

Cyanogenic Potential, Macronutrient Composition, and Free Sugar Content of Cassava (*Manihot esculenta* Crantz) Tuberous Roots Grown at the Oyo Agricultural Site, Republic of Congo

Célestine Kiminou Ngounga^{1,2,*}, Bertin Mikolo², Bob Wilfrid Loumouamou^{1,2}, Marie Geneviève Maloumbi³, Jean Mathurin Nzikou²

¹Multidisciplinary Food and Nutrition Research Team: Regional Center of Excellence in Food and Nutrition, Faculty of Science and Technology, Marien Ngouabi University, Brazzaville, B.P. 69, Congo.

²Process Engineering Laboratory, UNESCO-ENSP Chair, Marien Ngouabi University, Brazzaville, B.P. 69, Congo.

³Molecular and Sensory Food Engineering Laboratory, National Polytechnic School (ENSP), Marien Ngouabi University, Brazzaville, B.P. 69, Congo.

How to cite this paper: Célestine Kiminou Ngounga, Bertin Mikolo, Bob Wilfrid Loumouamou, Marie Geneviève Maloumbi, Jean Mathurin Nzikou. (2025). Cyanogenic Potential, Macronutrient Composition, and Free Sugar Content of Cassava (*Manihot esculenta* Crantz) Tuberous Roots Grown at the Oyo Agricultural Site, Republic of Congo. *International Journal of Food Science and Agriculture*, 9(3), 191-198. DOI: 10.26855/ijfsa.2025.09.006

Received: August 28, 2025

Accepted: September 25, 2025

Published: October 20, 2025

Corresponding author: Célestine Kiminou Ngounga, Multidisciplinary Food and Nutrition Research Team: Regional Center of Excellence in Food and Nutrition, Faculty of Science and Technology, Marien Ngouabi University, Brazzaville, B.P. 69, Congo; Process Engineering Laboratory, UNESCO-ENSP Chair, Marien Ngouabi University, Brazzaville, B.P. 69, Congo.

Abstract

Cassava (*Manihot esculenta* Crantz) is a key food crop in sub-Saharan Africa. Its tuberous roots represent a major energy source, but their consumption may be limited by the presence of cyanogenic compounds, as well as by significant nutritional variability. This study evaluated the cyanogenic potential, macronutrient composition (protein, lipids, water, dry matter, ash), and total free sugar content of 25 cassava cultivars harvested from four locations in the Oyo agricultural site (Republic of Congo). Results revealed significant variability between cultivars and locations: HCN contents ranged from 12.7 to 114.6 mg/kg, protein from 0.7 to 2.8%, lipids from 0.2 to 0.9%, ash from 0.8 to 2.7%, and free sugars from 0.4 to 10.1%. Some cultivars, such as Mouambalé and Opoupou, have good nutritional potential and low cyanogenic content, while others, such as Nzete ya Mbongo and Tokou, are highly cyanogenic. These results provide useful information to guide varietal selection, agri-food development, and the prevention of health risks associated with cassava consumption.

Keywords

Cassava; Cyanogenic compounds; Macronutrients; Free sugars; Food safety

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a major food crop in sub-Saharan Africa, playing a critical role in food security and energy supply for rural and urban populations [1]. These tuberous roots are an important source of carbohydrates but exhibit considerable variability in nutritional composition, including macronutrients, free sugars, and cyanogenic compounds [2-4]. The presence of cyanogenic glycosides, mainly linamarin and lotaustralin, constitutes a major constraint for the safe consumption of cassava [5-7]. These compounds, during their hydrolysis, release hydrocyanic acid (HCN), which can induce acute or chronic toxic effects if the tuberous roots are not properly detoxified [8, 9]. Furthermore, the content of proteins, lipids, and free sugars varies according to cultivars, pedoclimatic conditions, and cultural practices [10, 11]. In the Republic of Congo, cassava remains the primary

staple food, particularly in the Cuvette department, where the Oyo agricultural site constitutes a strategic production area. However, few systematic studies have characterized the nutritional composition and cyanogenic potential of local cultivars. Such evaluation is essential to guide varietal selection, processing practices, and agro-industrial valorization strategies.

The present study aims to evaluate the cyanogenic potential, macronutrient composition (proteins, lipids, water, and dry matter), and total free sugar content of cassava tuberous roots collected in four localities of the Oyo agricultural site (Ollombo center, Boundji, Owando center, and Allembe), taking into account the diversity of cultivars.

