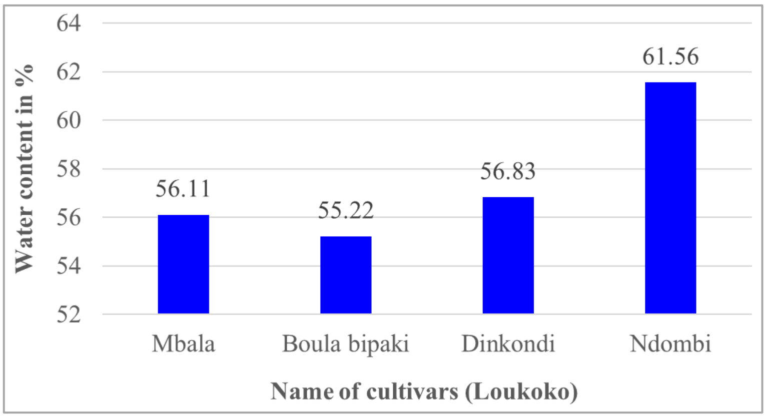

Figure 4*. Water content of cassava tuberous roots of four cultivars from the Loukoko locality.*

The water content values of Mbanza Nkolo tuberous roots (Figure 5) range from 54.48% (Mbouaki) to 65.20% (Mpembe mangama), with an average of 59.55% ±2.99. The majority of cultivars are between 56-62%, with two cultivars having high water content (Ta Balossa 2: 63.89%; Mpembe mangama: 65.20%). The average dry matter is about 40.45%. The wetter cultivars will imply higher drying cost and lower yields of dry products.

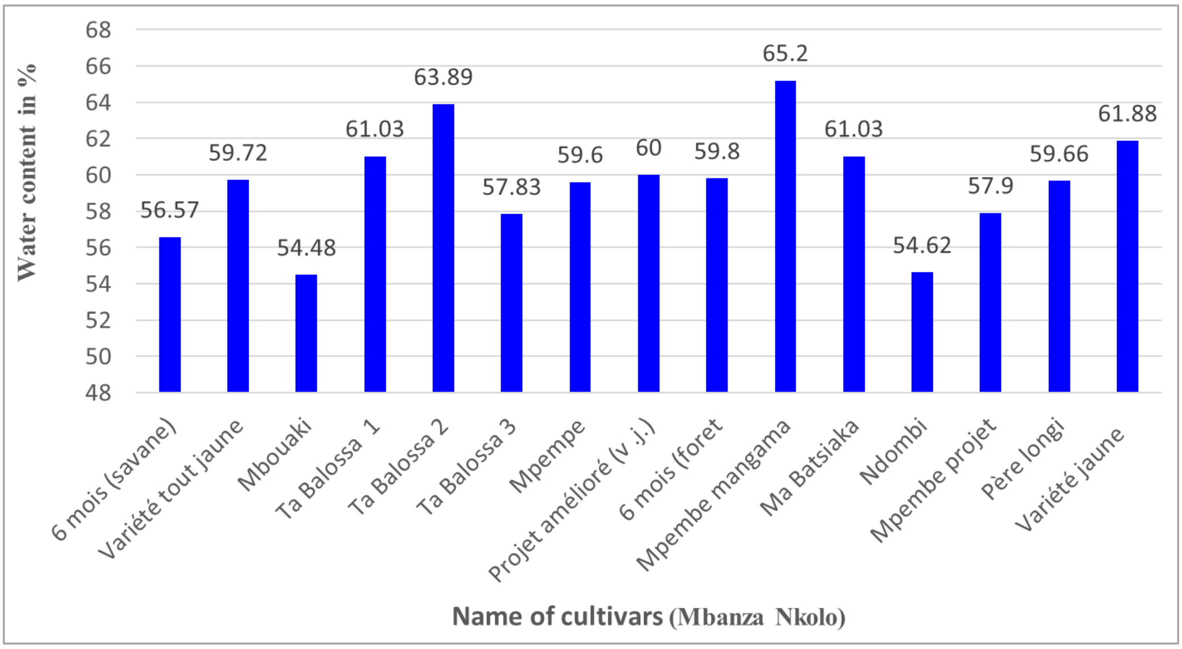

Figure 5*. Water content of cassava tuberous roots of fifteen cultivars from the locality of Mbanza Nkolo.*