2. Methods

2.1 Study area and sampling

The study was conducted at the Oyo agricultural site, located in the Cuvette department, Republic of Congo. Four localities were selected: Ollombo Centre, Boundji, Owando Centre, and Allembe. A purposive sampling approach was applied through a farmer survey to identify the locally cultivated cassava cultivars.

In total, 25 cultivars were recorded and sampled:

- Ollombo Centre: Ndely, Mouabale, Ongana, Lemboro Laba, Pea, Ewuru Oyéfé, Opé Pembe, Nzete ya Mbongo, Téké (8 cultivars).
- Boundji: Mbomo, Awuru Oyéba, Omaninga Mwassi, Omaninga Mobali, Nzete ya Mbongo (5 cultivars).
- Owando Centre: Violet, Ndeng-ndeng, Onganguina, Ebobo, Tokou, Onganienga, Ewuru Oyeba, “6 mois”, Opoupou, Mouambale (10 cultivars).
- Allembe: Eyaoya, Ewuru Oyeba (2 cultivars).

For each cultivar, 5 to 10 mature roots were randomly harvested from different fields, pooled to obtain a representative sample, and transported to the laboratory for analysis.

2.2 Physicochemical analyses

Cassava roots were washed, peeled, chopped, and homogenized prior to analysis.

- Cyanogenic potential: determined using the alkaline picrate method described by [12], with spectrophotometric quantification at 510 nm.
- Moisture and dry matter contents: determined by oven-drying at 105 °C to constant weight [13].
- Total protein: quantified using the Kjeldahl method, applying the nitrogen-to-protein conversion factor of N × 6.25 [13].
- Total lipids: extracted by Soxhlet apparatus using hexane as solvent [13].
- Total free sugars: determined colorimetrically by the phenol-sulfuric acid method [14] with absorbance read at 490 nm.

All analyses were performed in triplicate.

2.3 Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA), followed by Tukey's test ($p < 0.05$) to compare means among cultivars and localities, using XLSTAT software.

3. Results and Discussion

3.1 Variability of cyanogenic potential among cultivars and localities

The cyanide contents of cassava roots collected from the Oyo agricultural site showed substantial variability both among cultivars and across localities (Figure 1).

At Ollombo centre, cyanide contents ranged from 12.71 mg HCN/kg (Mouambalé) to 113.85 mg HCN/kg (Nzete ya Mbongo). At Boundji, values varied between 54.93 mg/kg (Mbomo) and 110.64 mg/kg (Nzete ya Mbongo). At the Owando centre, the extremes ranged from 21.19 mg/kg (Opoupou) to 114.57 mg/kg (Ndeng-ndeng).

These results confirm that cyanogenic potential is strongly influenced by both genotype (cultivar) and growing environment, as previously reported [3, 11].

According to the FAO/WHO thresholds (<50 mg/kg = low; 50–100 mg/kg = moderate; >100 mg/kg = high) [8]:

- Low-cyanogenic cultivars (<50 mg/kg): Ndely, Mouambalé (Ollombo and Owando), Opé Pembe, Opoupou.
- Moderately cyanogenic cultivars (50–100 mg/kg): Ongana, Lemboro laba Pea, Ewuru Oyéfé, Mbomo, Awuru

Oyéba, Omaninga mwassi, Violet, Onganienga, Ewuru Oyéba.

- Highly cyanogenic cultivars (>100 mg/kg): Nzete ya Mbongo (Ollombo and Boundji), Ndeng-ndeng, Tokou.

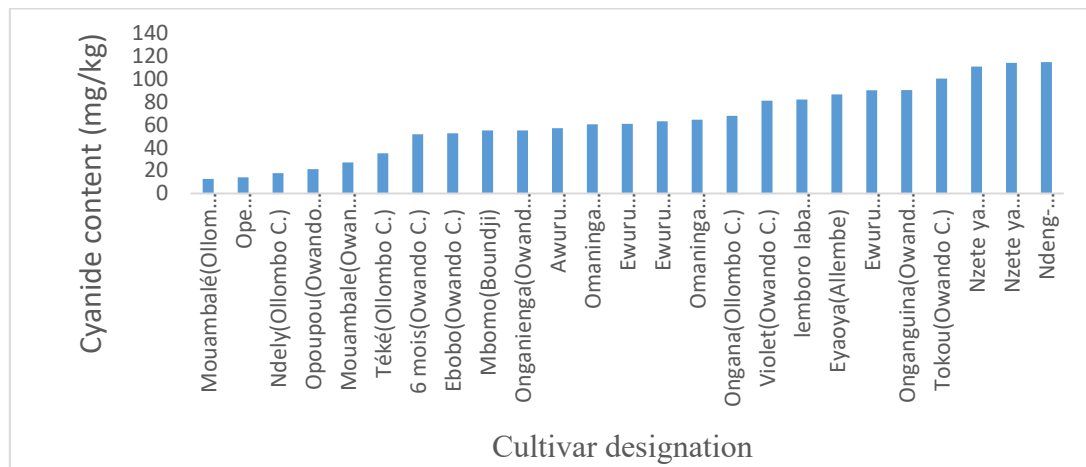


Figure 1. Cyanide content of cassava (*Manihot esculenta* Crantz) cultivars collected from the Oyo agricultural site, Republic of Congo.

This distribution indicates that some cultivars, although locally valued, may pose a high toxicological risk if consumed without adequate processing.

Our findings are consistent with results from Mozambique [9], where cyanide levels up to 120 mg/kg were measured in local varieties. Similarly, ranges between 10 and 150 mg/kg were reported in Ghana and Nigeria [9, 15], confirming that the variability observed in Oyo is typical of African tropical regions. However, the relatively high proportion of cultivars with elevated cyanogenic potential (>100 mg/kg) in our study could represent an increased risk for local populations, especially during food shortage periods or crises, when cassava may be consumed with insufficient processing.

Cassava is a staple food for most households in the Republic of Congo [16, 17]. Nevertheless, the presence of high-cyanogenic cultivars (e.g., Nzete ya Mbongo, Ndeng-ndeng, Tokou) calls for special attention. Repeated consumption of these varieties without adequate processing may lead to acute or chronic intoxication, including endemic goiter and konzo (irreversible neuropathy) [2,18].

In contrast, low-cyanogenic cultivars (Mouambalé, Opoupou, Opé Pembe) represent promising alternatives for food security, as they combine reduced HCN content with adaptability to local conditions.

These results highlight the need to promote:

- Appropriate processing practices (fermentation, drying, grating, soaking), which significantly reduce cyanogenic contents [8, 9]
- Selection and dissemination of low-cyanogenic cultivars, in order to reduce long-term toxic risks.

The high diversity observed also provides opportunities for breeding programs aimed at developing cultivars that combine low cyanogenic potential, high agronomic yield, and nutritional quality adapted to local needs. Moreover, further studies should assess nutrient bioavailability, evaluate the effect of traditional processing methods on cyanide reduction, and determine the seasonal variability of cyanogenic potential.

3.2 Moisture profile and processing suitability

Figure 2 shows the moisture content of cassava tuberous root cultivars grown on the Oyo agricultural site in the Cuvette department of the Republic of Congo.

The moisture contents of cassava tubers analyzed across the four localities of the Oyo agricultural site ranged from 53.64% (Mouambale, Ollombo centre) to 69.61% (Ewuru Oyéfé, Ollombo centre). This wide range reflects both the genetic diversity of cultivars and the influence of local agroecological conditions. These values fall within the ranges generally reported for fresh cassava, i.e., 50-70% moisture [19]. Save and Grow: Cassava – A guide to sustainable production intensification. Food and Agriculture Organization of the United Nations [11, 19].

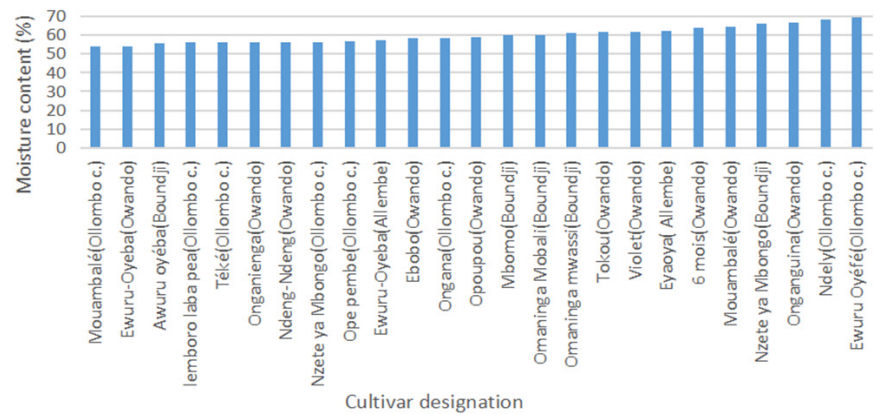


Figure 2. Moisture content of cassava (*Manihot esculenta* Crantz) cultivars from the Oyo agricultural site.