Figure 6 shows the water contents of the tuberous roots of nine cultivars from the locality of Ntoula. In Ntoula, the variability is the most marked: 53.12% (Moundele mpakou) to 69.49% (Mboutounkari), average 60.88% ±5.07 (coefficient of variation ~8.3%). Four cultivars are very humid (> 62%), notably Mboutounkari (69.49%) and Violet (65.56%). The average dry matter is only ~39.12%, which suggests lower flour/gari yields and greater sensitivity to post-harvest deterioration.

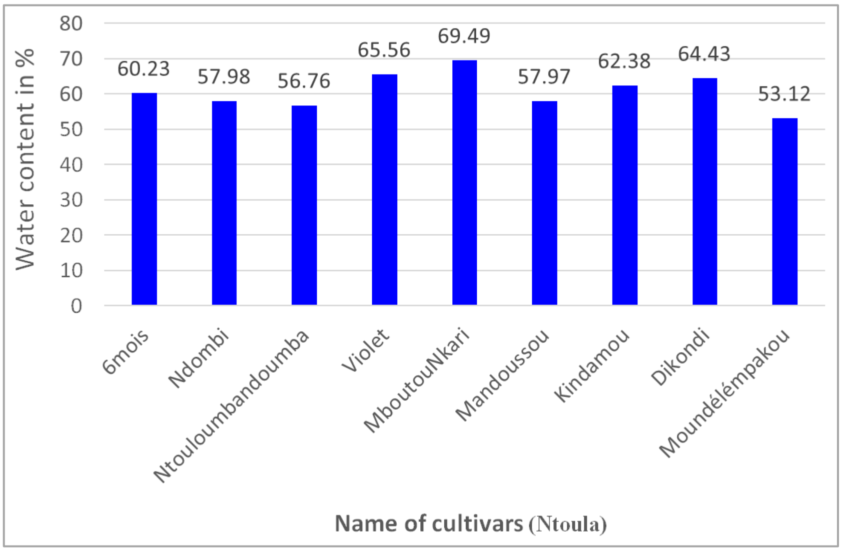

Figure 6. *Water content of cassava tuberous roots of nine cultivars from the locality of Ntoula.*

3.2.2. Ash Content (Total Minerals) of Cultivars

Figures 7, 8 and 9 present the ash contents of cassava tuberous roots from cultivars grown in the localities of Loukoko, Mbanza Nkolo and Ntoula in the Pool department, Republic of Congo.

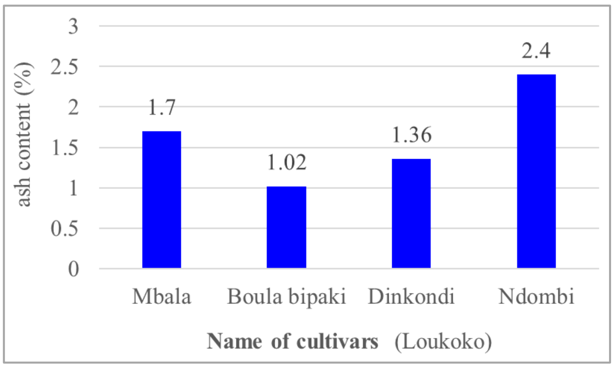

Figure 7. *Ash content of cassava tuberous roots of four cultivars from the Loukoko locality.*