A first observation is that certain cultivars, such as Ndely (68.3%), Ewuru Oyéfè (69.61%), Onganguina (66.7%), and Nzete ya Mbongo from Boundji (66.03%), exhibit high water contents. Such high levels are associated with a low dry matter density, which may limit their suitability for processing into derived products such as flour or gari [20]. Conversely, cultivars like Mouambale (53.64% at Ollombo centre), Ewuru Oyéba (53.74% at Owando centre), and Awuru Oyéba (55.74% at Boundji) showed lower water contents, which indicates a higher potential yield in dry matter and, therefore, greater efficiency in the production of dried derivatives [21].

These differences are attributable to both inter-cultivar genetic variability and environmental factors such as soil fertility, cropping practices, and harvest maturity [2, 22]. For instance, it is known that early-harvested tubers tend to have higher moisture content, while late harvesting favors the accumulation of dry matter [23].

Moreover, geographic location also seems to influence water content. Cultivars from the Boundji and Owando centre generally fall within an intermediate range (55–66%), suggesting relatively homogeneous agroecological adaptation. In contrast, the Ollombo centre displayed greater dispersion with notable extremes (53.64% for Mouambale vs. 69.61% for Ewuru Oyéfè), which suggests more pronounced genetic heterogeneity among the cultivars in this locality.

From a nutritional and technological perspective, high water content reduces post-harvest shelf life by promoting fermentations and enzymatic degradation [1, 24]. Thus, water-rich cultivars such as Ewuru Oyéfè and Ndely are less suitable for long-term storage but can be valorized in immediate consumption and fermented products. Conversely, low-moisture cultivars such as Mouambale and Ewuru Oyéba offer better prospects for drying and industrial processing.

In summary, the study highlights significant variability in water content among cultivars and localities. This variability constitutes a major agronomic selection criterion, allowing the orientation of cultivar use toward direct consumption, artisanal or industrial processing, and improvement of post-harvest conservation.

3.3 Variability in ash content and nutritional implications

Figure 3 shows the ash contents of the cassava root cultivars grown at the Oyo agricultural site.

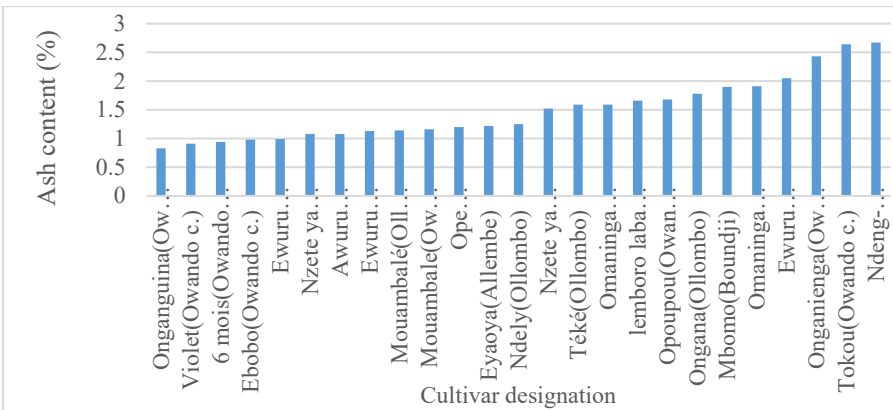


Figure 3. Ash content of cassava cultivars from the Oyo agricultural site.

Ash contents in cassava tubers cultivated at the Oyo agricultural site range from 0.83% (Onganguina, Owando Centre) to 2.67% (Ndeng-ndeng, Owando Centre), with several cultivars exceeding 2%, notably Tokou ($\approx 2.64\%$). Conversely, a cluster of varieties, including Violet, "6 months", Ebobo, and Ewuru-Oyebe, showed consistently lower values, all falling within a narrow range of 0.83% to 1.2%. The ash fraction, which reflects the total mineral load, displays a range (0.8-2.7%) consistent with values typically reported for cassava roots (0.2-2.5%), depending on genotype, maturity stage, and pedoclimatic conditions [1, 15]. The high values observed in Ndeng-ndeng and Tokou may indicate either a genetic predisposition for mineral accumulation or a local effect related to soil fertility, pH, or water regime, as previously reported [3]. From a nutritional standpoint, these high-ash cultivars could contribute more significantly to the mineral intake of local populations. However, elevated mineral contents may affect certain technological properties, particularly the color and quality of flours or semolina (e.g., darker hue after roasting). Nevertheless, such variations remain compatible with traditional uses, provided that particle size and moisture content are properly controlled [11].

3.4 Protein content and enrichment potential

Figure 4 presents the protein contents of cassava root cultivars grown at the Oyo agricultural site.