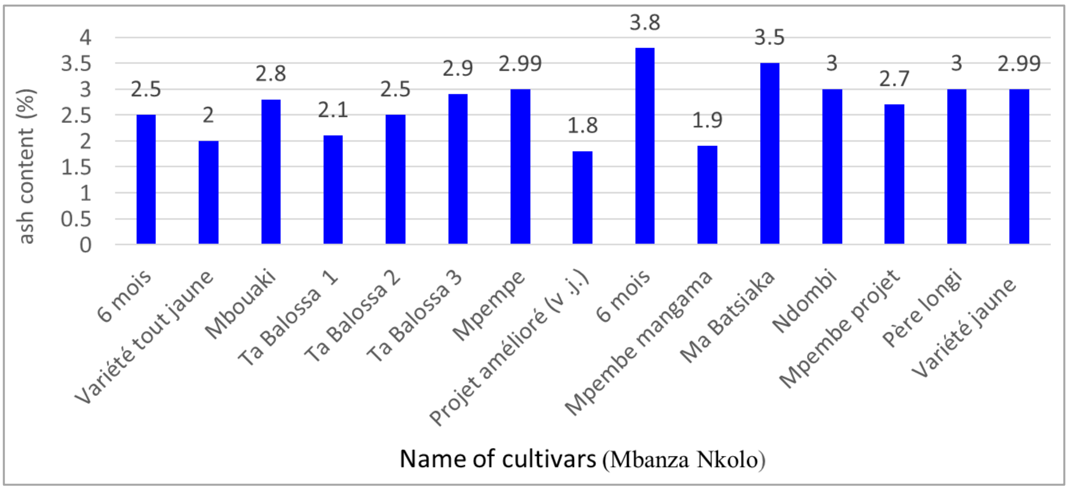

Figure 8. *Ash content of cassava tuberous roots of fifteen cultivars from the Mbanza Nkolo area.*

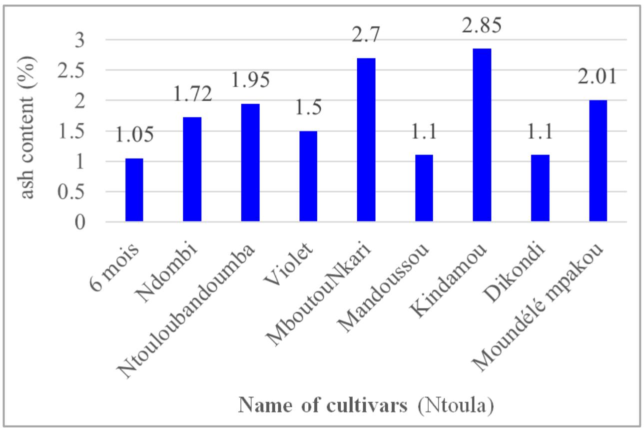

Figure 9. *Ash content of cassava tuberous roots of nine cultivars from the Ntoula locality.*

Ash contents range from 1.02% (Boula bipaki, Loukoko) to 3.8% (Mpembe mangama, Mbanza Nkolo). Mbanza Nkolo cultivars are distinguished by their mineral richness, which could reflect better absorption of soil nutrients or varietal selection oriented towards nutrient density.

Ash represents essential mineral elements such as calcium, potassium, and magnesium, which play a crucial role in enzyme regulation and bone health [21]. Cultivars with high ash content are therefore particularly interesting for populations at risk of micronutrient deficiencies.

3.2.3. Protein Content

Protein is a key indicator of nutritional quality. Observed values range from 1.0% (Père Longi, Mbanza Nkolo) to 2.94% (Ntouloubandoumba, Ntoula). Ntoula cultivars generally have the highest protein levels, making them particularly attractive for malnutrition control programs.

According to [1], cassava is often considered an energy source, but its low protein content limits its nutritional impact. The cultivars identified here as high in protein could be integrated into biofortification or dietary diversification strategies.

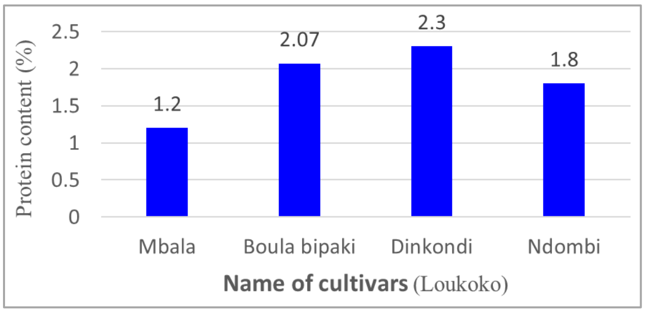

Figure 10. *Protein content of cassava tuberous roots of four cultivars from the Loukoko locality.*