The protein contents of the cassava tubers studied ranged from 0.7% (Ongana, Ollombo Centre) to 2.8% (Onganguina, Owando Centre). Relatively high levels, equal to or exceeding 2.3%, were observed in Omaninga mwassi, Tokou, and Onganguina—all originating from the Owando Centre locality. Conversely, several cultivars exhibited lower protein contents, equal to or below 1.2% (Ongana, Téké, Mouambalé, Nzete ya Mbongo, etc.).

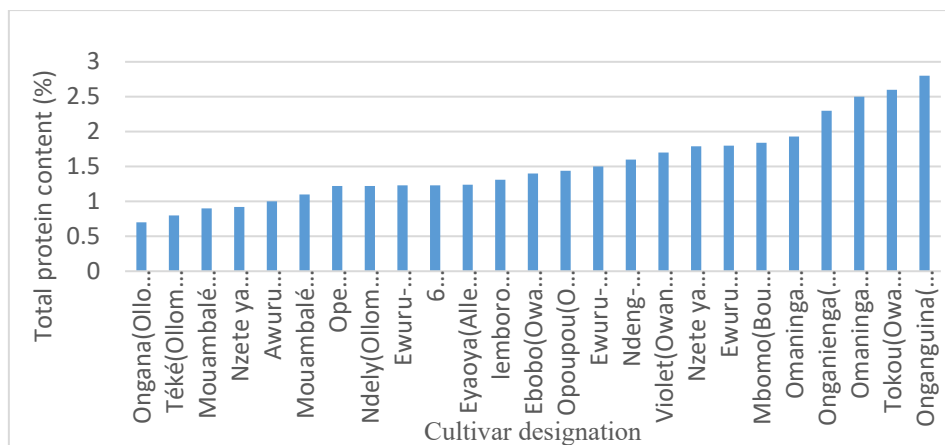


Figure 4. Total protein content of cassava cultivars from the Oyo agricultural site.

These results confirm the low protein density of cassava (generally 0.5-2.0% w/w), as previously reported in the literature [1, 15]. The observed variability primarily reflects the combined effects of genotype and environment. Although the highest values (≈ 2.3 -2.8%) remain modest in relation to nutritional requirements, they highlight cultivars with potential interest for improved formulations (e.g., combinations with legumes or protein enrichment).

The concentration of the most favorable protein profiles in Owando Centre suggests an influence of agroecological and cultural factors, such as nitrogen fertilization, water regime, or harvest maturity stage [3].

From a nutritional standpoint, given cassava's high energy contribution but low protein content, promoting cultivars with slightly higher protein levels and combining them with other protein sources (e.g., groundnuts, cowpeas, fish) appears essential to improve dietary balance in regions where cassava is a staple food [1].

3.5 Lipid profile and nutritional and technological implications

Figure 5 presents the lipid contents of cassava root cultivars grown at the Oyo agricultural site. Lipid levels range from approximately 0.21% (Mouambalé, Ollombo Centre) to 0.90% (6 months, Owando Centre). Several cultivars from Owando show relatively higher values: Tokou $\approx 0.80\%$, Violet $\approx 0.74\%$, and Opoupou $\approx 0.70\%$. The majority of profiles remain $\leq 0.5\%$.

Cassava roots are notably low in lipids (≈ 0.1 -1.0%), which aligns with our findings [1, 11]. Slightly higher lipid contents may result from advanced maturity, physiological status (reserve accumulation), or environmental factors such as water stress. From a technological standpoint, low lipid levels reduce the risk of rancidity and enhance the stability of dry products (e.g., flour, gari), which is advantageous for storage.