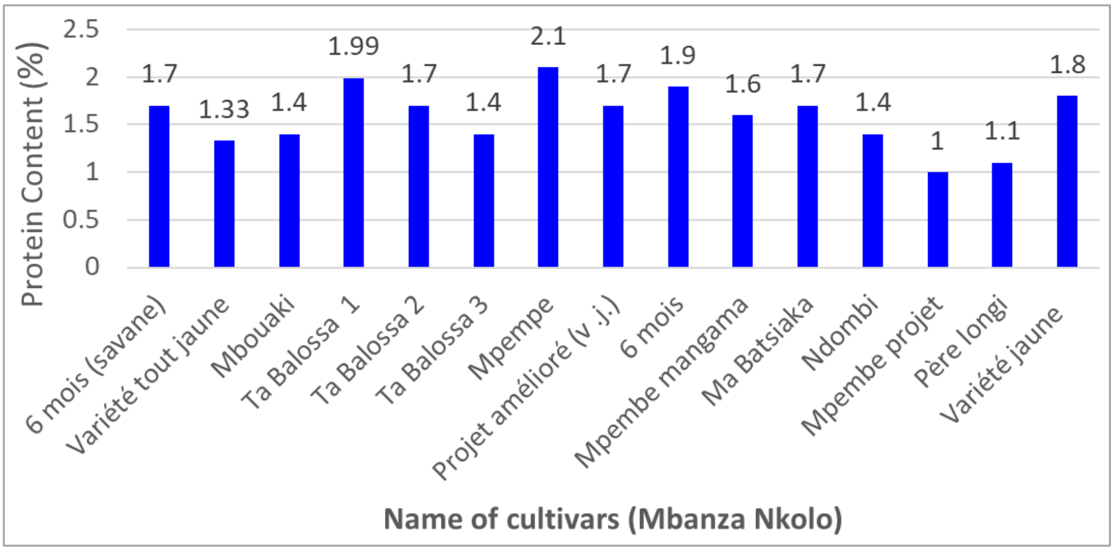

Figure 11. *Protein content of cassava tuberous roots of cultivars from the Mbanza Nkolo locality.*

3.2.4. Lipid Content

Lipids are generally low, ranging from 0.2% (Moundélé mpakou, Ntoula) to 0.81% (Ndombi, Ntoula). Although cassava is not a major source of lipids, slightly higher-fat cultivars can contribute to energy intake, particularly in low-fat diets.

Lipids also influence the texture and palatability of processed products [22]. The low levels observed promote oxidative stability, which is an advantage for storage.

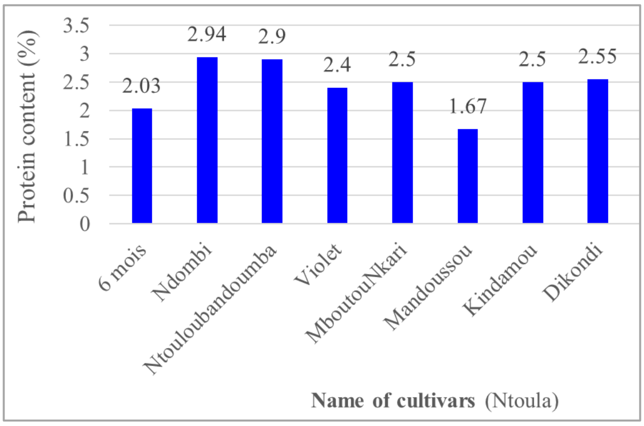

Figure 12. Protein content of cassava tuberous roots of cultivars from the Ntoula locality.

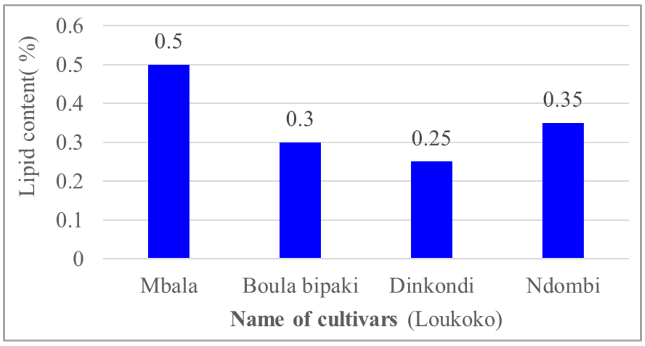

Figure 13. Lipid content of cassava tuberous roots of cultivars from the Loukoko locality.

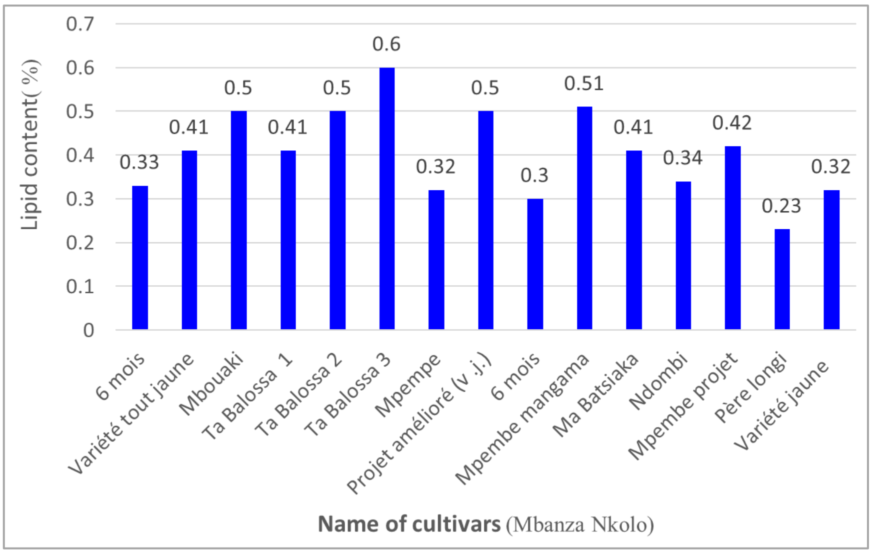

Figure 14. Lipid content of cassava tuberous roots of cultivars from the Mbanza Nkolo locality.

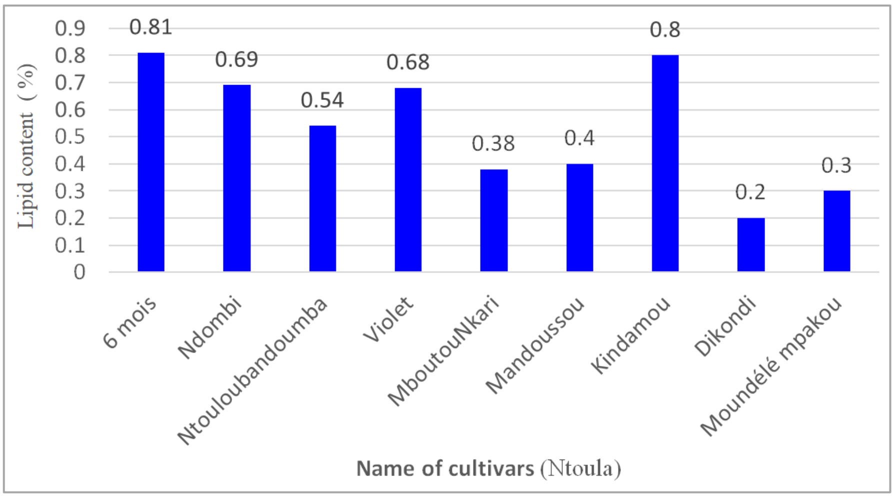

Figure 15. Lipid content of cassava tuberous roots of cultivars from the Mbanza Nkolo locality.

3.2.5. Total Free Sugar Content

Free sugars exhibit extreme variability, ranging from 0.2% (Ta Balossa 3, Mbanza Nkolo) to 14.9% (All Yellow Variety, Mbanza Nkolo). This dispersion is particularly marked in the Mbanza Nkolo area, suggesting significant genetic diversity.

Free sugars influence the sweetness, fermentation, and digestibility of roots. Cultivars high in sugars are suitable for the production of sweet or fermented products [23]. However, excessively high levels can pose storage problems.