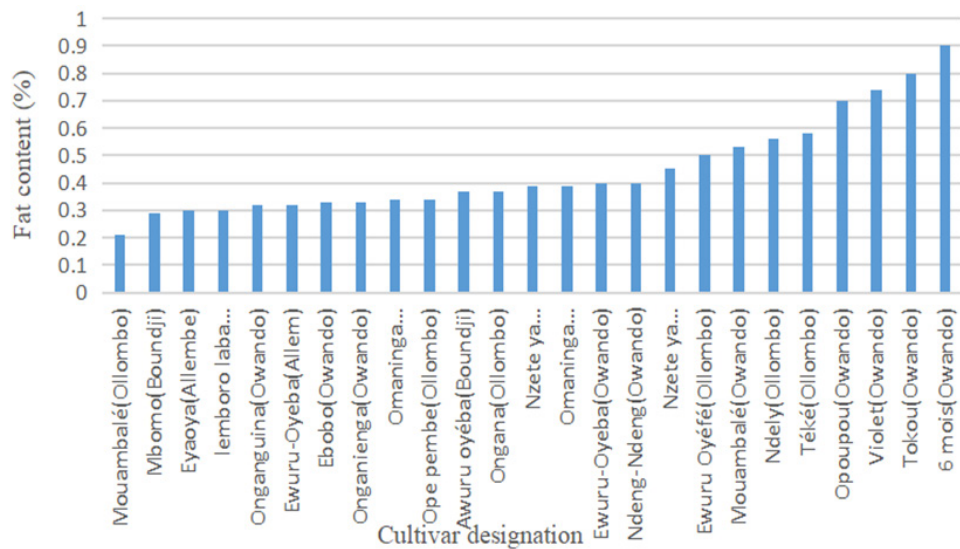


Figure 5. Total lipid contents of cassava cultivars from the Oyo agricultural site.

Overall, these results confirm the classical profile of cassava: low protein and lipid density, variable mineral content, and predominance of starch [1]. The highest ash and protein contents were concentrated in Owando Centre (Ndeng-ndeng, Tokou, Onganguina), suggesting environmental influence and/or notable genotype × environment (G×E) interactions [3].

For more mineral-rich flours: Ndeng-ndeng, Tokou. For slight protein enhancement: Onganguina, Tokou, Omaninga mwassi. For improved storage stability, the majority of cultivars (lipids ≤0.5%).

Potential link with cyanogenic content: Some cultivars with higher mineral and protein levels (e.g., Tokou) also exhibited elevated cyanogenic potential in previous figures. While this co-occurrence does not imply causality, it warrants post-processing tests (grating, fermentation, drying) to ensure safe levels of HCN [8, 9].

3.6 Variability in free sugars and technological implications of cassava cultivars

Figure 6 presents the total free sugar contents of cassava root cultivars grown at the Oyo agricultural site.

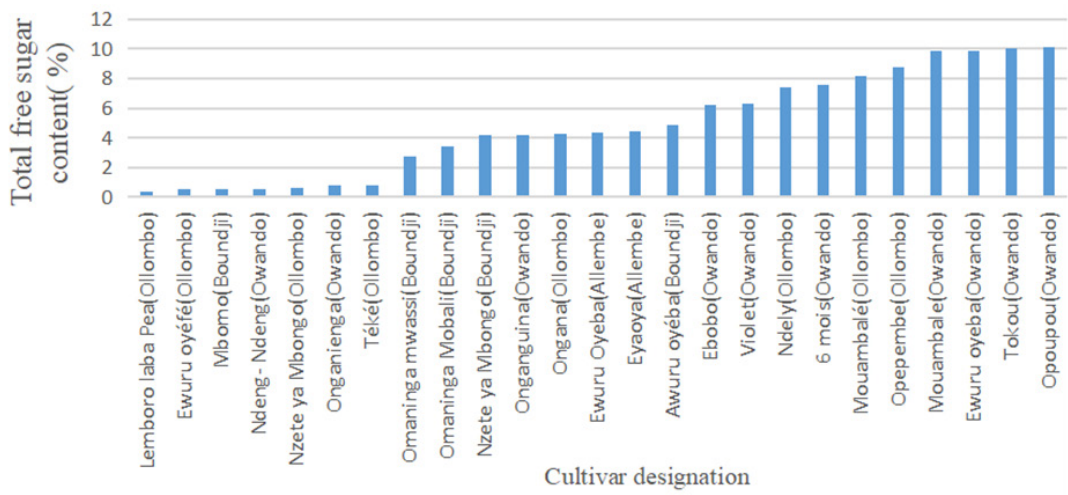


Figure 6. Total free sugar contents of cassava cultivars from the Oyo agricultural site.

The free sugar contents of the cassava tubers studied showed marked variability across cultivars and localities, with an overall range from 0.4% to 10.07% (w/w). At Ollombo Centre, some varieties exhibited very low values, such as Lemboro laba Pea (0.4%), Ewuru Oyéfé (0.5%), and Nzete ya Mbongo (0.6%), while others like Opé Pembe (8.75%), Mouambalé (8.2%), and Ndely (7.4%) displayed significantly higher levels. In Boundji, the variability was narrower (0.5-4.9%), with Awuru Oyéba reaching the highest value. Owando Centre stood out for its

pronounced heterogeneity, encompassing both the highest sugar contents (Opoupou 10.07%, Tokou 10.03%, Mouambalé 9.85%, Ewuru Oyéba 9.86%) and some of the lowest (Ndeng-ndeng 0.55%, Onganienga 0.8%). In Allembe, values were intermediate, ranging from 4.35% to 4.45%.

This variability reflects the combined influence of genotype, agroecological conditions, and harvest maturity, confirming the role of genotype $\times$ environment (G $\times$ E) interactions in soluble sugar accumulation [3, 11, 15]. For instance, the cultivar Mouambalé consistently exhibited high sugar levels across sites (8.2% at Ollombo; 9.85% at Owando), although its absolute concentration varied by locality.

From a technological and nutritional perspective, cultivars with high free sugar content ($\geq 8\%$), such as Opoupou, Tokou, and Mouambalé, are characterized by enhanced palatability, suitability for direct consumption after processing, and favorable potential for fermented products (sweet gari, porridges, beverages). In contrast, low-sugar cultivars ($< 1\%$), including Lemboro laba Pea, Ewuru Oyéfè, and Ndeng-ndeng, are better suited for flour and starch production due to their greater storage stability and lower tendency toward spontaneous fermentation.

3.7 Potential link with cyanogenic risk

Among the cultivars studied, some high-sugar varieties, such as Tokou, also ranked among the most cyanogenic. Conversely, low-sugar cultivars like Ndeng-ndeng and Nzete ya Mbongo (Ollombo) exhibited elevated HCN levels. These observations confirm the absence of a direct relationship between free sugars and cyanogenic compounds, as the two metabolic pathways are distinct. However, they underscore the need to guide varietal selection based on a dual constraint: sensory and energetic quality on one hand, and food safety on the other.

The observed sugar levels (0.4–10%) are consistent with ranges reported in the literature for cassava roots, which vary according to genotype, maturity, and environmental conditions [1, 11, 15]. The high values recorded at Owando (≥ 9 –10%) correspond to localized accumulations previously described in favorable environments or during early harvests, as seen with the “6 months” cultivar [1]. Conversely, very low levels ($< 1\%$) observed in Lemboro laba Pea, Ewuru Oyéfè, and Ndeng-ndeng characterize “starch-type” profiles suitable for stable flour and starch production.

Thus, sugar-rich cultivars (Opoupou, Tokou, Mouambalé, Ewuru Oyéba, 6 months, Violet, Ebobo) are well suited for direct consumption and sweet/fermented products, while low-sugar varieties (Lemboro laba Pea, Ewuru Oyéfè, Ndeng-ndeng, Onganienga, Nzete ya Mbongo) are better adapted to starch-processing chains. However, cultivars combining high sugar content with elevated cyanogenic potential, such as Tokou, must undergo intensive processing (fermentation, drying) to ensure safety without compromising sensory quality [8, 9].

4. Conclusion

This study highlights the considerable variability in cyanogenic potential and nutritional composition among cassava cultivars grown in Oyo. Certain cultivars combine low cyanogenic potential with valuable nutritional attributes, making them prime candidates for agro-industrial promotion and processing. Conversely, highly cyanogenic cultivars require rigorous transformation procedures to ensure consumer safety. These findings provide a valuable scientific foundation to guide varietal selection, processing strategies, and cassava improvement programs in the Republic of Congo.

Acknowledgements

The authors thank Professor Emeritus Thomas Silou for his various services rendered.

References

- [1] Montagnac JA, Davis CR, Tanumihardjo SA. Nutritional value of cassava for use as a staple food and recent advances for improvement. *Compr Rev Food Sci Food Saf.* 2009;8(3):181-94. <https://doi.org/10.1111/j.1541-4337.2009.00077.x>.
- [2] Chiwona-Karlton L, Nyirenda D, Mwansa NS, Kongor JE, Mkumbira J, Johansson L, et al. Bitter taste in cassava roots correlates with cyanogenic glucoside levels. *J Sci Food Agric.* 2015;95(8):1673-9. <https://doi.org/10.1002/jsfa.6800>.
- [3] Burns AE, Gleadow RM, Zacarias AM, Cuambe CE, Miller RE, Cavagnaro TR. Variations in the chemical composition of cassava (*Manihot esculenta* Crantz) leaves and roots as affected by genotypic and environmental variation. *J Agric Food Chem.* 2012;60(19):4946-56. <https://doi.org/10.1021/jf2047288>.
- [4] Schlienger JL. *Practical Clinical Nutrition: In adults, children and the elderly*. 4th ed. Issy les Moulineaux Cedex France: Elsevier Masson SAS; 2025.