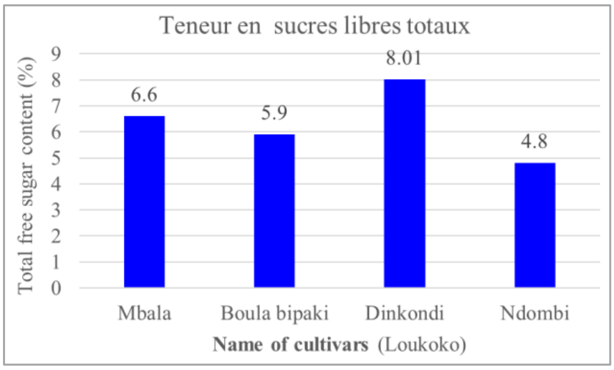

Figure 16. Carbohydrate content of cassava tuberous roots of cultivars from the Loukoko locality.

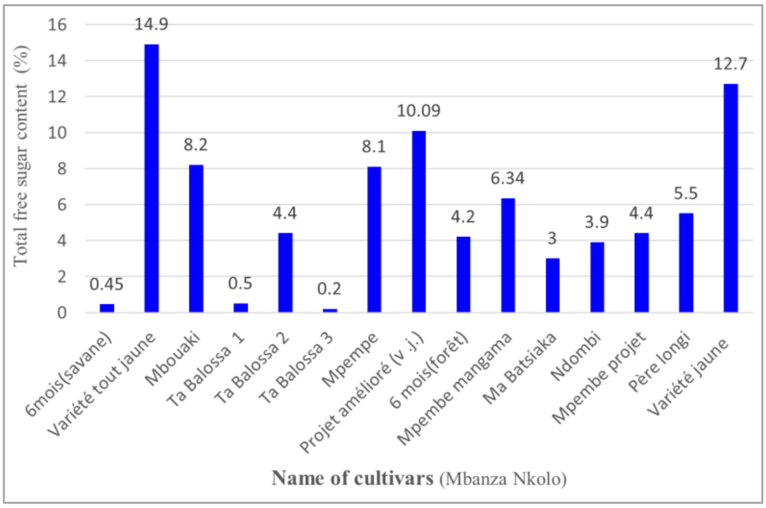

Figure 17. Carbohydrate content of cassava tuberous roots of cultivars from the Mbanza Nkolo locality.

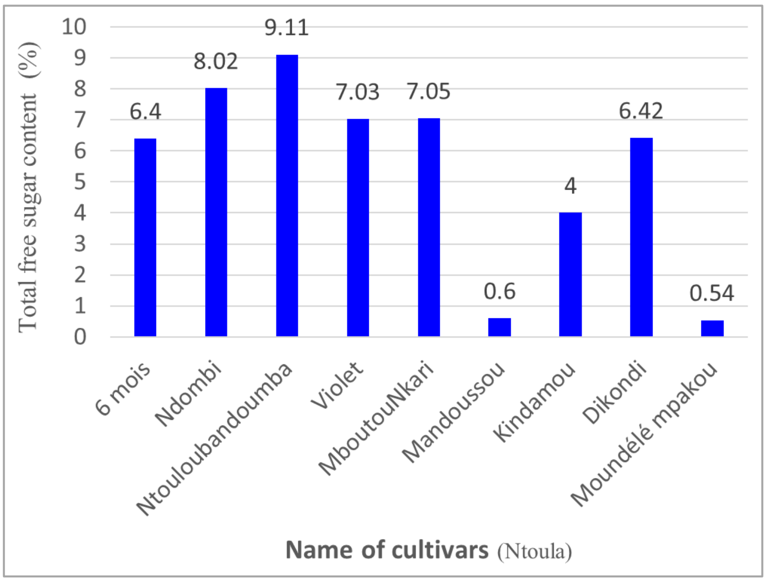

Figure 18. Carbohydrate content of cassava tuberous roots of cultivars from the Ntoula locality.