- [5] Odoemelam CS, Percival B, Ahmad Z, Chang MW, Scholey D, Burton E, et al. Characterization of yellow root cassava and food products: investigation of cyanide and β -carotene concentrations. *BMC Res Notes*. 2020;13:333. <https://doi.org/10.1186/s13104-020-05175-2>.
- [6] Mohidin SRNS, Moshawih S, Hermansyah A, Asmuni MI, Shafqat N, Ming LC. Cassava (*Manihot esculenta* Crantz): A systematic review for the pharmacological activities, traditional uses, nutritional values, and phytochemistry. *J Evid Based Integr Med*. 2023;28:2515690X231206227. <https://doi.org/10.1177/2515690X231206227>.
- [7] Nyaika J, Abayomi L, Parmar A, Coast O. Cyanide in cassava: Understanding the drivers, impacts of climate variability, and strategies for food security. *Food Energy Secur*. 2024;13(4):e573. <https://doi.org/10.1002/fes3.573>.
- [8] Cardoso AP, Mirione E, Ernesto M, Massaza F, Cliff J, Haque MR, et al. Processing of cassava roots to remove cyanogens. *J Food Compos Anal*. 2005;18(5):451-60. <https://doi.org/10.1016/j.jfca.2003.11.002>.
- [9] Cumbana A, Mirione E, Cliff J, Bradbury JH. Reduction of cyanide content of cassava flour in Mozambique by the wetting method. *Food Chem*. 2007;101(3):894-7. <https://doi.org/10.1016/j.foodchem.2006.02.028>.
- [10] Apea-Bah FB, Oduro I, Ellis WO, Safo-Kantanka O. Factor analysis and age at harvest effect on the quality of flour from four cassava varieties. *World J Dairy Food Sci*. 2011;6(1):43-54.
- [11] Charles AL, Sriroth K, Huang TC. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. *Food Chem*. 2005;92(4):615-20. <https://doi.org/10.1016/j.foodchem.2004.08.024>.
- [12] Essers AJA, Bosveld M, Van der Grift R, Voragen AGJ. Studies on the quantification of specific cyanogens in cassava products and introduction of a new chromogen. *J Sci Food Agric*. 1993;63(3):287-96. <https://doi.org/10.1002/jsfa.2740630306>.
- [13] AOAC. Official methods of analysis of AOAC International. 18th ed. Gaithersburg, MD: AOAC International; 2005.
- [14] Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. Colorimetric method for determination of sugars and related substances. *Anal Chem*. 1956;28(3):350-6. <https://doi.org/10.1021/ac60111a017>.
- [15] Eyinla TE, Fasoyiro SB, Karim RO, Akinola SA, Ojo DO, Ajani AO. Nutritional and functional properties of selected cassava varieties in Nigeria. *Int J Food Prop*. 2019;22(1):372-89. <https://doi.org/10.1080/10942912.2019.1584651>.
- [16] World Food Programme. Cassava at the crossroads in Congo. Rome: WFP; 2019 Aug 5.
- [17] Food and Agriculture Organization of the United Nations. Cassava production and utilization in Central Africa. Rome: FAO; 2021.
- [18] Tylleskär T, Banea M, Bikangi N, Cooke RD, Poulter N, Rosling H. Epidemiological evidence from Zaire for a dietary etiology of konzo, an upper motoneuron disease. *Bull World Health Organ*. 1992;70(2):253-63.
- [19] Food and Agriculture Organization of the United Nations. Save and Grow: Cassava – A guide to sustainable production intensification. Rome: FAO; 2013.
- [20] Tonukari NJ, Ezedom T, Enuma CC, Sakpa SO, Avwioroko OJ, Eraga L, et al. White gold: Cassava as an industrial base. *Am J Plant Sci*. 2015;6(7):972-9. <https://doi.org/10.4236/ajps.2015.670105>.
- [21] Akin-Idowu PE, Akinmoladun FO, Sulaiman PO, Olanmi B. Comparative study of proximate composition, cyanogenic potential and pasting properties of bitter and sweet cassava varieties. *Afr J Biotechnol*. 2017;16(15):712-9. <https://doi.org/10.5897/AJB2016.15740>.
- [22] Uchechukwu-Agua AD, Caleb OJ, Opara UL. Postharvest handling and storage of fresh cassava root and products: A review. *Food Bioprocess Technol*. 2015;8(4):729-48. <https://doi.org/10.1007/s11947-015-1478-z>.
- [23] Zainuddin IM, Fathoni A, Sudarmonowati E, Beeching JR, Gruissem W, Vanderschuren H. Cassava postharvest physiological deterioration: From triggers to symptoms. *Postharvest Biol Technol*. 2014;90:115-23. <https://doi.org/10.1016/j.postharvbio.2013.12.015>.
- [24] Rickard JE, Coursey DG. Cassava storage. Part 1: Storage of fresh cassava roots. *Trop Sci*. 1981;23(1):1-32.