4. Discussion

The integrated analysis of the biochemical and antinutritional parameters of cassava tuberous roots has made it possible to identify several cultivars with characteristics particularly favorable to direct consumption and agri-food processing. For direct consumption, the cultivars Moundélé mpakou (Ntoula), 6 mois (forest) (Mbanza Nkolo) and Ma Bataska (Mbanza Nkolo) are distinguished by their low hydrocyanic acid content, their balanced nutritional profile and their aptitude for conservation. These cultivars have moderate moisture contents, an appreciable richness in proteins and free sugars, as well as low toxicity, making them suitable for domestic consumption after simple processing processes.

Regarding agri-food processing, the cultivars Dikondi (Loukoko/Ntoula), Variété tout jaune (Mbanza Nkolo) and Ntouloubandoumba (Ntoula) appear particularly promising. The Dikondi cultivar is characterized by a high protein and free sugar content, making it suitable for fermentation and the production of enriched products. The Variété tout jaune cultivar has the highest total free sugar content (14.9%), making it particularly suitable for the production of syrups, confectionery or fermented products with high sensory acceptability. Finally, Ntouloubandoumba stands out for its protein richness and good energy profile, making it relevant for targeted nutritional formulations.

The results obtained in this study offer interesting perspectives for the development of integrated cassava sectors, based on the promotion of local cultivars with high nutritional and technological potential. The selection and promotion of cultivars identified as promising could contribute to improving food and nutritional security in rural areas of the Pool department, while stimulating the local economy through agri-food processing.

Furthermore, these data provide a scientific basis for guiding varietal selection programs towards genotypes with low antinutritional compound content and high added value. A participatory approach involving local communities, researchers and agro-industrial stakeholders would be desirable to ensure the sustainable adoption of these cultivars. Finally, additional studies on genetic characterization, agronomic performance and sensory acceptability of derived products would help consolidate the results obtained and promote optimal exploitation of cassava genetic resources in this region.

5. Conclusion

The evaluation of the nutritional composition and cyanide content of cassava tuberous roots grown in the Pool department highlights significant biochemical diversity between cultivars and localities. The results show that some cultivars, particularly those from Ntoula, have improved nutritional profiles, with high protein and free sugar contents, while those from Mbanza Nkolo are distinguished by their mineral richness. However, the cyanide content observed in all samples far exceeds food safety standards, which requires systematic processing before consumption. This constraint underlines the importance of raising awareness among rural communities about traditional detoxification techniques such as soaking, fermentation and drying. From an agronomic perspective, the results obtained can guide breeding programs towards cultivars with high nutritional value and low toxicity, while taking into account local preferences and agroecological conditions. Integrating these data into agricultural and nutritional policies could help improve food security and nutritional resilience of rural populations in Congo.

Abbreviations

HCN	Hydrocyanic Acid
FAO	Food and Agriculture Organization
WHO	World Health Organization
AOAC	Association of Official Analytical Collaboration
N	Nitrogen
Mi	Initial Mass
Ms	Mass of the Dry Sample
DM	Dry Matter

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Celestine Kiminou Ngounga is a lecturer in the Food Engineering Department at the Ecole Nationale Supérieur Polytechnique (ENSP) of Marien Ngouabi University. She obtained her unique doctorate in chemistry and food technology from Marien Ngouabi University in 2020 and her master's degree in chemistry and food technology from the same University in 2014. She is part of an international research project of the Central African Economic and Monetary Community (CEMAC): PRASAC (Regional Pole of Applied Research for the Development of Agricultural Systems in Central Africa). She is also one of the experts of the mirror and technical committee of ACONOQ (Congolese Agency for Standardization and Quality) in her country, participates in the setting of ARSO (African Organization for Standardization).

Research Field

Celestine Kiminou Ngounga: Agri-Food Engineering, Biotechnology, Food Technology, Food Chemistry, Agro-Resource Processing.
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Bob Wilfrid Loumouamou: Agri-Food Engineering, Food Chemistry, Agro-Resource Processing, Food Technology, Biotechnology.
Marie Geneviève Maloumbi: Nutrition, Analytical Chemistry, Instrumental Chemistry, Agri-Food Engineering, Agro-Resource Processing.
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